Radio equipment
Air band DIY receiver

Item No	air_band-kit_201809
Name	**118-136MHz Air band DIY receiver from Aliexpress (building, tuning and enhancing)**
Q'ty	1
Source	Aliexpress
Date	2018/09/02 - 2020/04/05
Author	-DarS007 https://github.com/DarS007/

This receiver was purchased as a kit on Aliexpress, then assembled, tuned and improved (several times!) in order to prepare it for real operation. Since 2019 it is used for monitoring air operations of a quite large airport nearby. Great pleasure, fun and educational value!

Additional note: this receiver is just one component of the system. You need to have appropriate air-band antenna! You cannot substitute it with anything else !!
Don't buy any additional preamps or other gadgets unless you have at least decent (if not good) air-band tuned antenna. Otherwise frustration is guaranteed!

It turned out that the receiver's schematic had been popular for a quite some time. Therefore multiple versions/variations were found on Internet. They were somehow adopted by Chinese makers. Nowadays (2018 - 2019) at least two types of kits are in production:

- with standard, manually wound inductors
- with inductors 'printed' on PCB.

The second version (inductors on PCB) was purchased.

Short description from one of manuals found on Internet:
The Aviation Receiver, designed to tune the 118-135MHz band, features exceptional sensitivity, image rejection, signal-to-noise ratio, and stability. The receiver is ideally suited to listening in on ground and air communication associated with commercial airlines and general aviation.

1. DESCRIPTION ON ALIEXPRESS

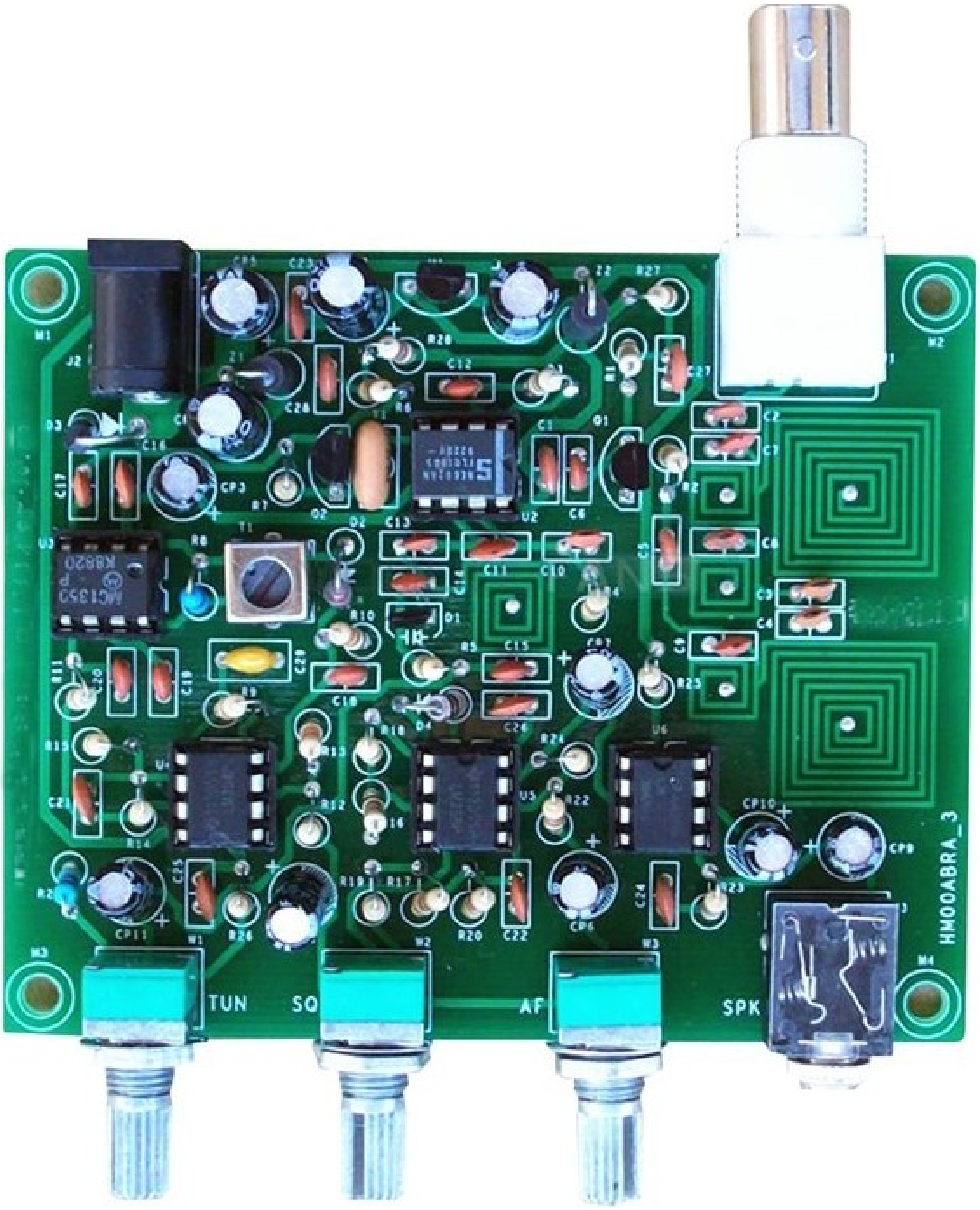
The description below was copy-pasted from Aliexpress web page.

Kit welding requires some electronic technology, please bring a multimeter and a soldering iron and other tools, manuals, etc. Kit manual will be placed on the network for all to download.
Dedicated to receiving calls between the aircraft and the tower, with the good performance of the antenna (VHF Yagi paragraph), open at the maximum acceptable within approximately 190 km between the various types of aircraft and the tower.

Characteristics:

- *the package uses a band-pass filter 3355, NE602 mixer, MC1350*
- *can receive 118-136 MHz AM signal*
- *PCB inductances (printed directly on PCB) greatly simplifying the assembly, reducing overall difficulty*
- *the board includes AGC circuit to ensure comfort, while avoiding the long squelch noise*
- *12 V power supply*
- *PCB board size is 9.2 * 7.5cm, can be placed in 97 * 40 * 120mm aluminum chassis*

Tip: Due to the VHF bands propagation, for distances greater than 25 km VHF Yagi antenna must be installed.

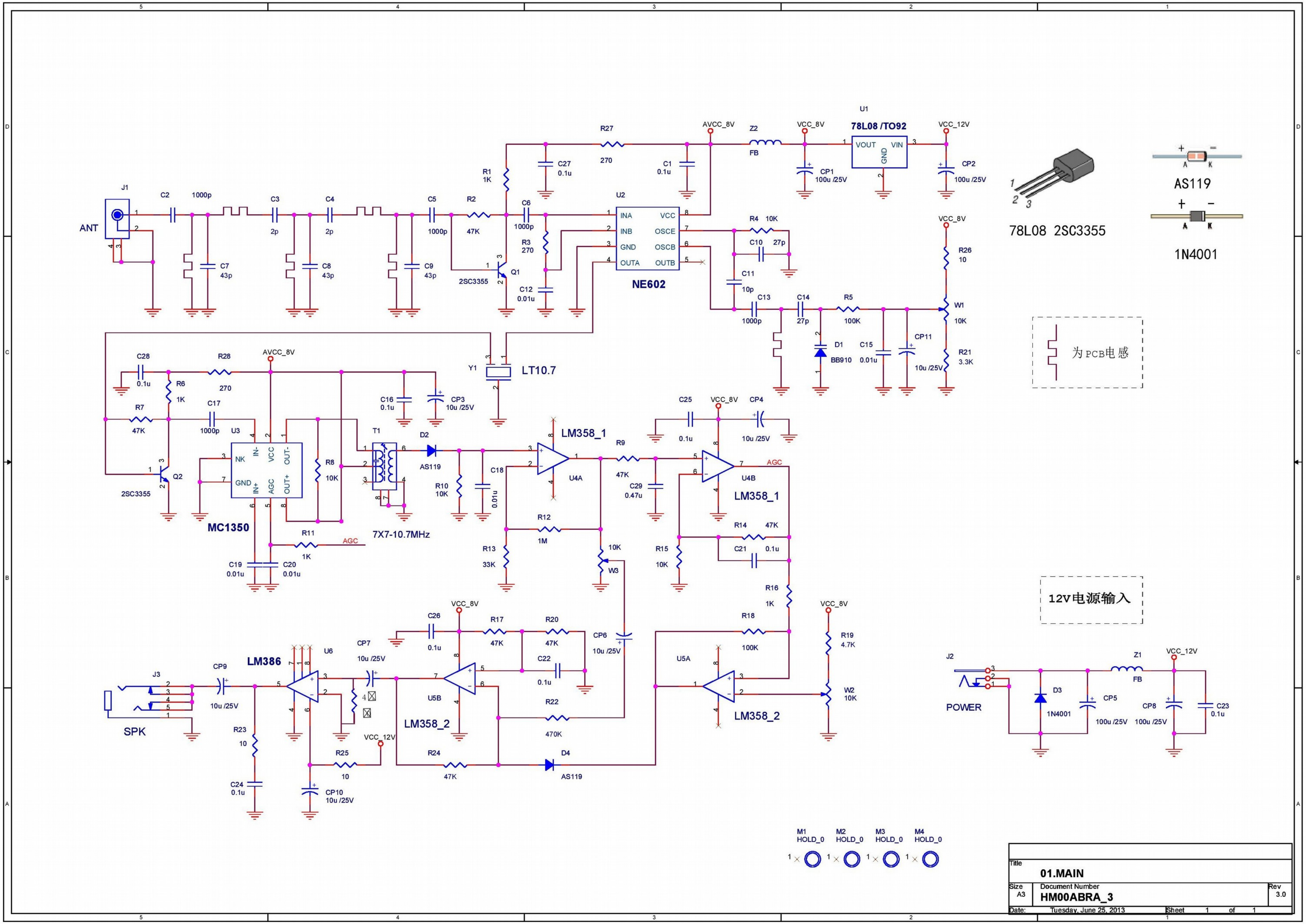


Picture of assembled kit
(six PCB ‘printed’ inductors are clearly visible)

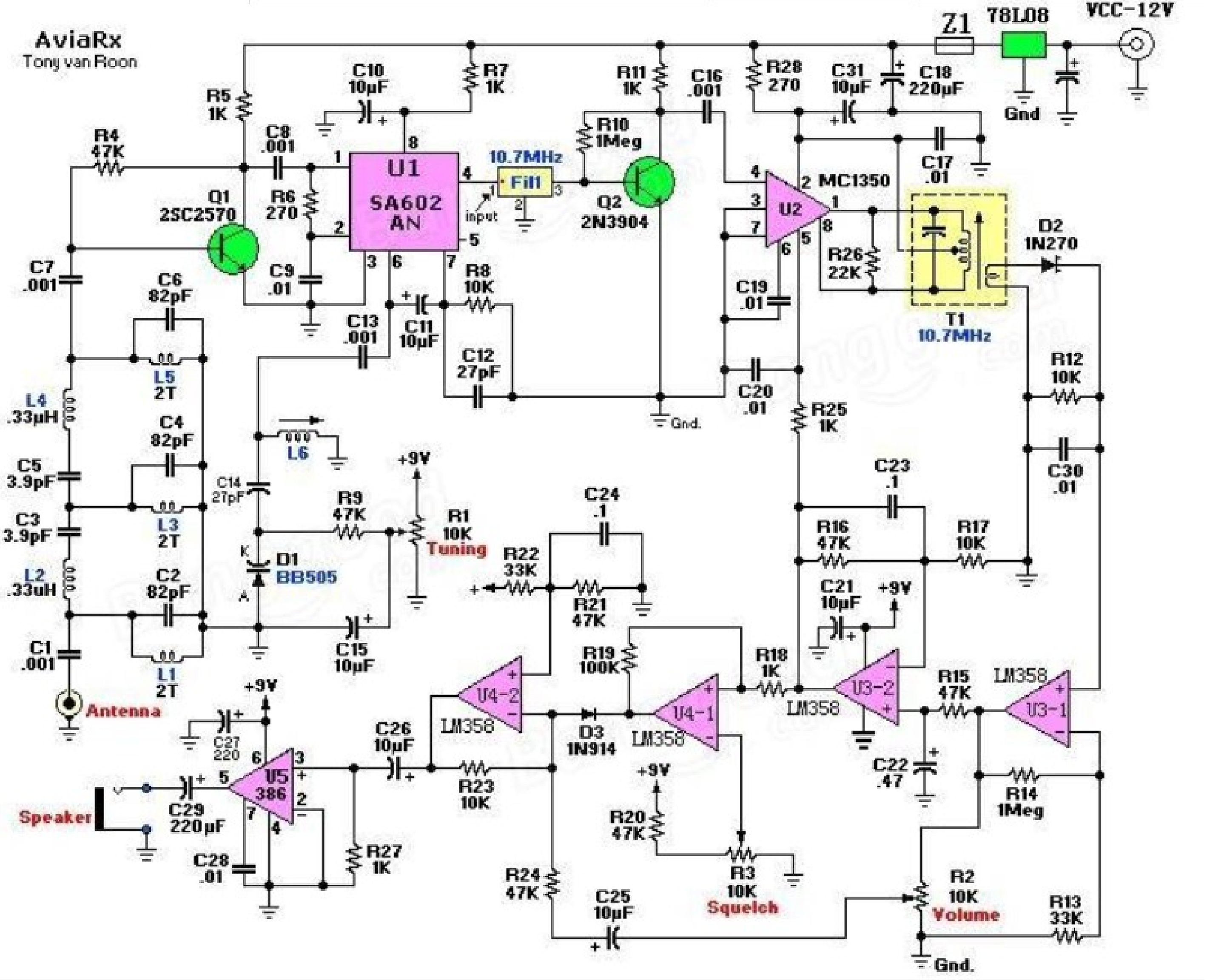
Frequently Asked Questions

Q: What issues should pay attention to?
A: VHF has been close to a straight line, so the VHF communications can not be blocked, listen to the signal tower more necessary attention to this point, listen to the aircraft entry and exit signals slightly better, because the aircraft height from the ground close to the airport, there are hundreds to thousands of meters high, so the signal can cover long distances.
Meanwhile, in order to better results, we recommend using an external frame, high antennas, such as 1/4 wavelength (about 60 cm) of GP antenna or use a better VHF Yagi antenna section! In short, according to the actual environment, appropriate tie antenna, in order to achieve good results!

Q: What kind of antenna to use?
A: For the primary enthusiasts recommend using GP antenna or Yagi antenna, the two antennas is relatively simple, very suitable for self-control.


ANT
J1
C2 1000p
C3 2p
C4 2p
C5 1000p
C7 43p
C8 43p
C9 43p
R2 47K
R1 1K
Q1 2SC3355
C6 1000p
R3 270
C12 0.01u
C27 0.1u
R27 270
AVCC_8V
C1 0.1u
Z2 FB
VCC_8V
CP1 100u /25V
U1
78L08 /TO92
VOUT VIN GND
VCC_12V
CP2 100u /25V
U2
INA INB GND OUTA VCC OSCE OSCB OUTB
NE602
R4 10K
C10 27p
C11 10p
C13 1000p
C14 27p
R5 100K
D1 BB910
C15 0.01u
CP11 10u /25V
R26 10
W1 10K
R21 3.3K
78L08 2SC3355
AS119
1N4001
为PCB电感
Y1
LT10.7
C28 0.1u
R28 270
R6 1K
R7 47K
C17 1000p
U3
NK GND IN- IN+ VCC AGC OUT- OUT+
MC1350
Q2 2SC3355
R8 10K
C16 0.1u
CP3 10u /25V
T1
7X7-10.7MHz
D2 AS119
R10 10K
C18 0.01u
LM358_1
U4A
R9 47K
C29 0.47u
C25 0.1u
CP4 10u /25V
U4B
AGC
R12 1M
R13 33K
W3 10K
R14 47K
C21 0.1u
R15 10K
R16 1K
R11 1K
C19 0.01u
C20 0.01u
12V电源输入
SPK
J3
CP9 10u /25V
LM386
U6
R23 10
C24 0.1u
CP10 10u /25V
R25 10
CP7 10u /25V
C26 0.1u
R17 47K
R20 47K
C22 0.1u
U5B
LM358_2
R22 470K
R24 47K
D4 AS119
CP6 10u /25V
R18 100K
U5A
R19 4.7K
W2 10K
J2
POWER
D3 1N4001
CP5 100u /25V
Z1 FB
CP8 100u /25V
C23 0.1u
M1 HOLD_0
M2 HOLD_0
M3 HOLD_0
M4 HOLD_0
Title
01.MAIN
Size A3
Document Number
HM00ABRA_3
Rev 3.0
Date: Tuesday, June 25, 2013
Sheet 1 of 1

Alternate schematic



2. DEBUGGING AND TUNING

Theoretically, the kit with one or two tunable components should be easy to build. Practice proved that this was the wrong assumption! Why?

- input filter has inductors (L) ‘printed’ on PCB. When matching with standard capacitors (5% accuracy) the filter should resonate at calculated (and desired) frequency. But this was not the case in our kit …
- receiver’s schematic is … buggy! Despite being available for years (and being published in several variants on many web pages), there are few fundamental flaws on the schematic.

So instead building the kit in a one go, we advise to build it step-by-step. Proper measurements and tuning after each step are a must.

2A. Test instruments

What are the best measurement instruments for dealing with the kit?

Network analyzer NWT-500 or similar https://sites.google.com/site/sq5ebo/NWT500_V1_06.pdf 	Ideal for tuning the entire radio path: - input pass-band filter 118-135 MHz section - IF filter 10,7 MHz, IF amplifier and AM detector NWT analyzers are available on eBay or Aliexpress, with different frequency ranges and models. The concept, hardware and software were developed by German ham amateur Andreas DL4JAL (http://www.dl4jal.eu/) and then copied by Chinese makers. NWT analyzer includes: - DDS generator (so called tracking generator) - logarithmic amplifier and signal level detector - microprocessor with USB port If you happen to have one of more advanced models (like NWT-500 with 550 MHz range), you can check both air-band input filter and IF path. You then don’t need any other instrument (except generic purpose multimeter). If you have the original NWT-7 model (60 MHz range), you can tune IF path only.
High-freq. signal generator - with 150 MHz range and AM modulation, or - just a cheap single-chip 125 MHz generator (usually in a metal can or DIP package) with some form of output signal attenuation	If you don’t have fully featured HF signal generator (with 150 MHz tuning range), you can re-use one of widely available 125 MHz generator chips used on PC motherboards and in consumer electronic. It’s frequency is right in the middle of air band, but you need to attenuate it’s output (from hundreds of milivolts down to dozens of microvolts).

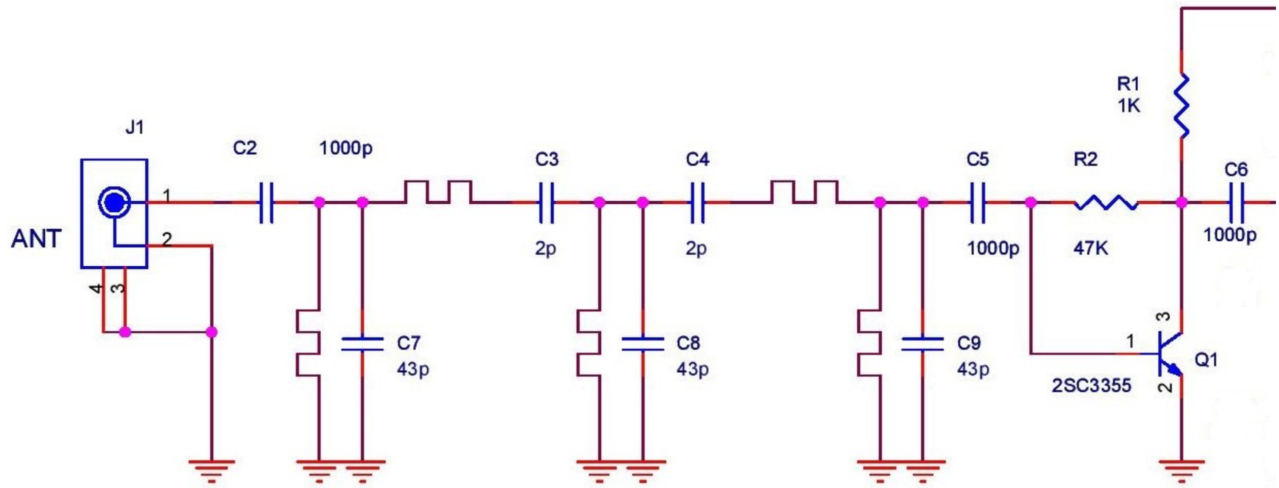
	
Oscilloscope - with 15 MHz bandwidth - for IF tuning - with 150 MHz bandwidth - for input filter and IF tuning	Don’t expect to see input airband signals on the oscilloscope! These signals are in microvolts range, whereas the scope can reliably display levels few magnitudes higher. The scope, however, can be a good indicator of signal presence at later stages of amplification (e.g. output of IF amp)

You might see some contradiction here… The air-band receiver kit is advertised as great fun for beginners. But to build it and tune properly, you need to have quite well equipped lab. This is the reality, however. If you don’t have proper instruments, you don’t really know how the device performs.

2B. Pass-band filter tuning

(2018/10) Pass-band input filter for 118-135 MHz air-band frequencies was the very first thing tuned. Appropriate measurements were done before all other (active and passive) components were mounted on the board. This allowed relatively easy access to the filter input and output.

Schematic of input pass-band filter:



As you can see, this is a 5-poles LC circuit:

- LC7, LC8, LC9 circuits - they shunt the out-of-band signals to ground, and resonate (isolate from ground) for in-band frequencies
- LC3, LC4 - they attenuate the out-of-band signals and resonate (pass through) the in-band frequencies

You have to make sure all these circuits are tuned properly (although no tunable elements are available in the kit!), otherwise wild things will happen!

In our case, the NWT-500 network analyzer was used to measure the frequency response of the pass-band filter.

Band-pass filter with capacitors from the kit

Initially, the input band-pass filter was soldered together with the input amplifier:

- capacitors C2-C9
- resistors R1 + R2
- transistor Q1

We wanted to measure the bandwidth of the input filter, therefore the Q1 amplifier was handy in isolating the filter output from low (50 Ohm) impedance of NWT-500 input. Initially, the capacitors from the kit were soldered. This was … wrong!

See below how the frequency response looked at the beginning, with the default components (capacitors) soldered:

Total disaster… Lack of clearly defined pass-band range, high attenuation (-25 dB at best, -42 dB in the middle of 'the band' *), etc.

*) - CAUTION - the generator's output level was <u>not</u> recorded, therefore it is impossible now to determine the real value of NWT-500 output signal or attenuation. If the generator\s output had 20 dB attenuation, the real attenuation of the input filter was just 5 dB and not 25 dB.

Attempts to correct C7, C8, C9

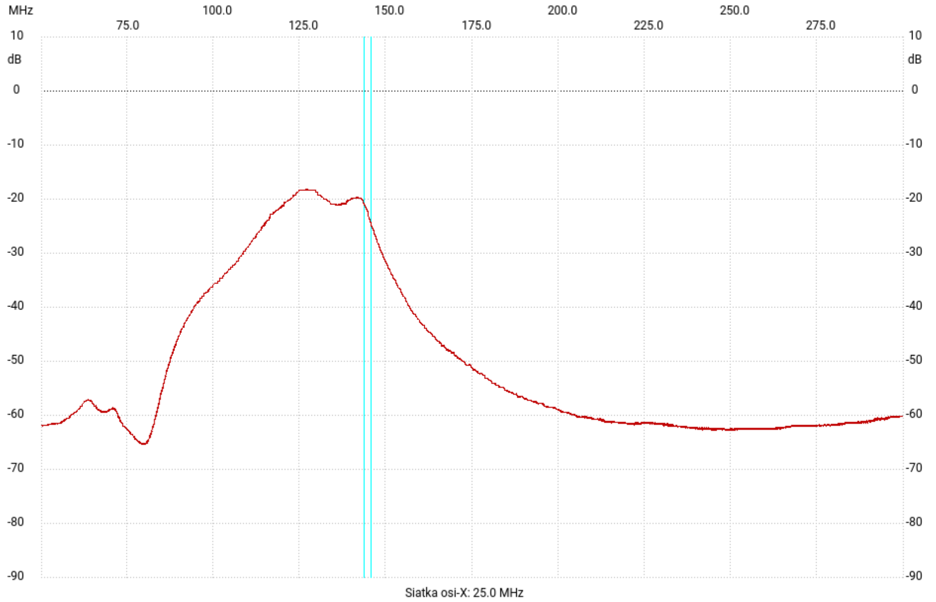
First attempt was to correct one (or more) LC7, LC8, LC9 segments. Because the inductors were printed on PCB, the only option for correction were capacitors. 10pF additional capacitors were connected in parallel to C7, then to C8 and C9. To our surprise, this … changed (almost) nothing.

Example - C7 increased by 10pF:

As you can observe, no significant changes were obtained. It was clear that adjustment of parallel LC7, LC8, LC9 filters will not lead to success.

Attempts to correct C3, C4

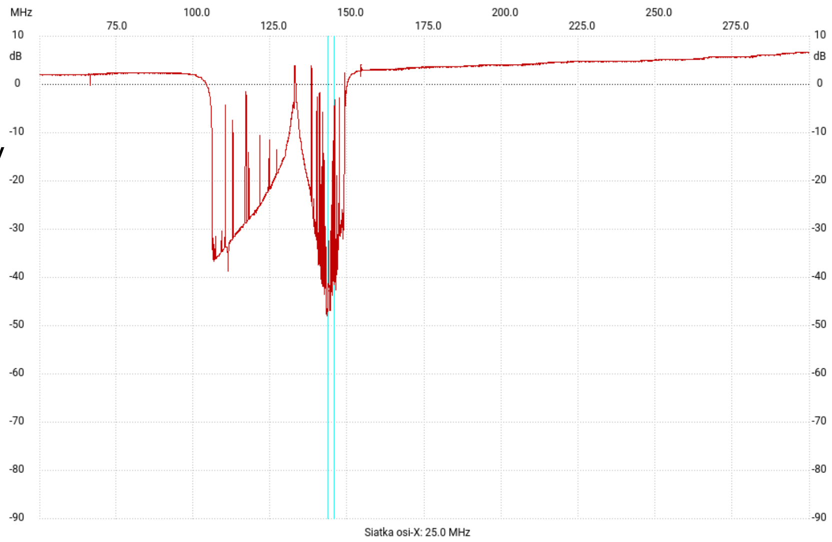
This time LC3, LC4 serial filter segments were adjusted. It was a bit difficult due to extremely low values of capacitors: just 2pF each. This is why the original 2pF were de-soldered and replaced by new 3pF equivalents. And … bingo!
The frequency response looked <u>much</u> better:



Still not ideal, but quite <u>acceptable</u>! So **C3** and **C4** got their new value: **3pF**.

Please remember - the generator’s output level was not recorded, therefore it is impossible now to determine the real value of NWT-500 output signal or attenuation. Therefore the dB scale on the chart is relative.

2C. Self-oscillations - IF (10.7 MHz) amplifier

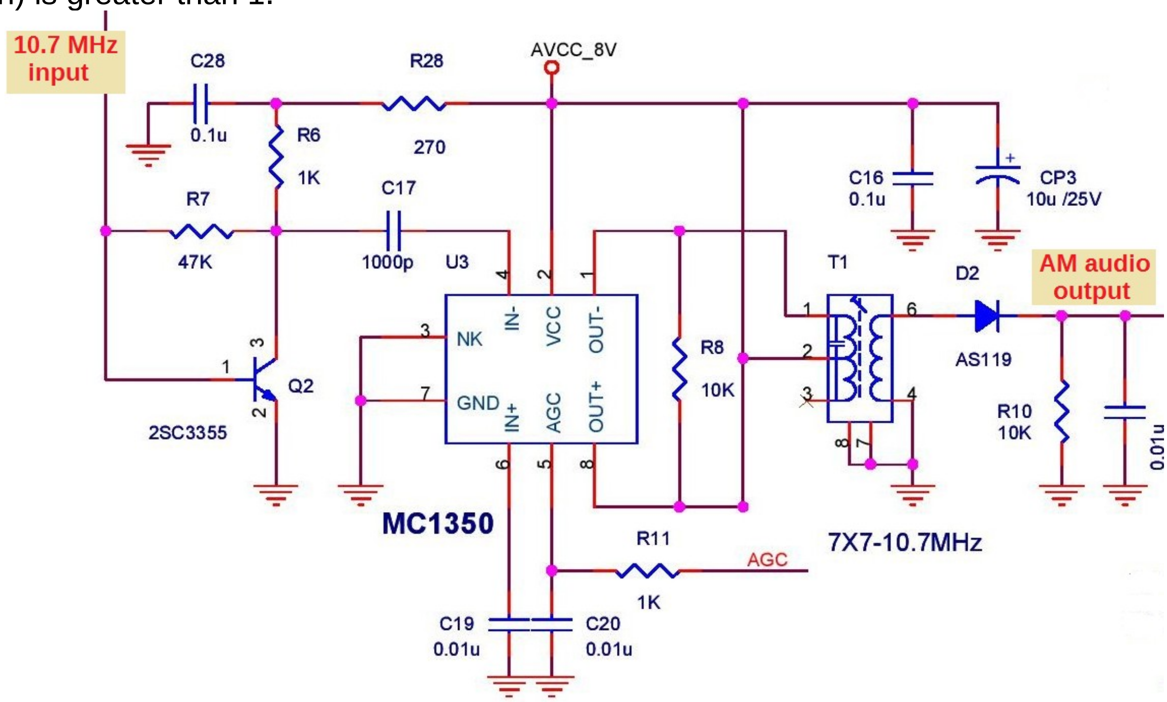


When the input pass-band filter was properly tuned, it was time to mount IF amplifier section (Q2, U3) and to test it.
The mixer (U2) was intentionally omitted at this stage of testing.

But weird thing happened then! The IF amplifier had some strange output signal even when there was no input signal.

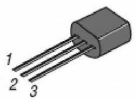
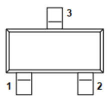
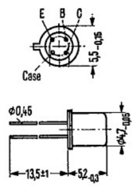
Detailed analysis revealed an oscillation at 10,7 MHz. This is why the NWT-500 analyzer indicated almost continuous presence of 2 dB signal up to 100 MHz and from 150 MHz above (straight horizontal lines on the diagram).

Such self-oscillations are quite common in high-frequency circuits, when the phase shift (between input and output signal) reaches 360 degree and amplification of the entire chain (path) is greater than 1.



This is why the removal of Q2 transistor was initially considered - this transistor works as inverting (180 degree phase shift) amplifier, so it’s removal could return the entire amplification chain phase shift back to the safe value. But tests showed that the overall sensitivity of the receiver (without Q2) was too low for a comfortable use.

Further tests revealed that proper selection of Q2 is quite important. Additional 3-pin socket was soldered for Q2 to be able to replace the transistors on the go and to select the best.

Q2		Results
2SC3355 (from the kit)		High-performance VHF transistor included in the kit, with 6.5 GHz transition frequency. IF section tended to self-oscillate, perhaps due to Q2 high gain (too high)
BFS17		High-performance VHF SMD transistor with 1 GHz transition frequency. IF section tended to self-oscillate, perhaps due to Q2 high gain. When not self-oscillating, the received air band communication was strong and loud, but a bit noisy. Additionally, strong noise was heard when no signal - annoying during longer sessions.
BFW30		Old transistor (mid-80s of XX century ?) but a clear winner. It has enough gain on 10.7 MHz (transistor’s max frequency is 1.6 GHz), but never self-oscillated. Great output sound: little noise when no signal, loud and clear for air band communication.
BC148		Old transistor for audio band, not optimized for high frequencies. It was visible - high noise when no signal, not enough gain for air band communication (voice with noise).

Finally, the **BFW30** was mounted on PCB (in 3-pin socked) as it ensured the best audio experience:

- little/no noise when no signal
- loud and clear communication

2D. IF amplifier / AM detector tuning

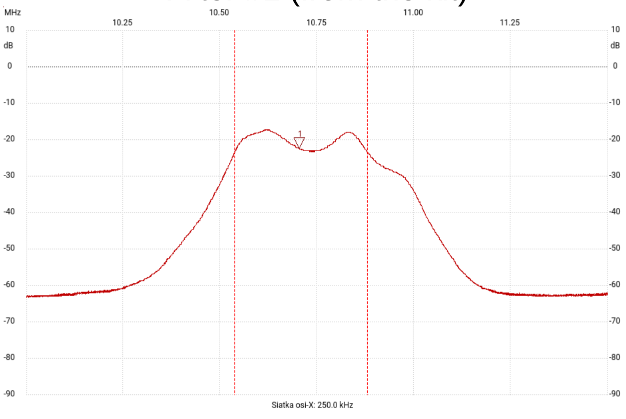
Once the self-oscillations were successfully removed, it was time to finish the tuning of IF section. Two key elements there had to cooperate with each other:

- **Y1** quartz filter, and
- **T1** LC filter

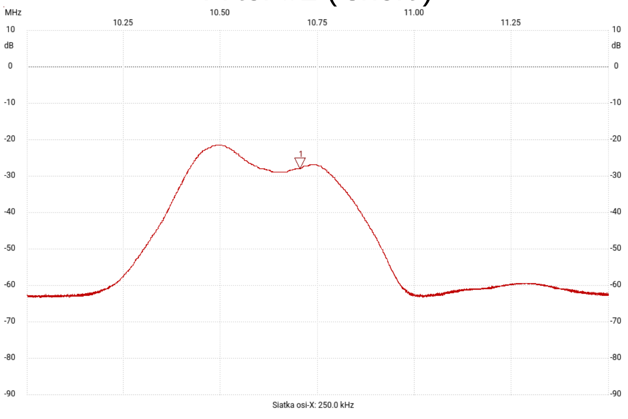
In other words, the T1 LC filter had to be tuned to the exact frequency of the Y1 quartz

filter.
Few quartz filters (including the one from the kit) were tested and measured:

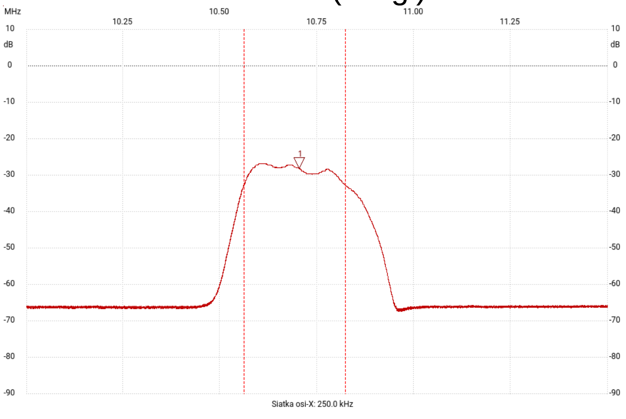
Filter #1 (from the kit)



Filter #2 (‘short’)



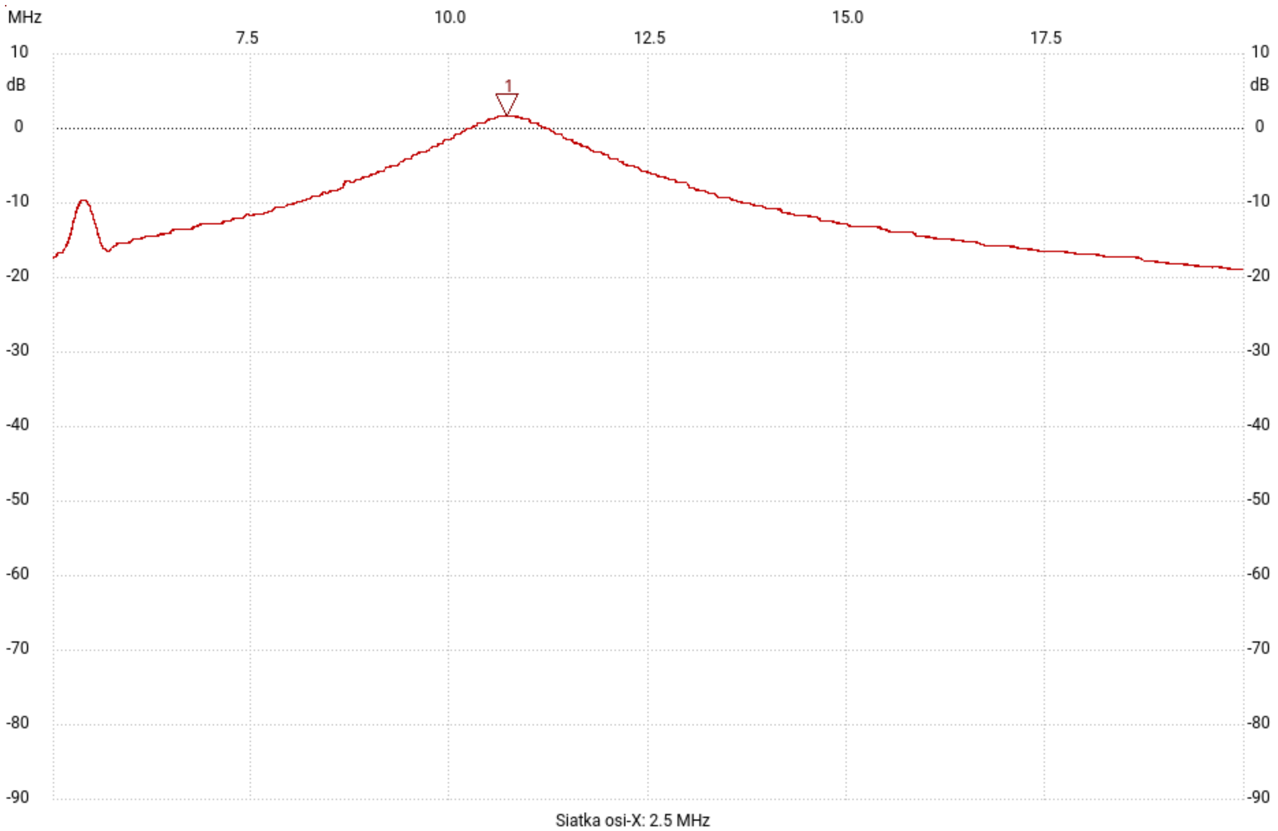
Filter #3 (‘long’)



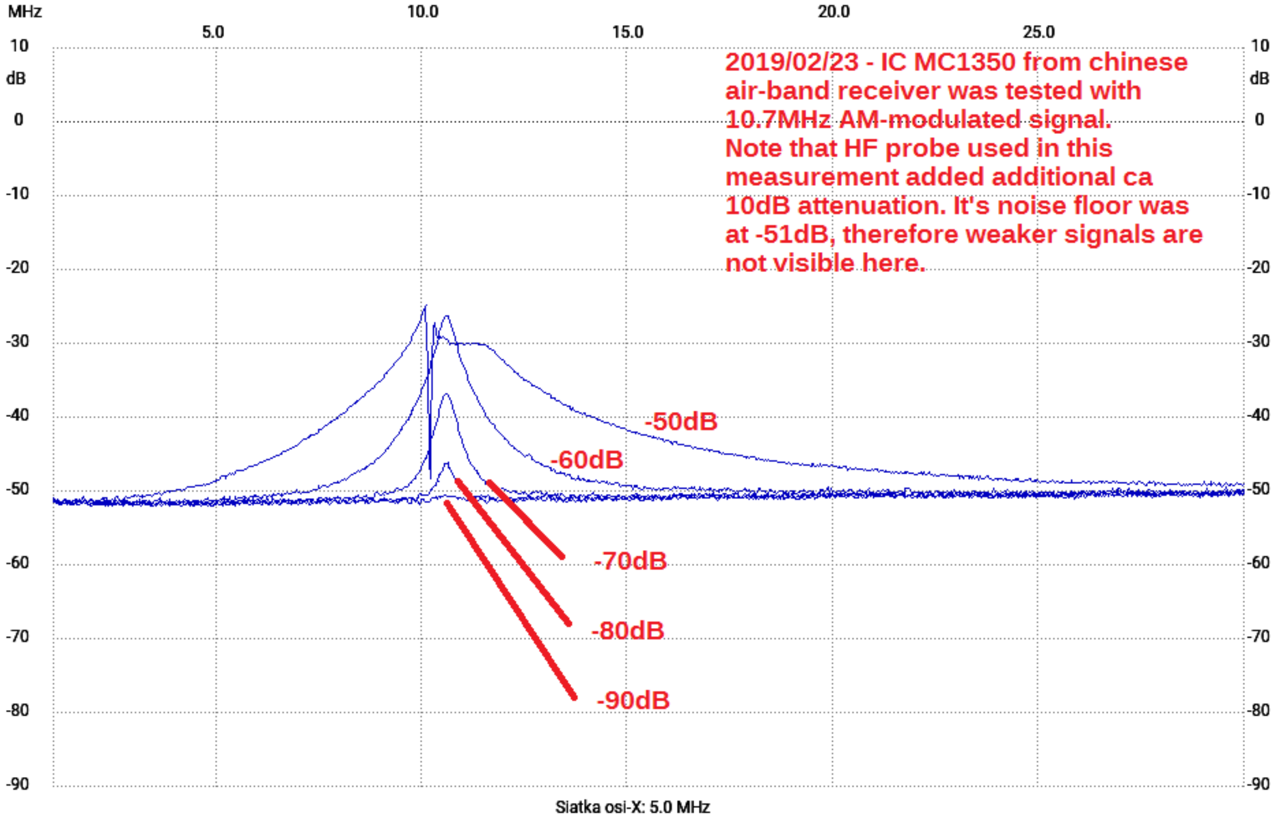
All of them worked as desired - it means they were properly selecting 10.7 MHz signal (no surprise :-). Filters #1 and #2 had lower insertion loss than filter #3, but the last one had better selectivity. Further real-life tests proved that the selectivity did not matter much, but the extra loss of filter #3 tend to kill weak signals. Therefore filter #1 or #2 had to be selected for operational receiver.

Additional 3-pin socket was soldered to be able to replace the Y1 filter on the go and to compare the results.

T1 LC filter (from the kit) had to be tuned to the center 10.7 MHz frequency. Again, NWT-500 was to help here!
Once tuned, T1 properly responded to 10.7 MHz signal - this ensured maximum sensitivity of the overall IF section.



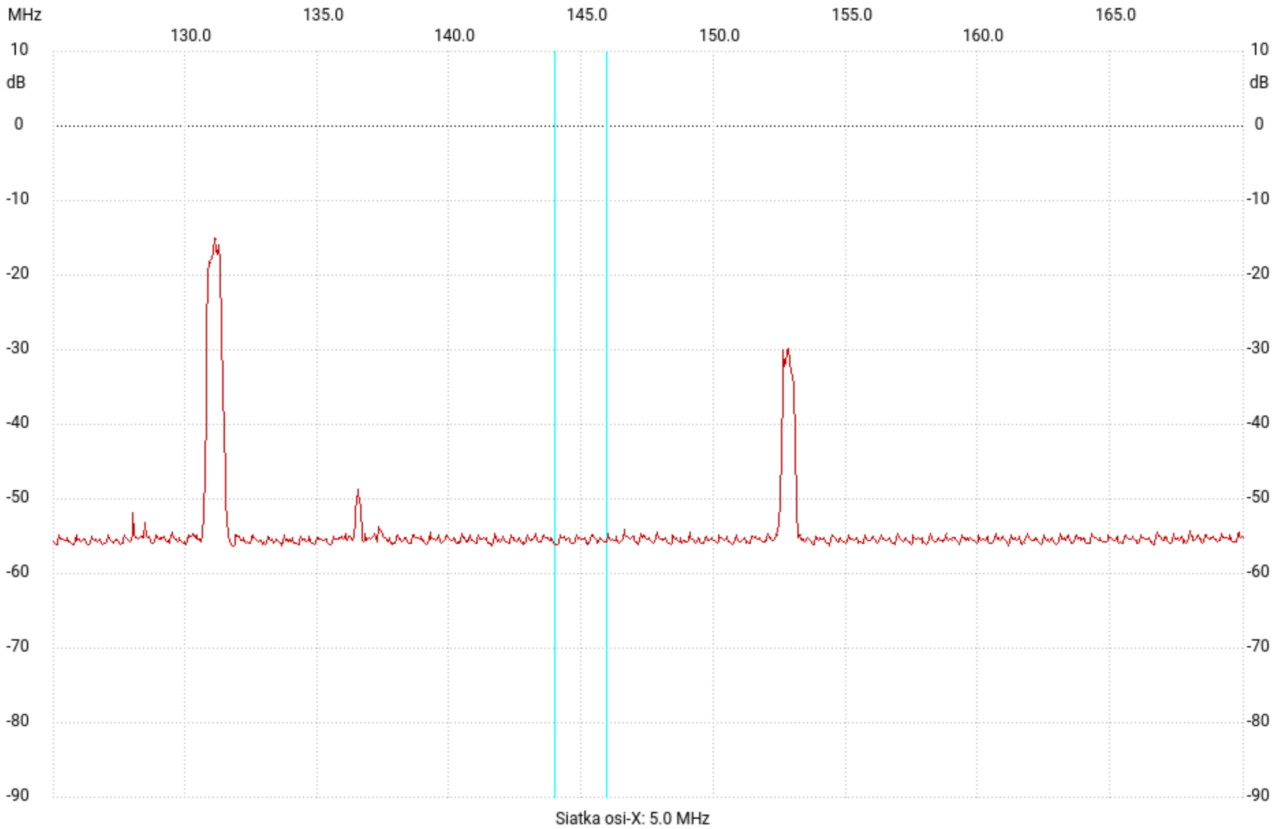
When **T1** LC filter was tuned to 10.7 MHz, we could measure the entire IF tract:



All looked good so far! Receiver’s sensitivity (or rather IF section sensitivity) was about -80 dB (relative to NWT-500 0 dB output signal). Great!

2E. Radio section check

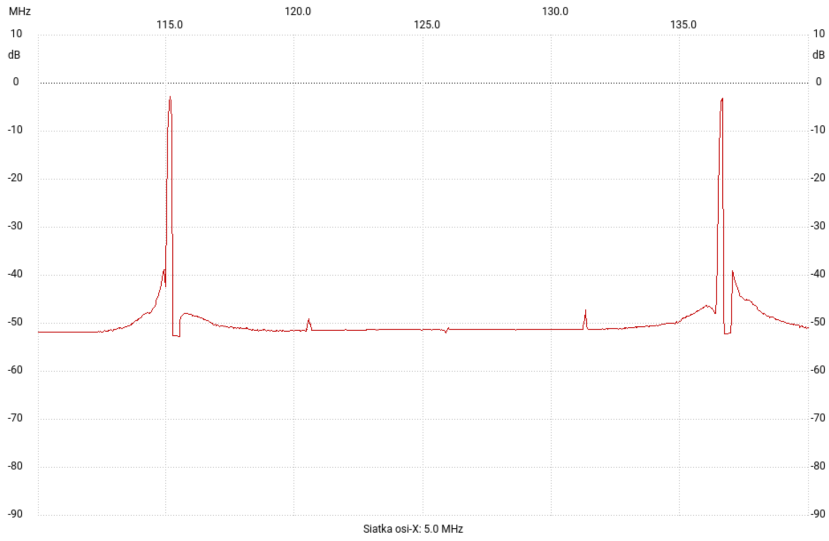
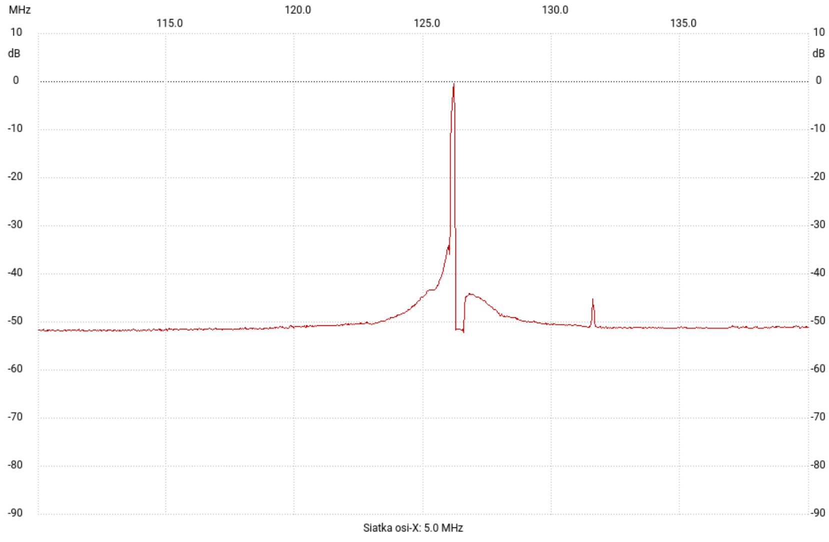
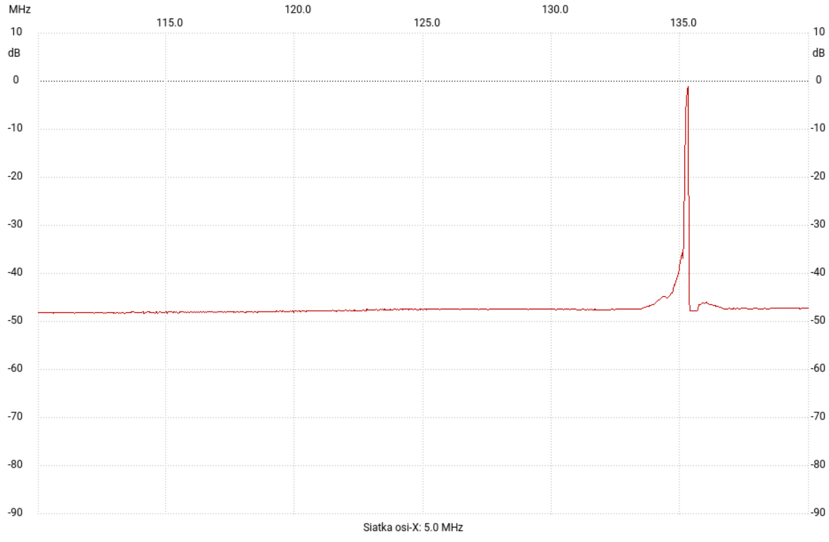
It was time to mount U2 mixer (NE602 / 612) and to join the input filter/amplifier with the IF amplifier. It was the firs time the kit could be named ‘the receiver’ :-)
NWT-500 was used to see the overall frequency response of this freshly mounted receiver:



Great! You can see that the NE612’s oscillator/VFO (heterodine) was working and it was (accidentally) set for a such frequency that the receiver was tuned to slightly above 131 MHz.
You can also observe (undesired) mirror frequency around 153 MHz. You have to live with it:

- input band-pass filter has so wide reception that it treats 131 and 153 MHz signals almost the same way (bad)
- 130 - 150 MHz band is not commercially used (no radio/TV broadcasting there), therefore you should not expect any negative side effects coming from the mirror frequency (good!)

Further measurements were made to see the receiver’s response at the beginning and at the end of air-band range.

118 MHz	
126 MHz	
135 MHz	

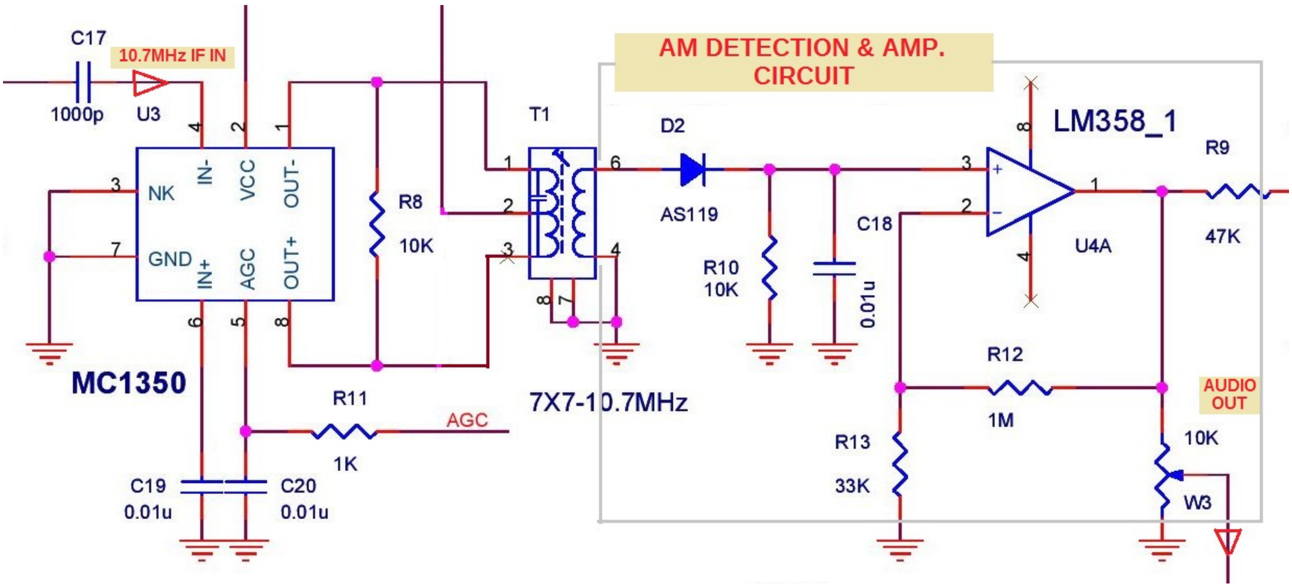
Please disregard some steep response ad the trailing edge - this was caused by erratic work of AGC (Automatic Gain Control) scheme, adjusted further in next steps. But you can see that the kit was able to receive signals throughout the entire air-band width.

3. ADD-ONs AND ENHANCEMENTS

Several changes were made to the construction of this radio receiver.

3A. AM Detector sensitivity improvement

The original AM detector circuit seemed to be far from optimal. Simple changes there could bring fast (and audible) results, therefore we advise you start from this modification.



Picture: Original schematic of AM detection section.

Three problems with the kit schematic:

- **D2** diode, although germanium, still needs some initial voltage to work properly. It will start detecting above 50-70 mV. So IF signals with smaller amplitude are not going to be detected.
- when idle (no input signal), there is **0 V** on the non-inverting input (pin 3 - grounded via R10) of **LM358** opamp.
  However, LM358 is not a so-called *rail-to-rail* device that can work properly from minus to plus of power voltage values (GND and +8V in our case). Although LM358 inputs work better with *close to GND* than *close to Vcc* values, let's try to add some input bias voltage.
- **LM358** performs badly for low level signals. Source:
  https://www.electro-tech-online.com/threads/reducing-lm358-output-noise.142937/
  The LM358 is the dual opamp version of the LM324 quad. They were one of the first low power opamps so their output transistors have no bias and produce horrible crossover distortion.

Picture right: draft schematic of LM358 internal structure

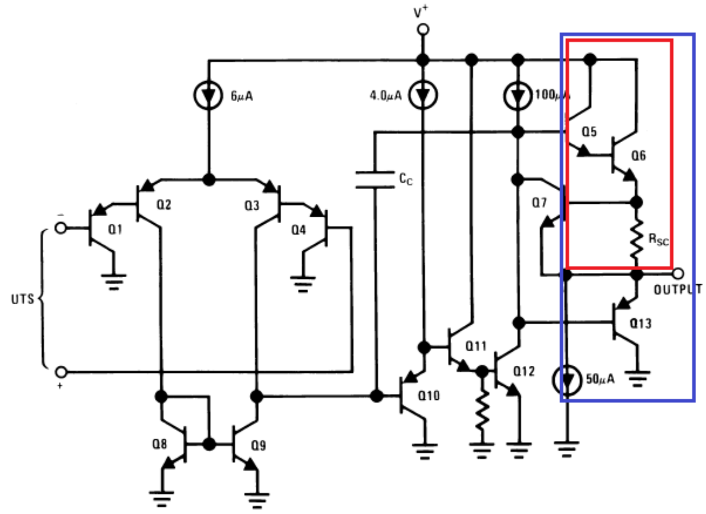
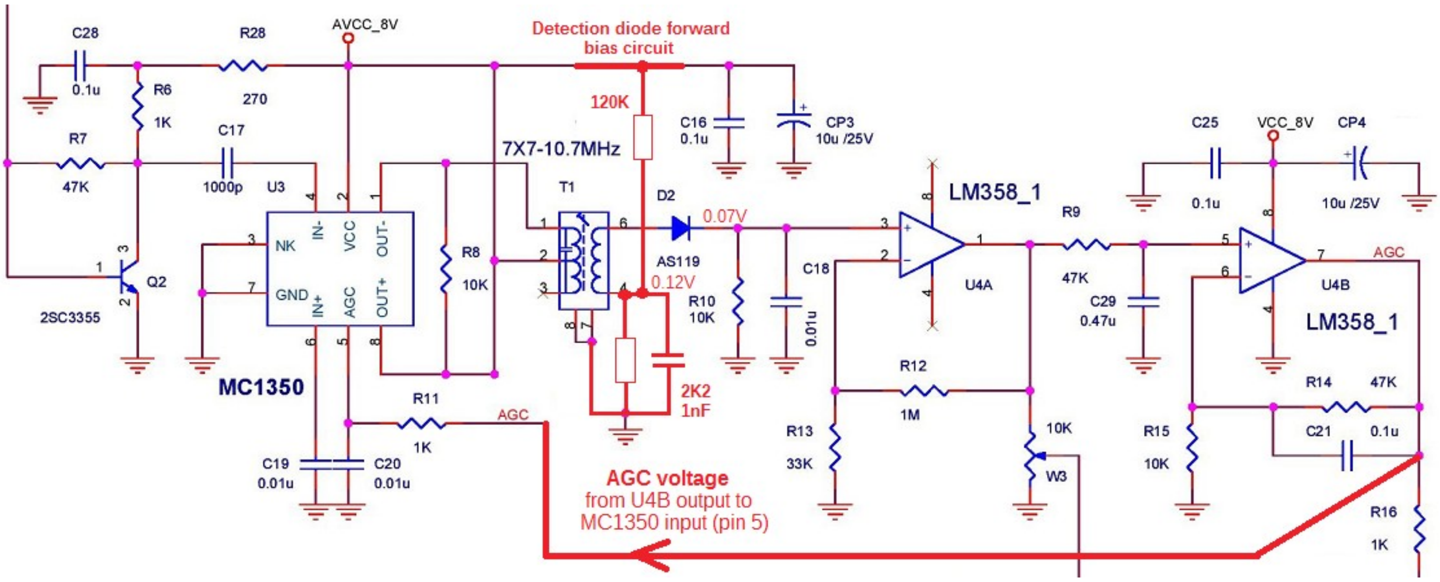


Figure 16. Schematic Diagram

Schematic changes were made to provide initial (DC) bias for the AM detector diode and, at the same time, some little input voltage (bias) for non-inverting LM358 input. Two resistors, capacitor and some PCB track cuts did the trick.

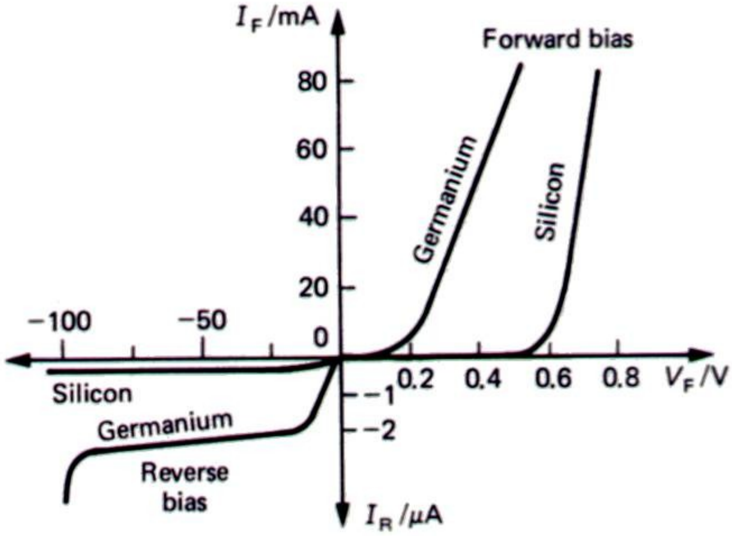


Picture: Adding DC voltage bias for D2 detection diode and U4A opamp input
(AGC voltage path was also shown)

How it was implemented? Bottom right pin of T1 transformer (pin 4) was isolated from the ground by cutting PCB track. The pin was then connected to the resistive voltage divider (120K and 2K2). The divider is connected to 8 V analog power supply voltage, so it generates a fraction of this value (0.12 V_{DC} in our case). Additional 1nF capacitor provides *virtual ground* for 10.7MHz IF signal.
In-circuit measurement confirmed diode’s DC voltage drop of 50 mV. This leaved +70mV_{DC} for opamp bias. Great!
We can also calculate the diode’s bias current - it flows through 10 kOhm resistor and generates 70 mV drop. Therefore the diode current is around (or less) **7 uA**.

Is the 50 mV_{DC} diode drop enough? It depends.

For silicon diode it would be perhaps not visible at all. But germanium p-n junction functions from much lower levels than silicon. See for instance:
https://aviamech.blogspot.com/2011/01/aircraft-electronics-diodes.html



In practice, the receiver's perceived sensitivity increased after the modification. In particular for weaker signals. You can now hear input signal down to a noise level, without some steep disappearance observed previously.

We can roughly assume that all audio signals below 50 mV (measured at T1 output coil) were previously not detected. It translates to 50 uV on MC1350 input (assuming 60 dB gain / 1'000:1 of this IC) or to several uV at the receiver input (counting the SAA602 mixer gain and Q1 + Q2 amplification).

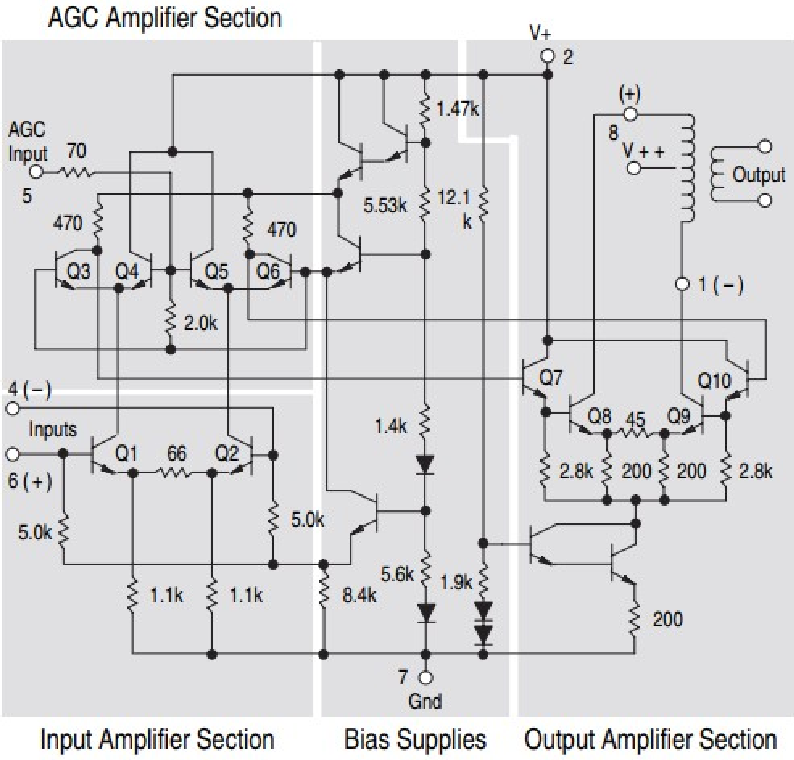
3B. AGC and squelch - improvements, squelch LED indicator

MC1350 IC is a pretty decent IF amplifier, considering it's age. But it is not perfect, though.

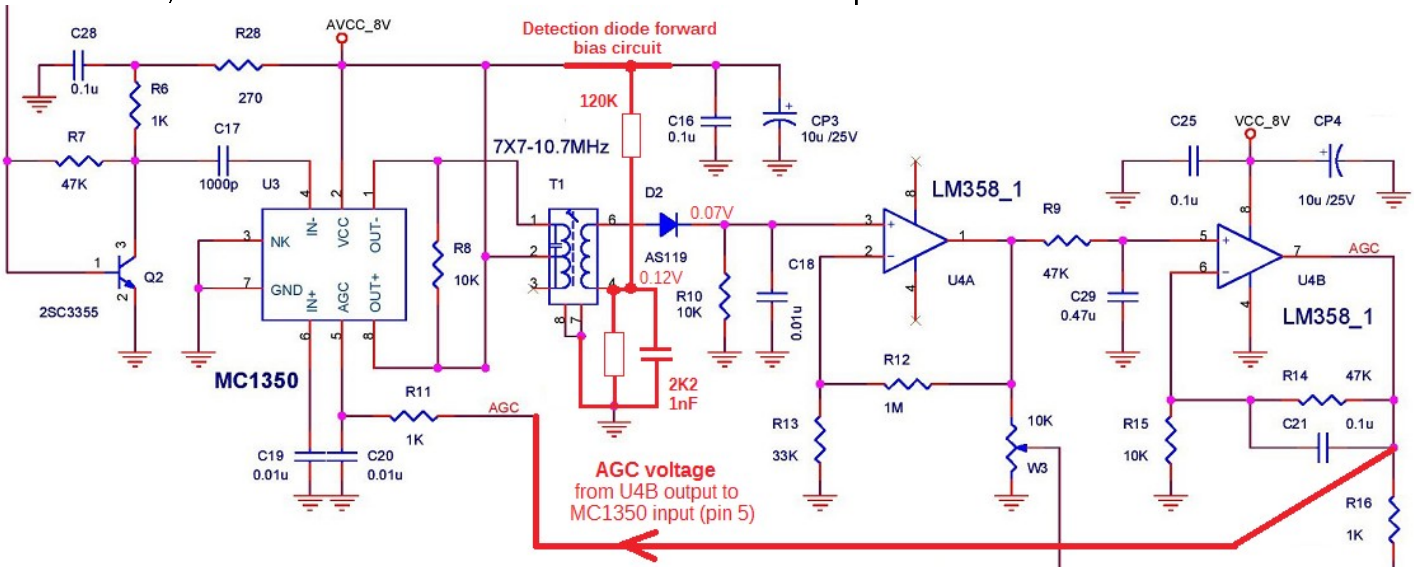
Many sources list it's downsides:
https://groups.io/g/BITX20/topic/4104439
The MC1350 is a blast from the past. It has a 60 db gain range. Which is not bad at all. However, its noise figure increases with decreasing gain. That means, as stronger signal pumps the AGC (Automatic Gain Control), the strong signals appear noisier.
http://www.redwaveradio.com/5_eabb445e404bf745_1.htm
- Dan Tayloe, WB0NVB, Phoenix, Az
The AGC voltage on the MC1350 is specified as useful in a range from 5 to 7 volts, 5 volts being maximum gain (50 to 60 dB), 7 volts being minimum gain (up to a 10 dB net loss). Although everyone talks AGC voltage (using the standard 5K resistor to feed AGC to the MC1350), what is really important is the AGC input current. Max gain is 5V, at a current of 0.1 mA, Min gain is 7V at 0.2 mA.
*However, more important than this is the fact that at max gain, the *noise figure* of the device is **6-8 dB** (50 to 60 MHz), whereas at 30 dB gain reduction (about 6.25V), the noise figure is way up to **22 dB** - extremely noisy indeed.*
Therefore, if two MC1350s are ganged together, it is preferred to run the first one with less AGC gain reduction than the second in order to keep the overall noise figure for the IF

amp reasonable. This is usually done by increasing the resistance for the AGC feed to the first amp (10K) so that less gain reduction is done by that stage, and more is done by the second stage where noise figure is no longer a consideration due to the gain of the stage(s) in front of it.

MC1350 internal structure is relatively typical: input stage connected to gain control section and then to output amplifier.
Everything is smartly packed together in a small 8-pin DIL package.
Why gain control? To amplify weak input signals and to attenuate the strong ones. Designing radio receiver you <u>cannot</u> assume it will work with stable/constant input level!
Please also note the IC's output section: it is symmetrical, so the output transformer is a must (this is T1 on the air-band DIY receiver schematic).



Overall, MC1350 is worth our attention! This is how it is placed in the air-band receiver:



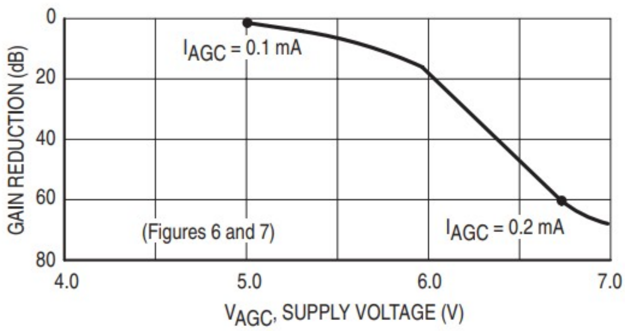
Picture: MC1350 IC implementation in air-band radio receiver (with AGC loop highlighted).

In February 2019, additional measurements were performed to study the variable gain section of MC1350.
Please note these measurements were done BEFORE the DC bias for AM detector diode was introduced (see the chapter above)!

Initially, it was assumed that the gain reduction graph from the IC datasheet was valid (see right). Therefore the AGC voltage supposed to change from 5.0 to 7.0 V.

But the in-circuit measurements oscillated around 1.5 - 4.2 volts. Was the datasheet graph wrong? Keep reading...

Figure 2. Typical Gain Reduction



Test bed for AGC measurements

1. DUT

DUT: MC1350 IC in air-band receiver application, with 10.7MHz filter removed.
AM-modulated input signal was connected directly to the output pins of removed 10.7MHz filter.

2. Measured signals

Two signals were measured:
A) **V10.7MHz HF voltage** (in milivolts peak-to-peak) at the output coil of transformer connected to MC1350 IC.
To reduce the inducted load, this measurement was done via MOSFET active probe.
Additional attenuation introduced by MOSFET probe: ca 10dB
B) **Uagc** - voltage measured at pin 5 (AGC input) of MC1350 IC.

3. Equipment

A) HF Signal Generator: AVT generator with added external AM modulator
B) Audio Signal Generator (for 1kHz AM modulation signal): russian
C) Network Analyzer: NWT-7 (to measure HF signal level)
D) 0-60dB HF attenuator (later replaced by 0-90dB attenuator with 1dB step)
E) DSO: Tektronix
F) Digital multimeter

Signal generator reference level

Ugen = **280mVpp** (with 50Ohm load of NWT-7)
Ugen2 = 400mVpp (DSO 1MOhm load) - no-load output level was measured to assess signal generator stability. This value is not used in any of further measurements nor calculations.
AM modulation level was not measured, but was perhaps in range of 20-30%.
NOTE: **Ugen** signal was measured at output of AM modulator (not at output of AVT generator).

Measurement 01

Assesment of wide-range MC1350 sensitivity

Correlation of Uagc and input signal level.

Attenuator				V10.7M signal level		
[dB]	signal level* [mVpp]	Uagc [V]	Audible?	measured [mVpp]	real** level [mVpp]	Amplifi-cation [dB]
-60	0,28	1,76	**barely**	30	95	51
-50	1	3,77	**much noise**	70	221	48
-40	2,8	3,98	**some noise**	70	221	38
-30	9	4,02	**clear**	70	221	28
-20	28	4,06	**clear**	74	234	18
-10	89	4,10	**clear**	75	237	9
0	280	4,13	**low dynamic**	75	237	-1

*) - signal level recalculated with the assumption that 0dB means 280mV peak-to-peak at the output of AM modulator

**) - real value means the measured value recalculated to consider 10dB attenuation of active MOSFET probe

Findings from the measurement 01:

- AM detector (german diode) begins to work reliably at level between 95 and 221 mV (closer to 200 mV perhaps).
  [NOTE: this was later addressed by introducing DC bias for AM detector diode - see the previous chapter]
- MC1350 IC achieved amplification of 51 dB, staying close to the declared 60 dB max gain (see datasheet)
- MC1350 IC achieved high dynamic range (thanks to internal signal attenuation and external circuit for generating U_{AGC}), close to the declared 60 dB.

Measurement 02

Assesment of no-attenuation range for MC1350
Assesment of linear (no attenuation) signal range for MC1350

Attenuator's position* [dB]	Uagc [V]	Audible?	V10.7M signal level measured [mVpp]	V10.7M signal level real** level [mVpp]
-61	1,76	barely	27	85
-60	1,76	barely	29	92
-59	1,76	barely		
-58	1,76	barely		
-57	1,82	barely		
-56	1,98	barely	39	123
-55	2,17	low volume, high noise	45	142
-54	2,42	low volume, high noise	49	155
-53	2,74	low volume, high noise	52	164
-52	3,13	low volume, high noise	59	186
-51	3,61	low volume, high noise	66	209

*) - relative value. It is assumed that the initial attenuation value was 61dB, but no real value was noted
**) - real value means the measured value recalculated to consider 10dB attenuation of active MOSFET probe

Findings for measurement 02:

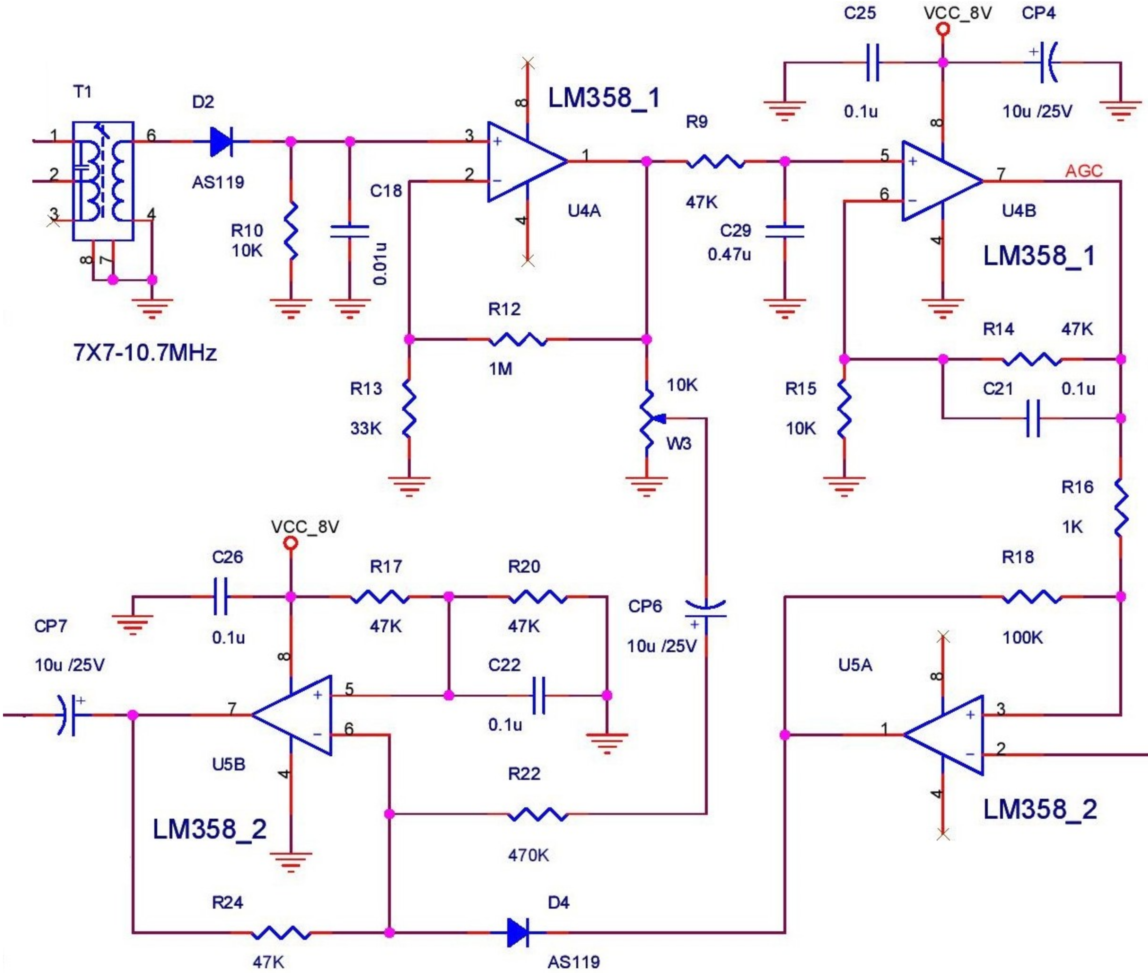
- *No-attenuation* operation of MC1350 IC is possible for a relatively small range, 7-8 dB. Then, the IC begins to reduce gain (attenuate) to keep and stabilize the output level.
- U_{AGC} is a good indicator of signal presence / absence. It is currently used for squelch function. But it can be used to drive LED or a similar indicator.

But why, the hell, the data sheet was providing 5.0-7.0 V_{AGC} range while the real results showed 1.5-3.6 V? This was a mystery for quite some time. Another look at IC data sheet brought the explanation. It is not the AGC voltage that is important. It is the AGC current that really does the gain adjustment job. The current needs to change in 0.1-0.2 mA range!

- IC datasheet schematic had 5 kOhm resistor connected to AGC pin (5).
- Air-band receiver had 1 kOhm resistor in AGC loop. Therefore the voltage levels differed.

Squelch circuit

Once we know how the AGC voltage varies with the input signal level, we can dig deeper into the squelch circuitry.



Picture: U4B and U5A form the squelch circuit. U5B is the audio amp.

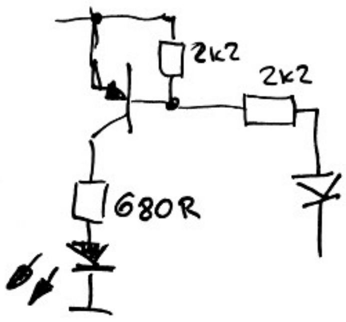
As you see, U4B filters AM-demodulated audio signal and amplifies it. Opamp U5A is configured as a comparator with some hysteresis. Comparator trigger level is set by W2 (10K) potentiometer. Circuit R19/W2 forms a voltage divider that defines the upper trigger level. Therefore the comparator's threshold can be set by W2 potentiometer between **0.0 V** and **5.4 V** (the max. output of voltage divider).

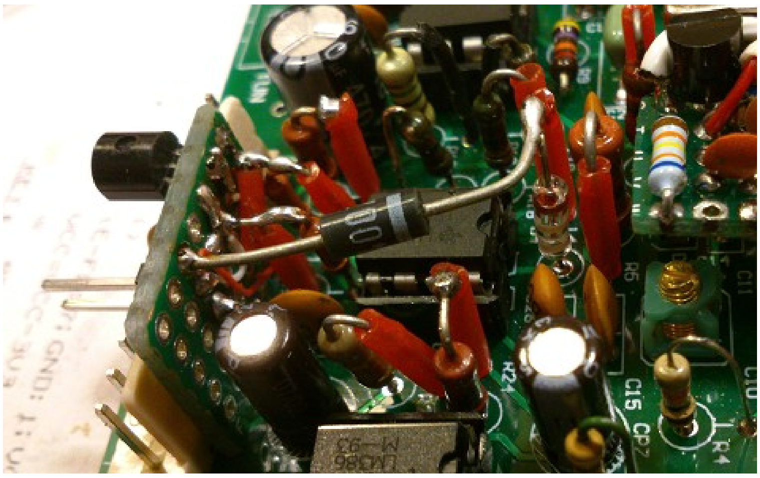
When radio input signal (air-band transmission) and the associated AGC voltage drop below the set threshold, the comparator output (pin 1) grounds the audio signal through D4 diode. So you hear no noise nor low amplitude signals in the speaker (squelch is ON). Larger voltage inputs generate higher AGC, which turns the comparator OFF (squelch is OFF) and audio freely flows to U5B opamp.

Squelch LED indicator

Simple LED squelch indicator was added to the receiver. It was connected to U5A opamp output (pin 1), in parallel to D4 (junction at it's cathode). The indicator is ON (LED diode lit) when squelch is ON. This additional indication can help user to properly set W2 potentiometer.

Schematic	Picture



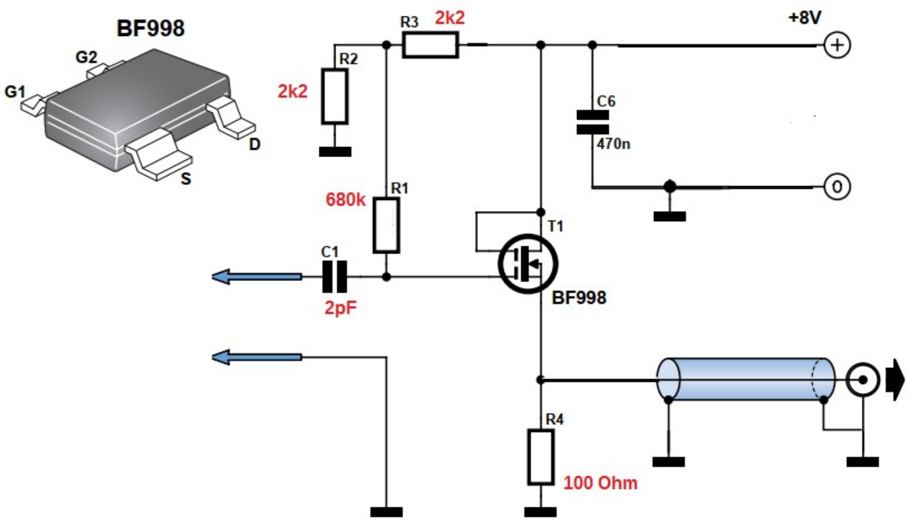


Squelch LED addon module mounted vertically, with 1N4001 diode playing also role of additional mounting aid.

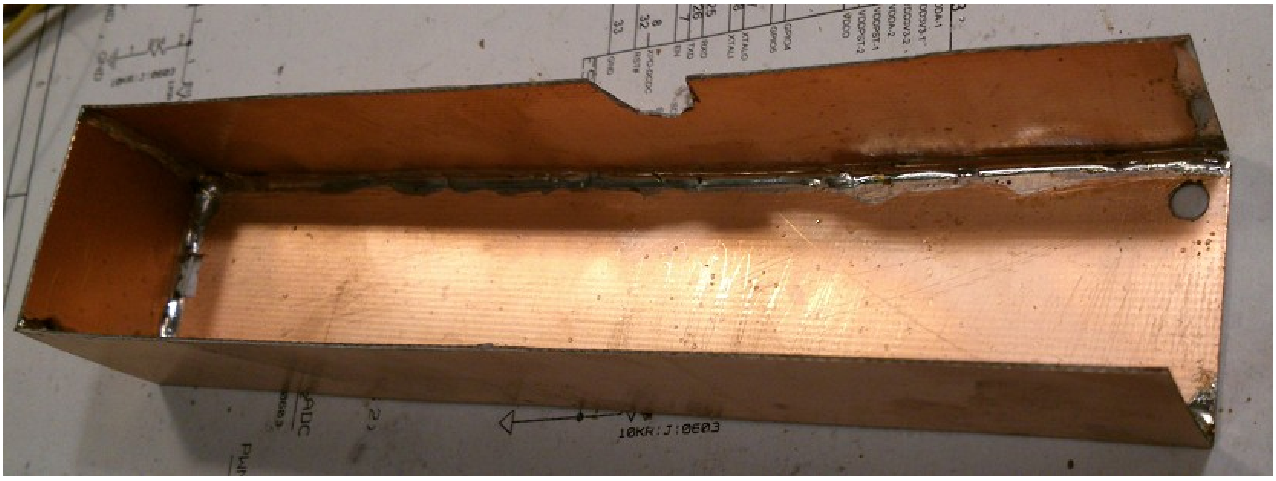
3C. Additional frequency counter

(2019/04) The kit started to receive radio signals, but we were unable to see what frequency it was tuned for. Additional frequency counter was required to display the frequency of received signal.
Cheap (but good!) 8-digit frequency counter bas purchased on Aliexpress. But the problem, however, was how to connect it to the kit?
Kit’s VFO (heterodyne) is electronically tuned (via potentiometer) and the generator is inside SA/NE612 mixer/gen IC. At first look, there is no connection point for feeding VFO signal to the external frequency counter. Some form of a signal buffer was necessary, but how to connect it?

Please refer to the additional material (attachment) on connecting the frequency counter.
Here you find just the final schematic of add-on *VFO signal separator* module. It was mounted on a small PCB and then soldered to the receiver’s kit PCB.



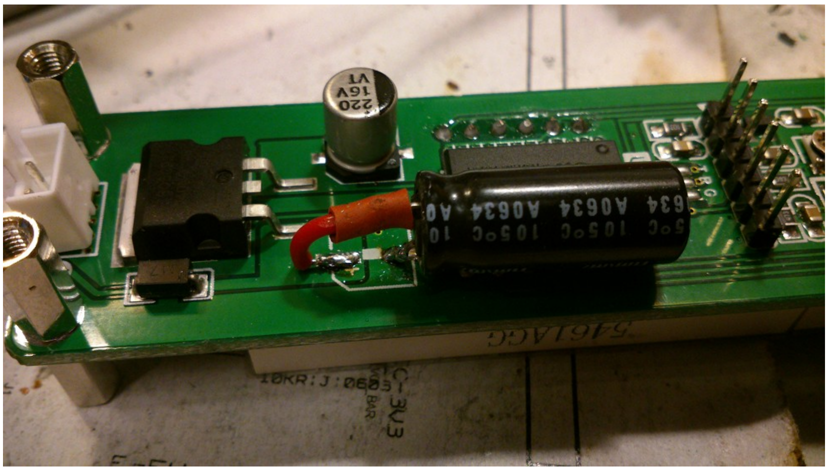
Additional shield was built for the frequency counter to eliminate (potential) spike and radio noise coming from counter’s digital parts (LED drivers, micro-controller, etc.)



Picture: The shield

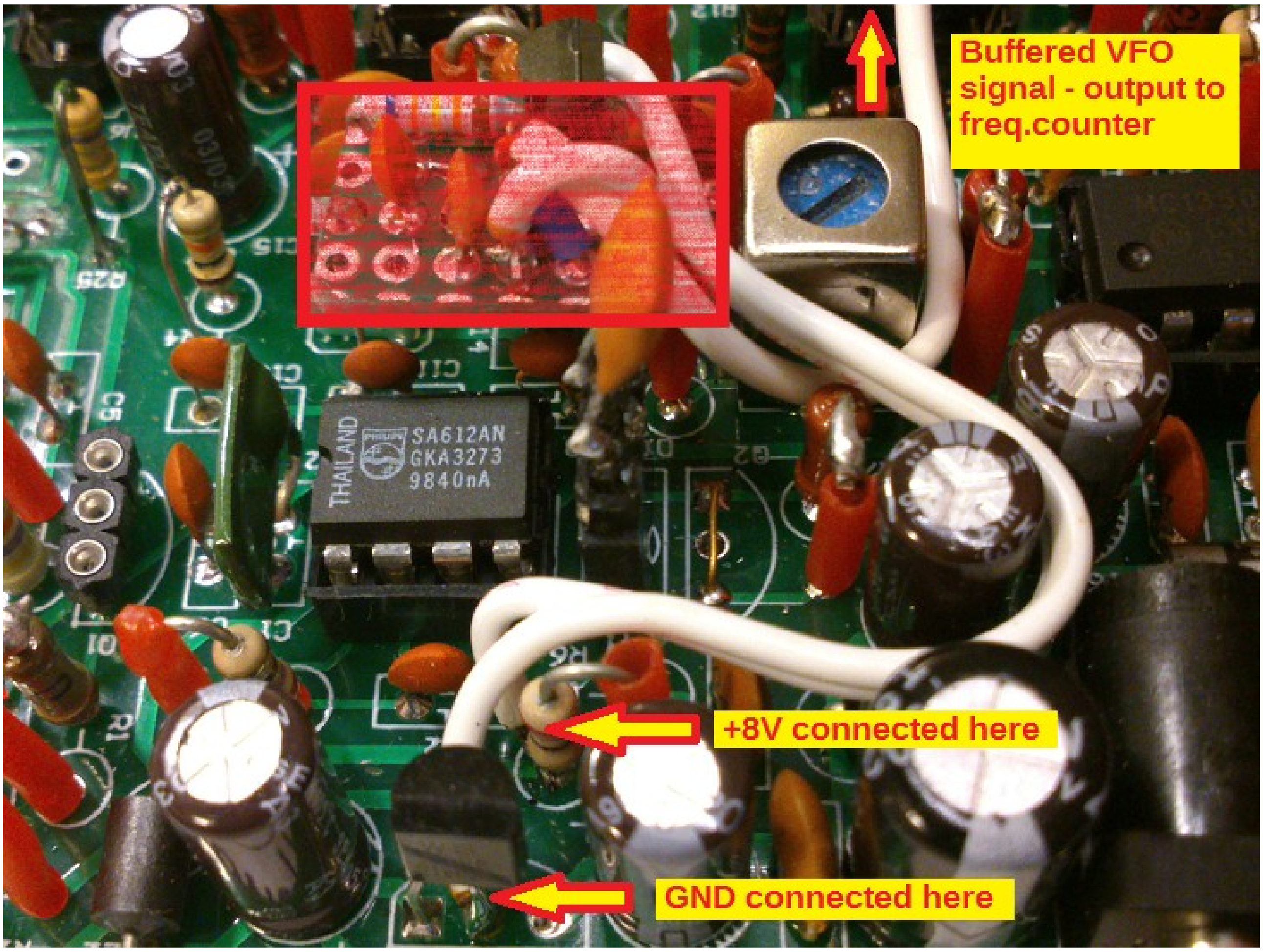
Picture: Frequency counter inside the shield

Real-life tests proved that the F-counter shield was perhaps <u>not needed</u> - radio signals received by the kit were not weaken or distorted when shield was dismantled. This just confirms the high quality of the Chinese module!



Please take care, however, about power voltage for the counter.
It needs to be well filtered, with additional high-capacity caps and (potentially) LC filters.

In our case, the on-module electrolytic cap was replaced with much bigger one. Few wounds of power wires around magnetic core was added as well.



Picture: frequency counter amplifier add-on mounted inside the receiver.

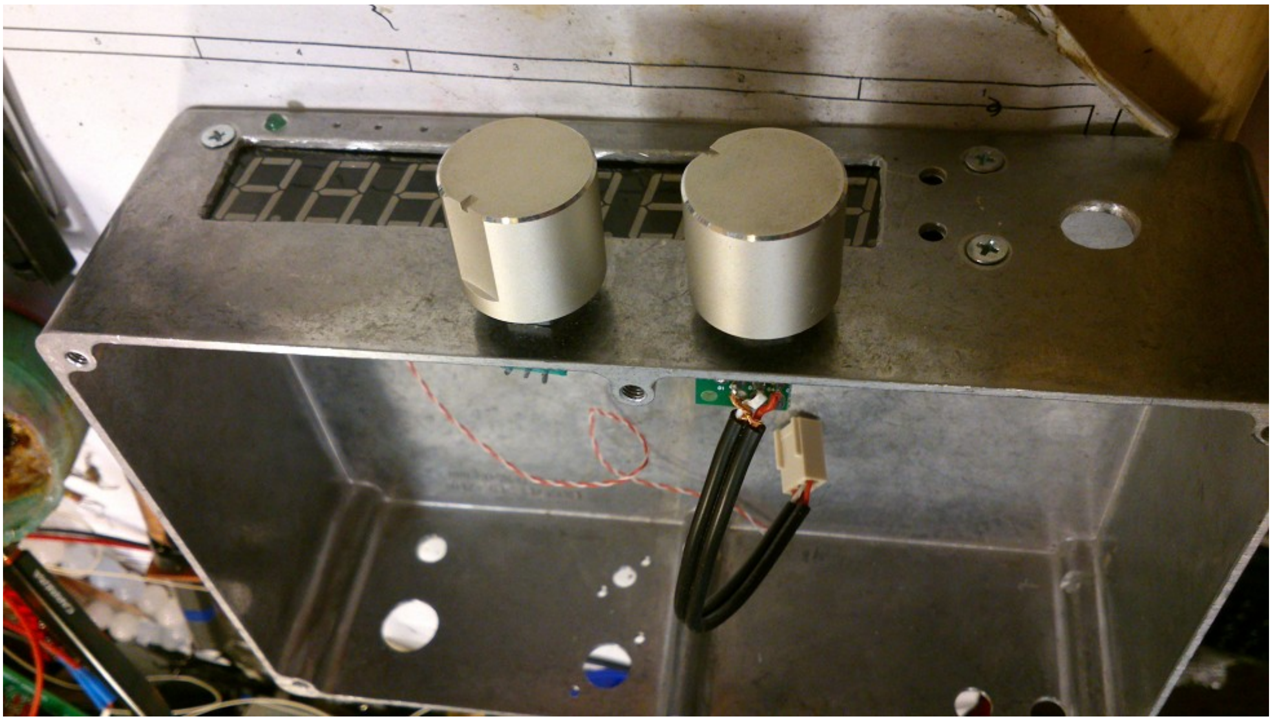
Note, this picture was taken <u>before</u> the voltage regulator 78L08 was replaced by more powerful 7807 (in TO-220 case).

3D. 78L08 voltage regulator replacement

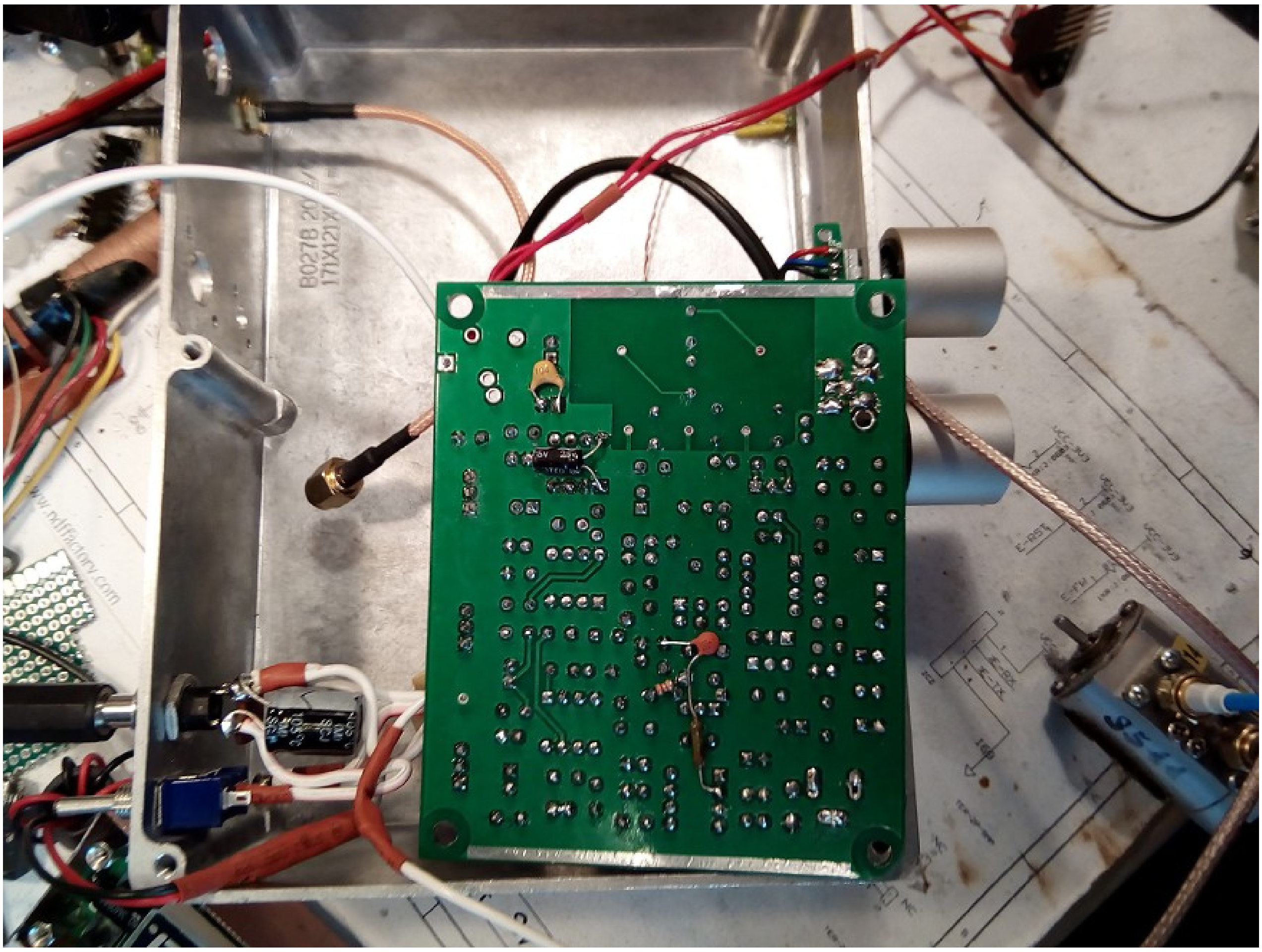
Small IC 78L08 regulator from the kit was replaced with it’s TO-220 full-size version to ensure proper thermal safety margin and to provide enough current for future enhancements.

3E. Metal case

Aluminum metal case was chosen for the receiver. It was spacious enough to accommodate the PCB, additional frequency counter, connectors and knobs.



Picture: Metal case - view from the (open) bottom.



Picture: Metal case (upside down) with the PCB. Note the necessary modifications on the board plus large electrolytic capacitor (black with white strip, located bottom left) soldered directly to DC input power socket.

IMPROVEMENTS - SUMMARY:

- IC 78L08 replacement
- 3-pin sockets for transistors Q1 and Q2
- 3-pin socket for quartz filter
- Frequency counter
- Additional VFO buffer

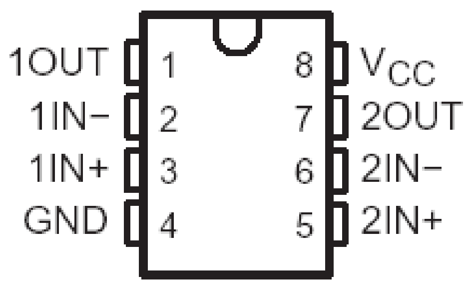
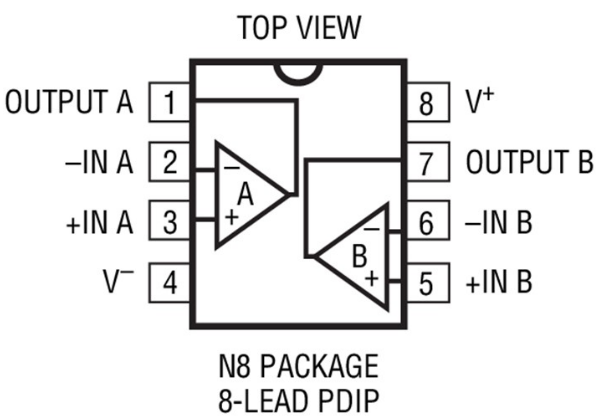
4. POTENTIAL ENHANCEMENTS

4a. LM358 opamp replacement

LM358 opamp seems to be a bad choice due to its distortions and noise. See, for instance, this source:
https://www.electro-tech-online.com/threads/reducing-lm358-output-noise.142937/
The LM358 is the dual opamp version of the LM324 quad. They were one of the first low power opamps so their output transistors have no bias and produce horrible crossover distortion. *Their low power also causes them to be very noisy and have a poor slew rate that limits the full output level response to only 1kHz (most opamps go to 100kHz).*
To reduce the crossover distortion the LM358 needs a DC load to the positive supply or to ground of 2k to 3k if it is feeding a high impedance.

Alternatives:

- **LT1006/LT1013/LT1014** are relatively low cost lower noise improved replacements for the LM358/LM324.
- **LT1013** is the first precision dual op amp in the 8-pin industry standard configuration, upgrading the performance of such popular devices as the MC1458/ MC1558, LM158 and OP-221.

<table>
<tr><th>LM358</th><th>LT1013</th></tr>
<tr><td>
</td><td>
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