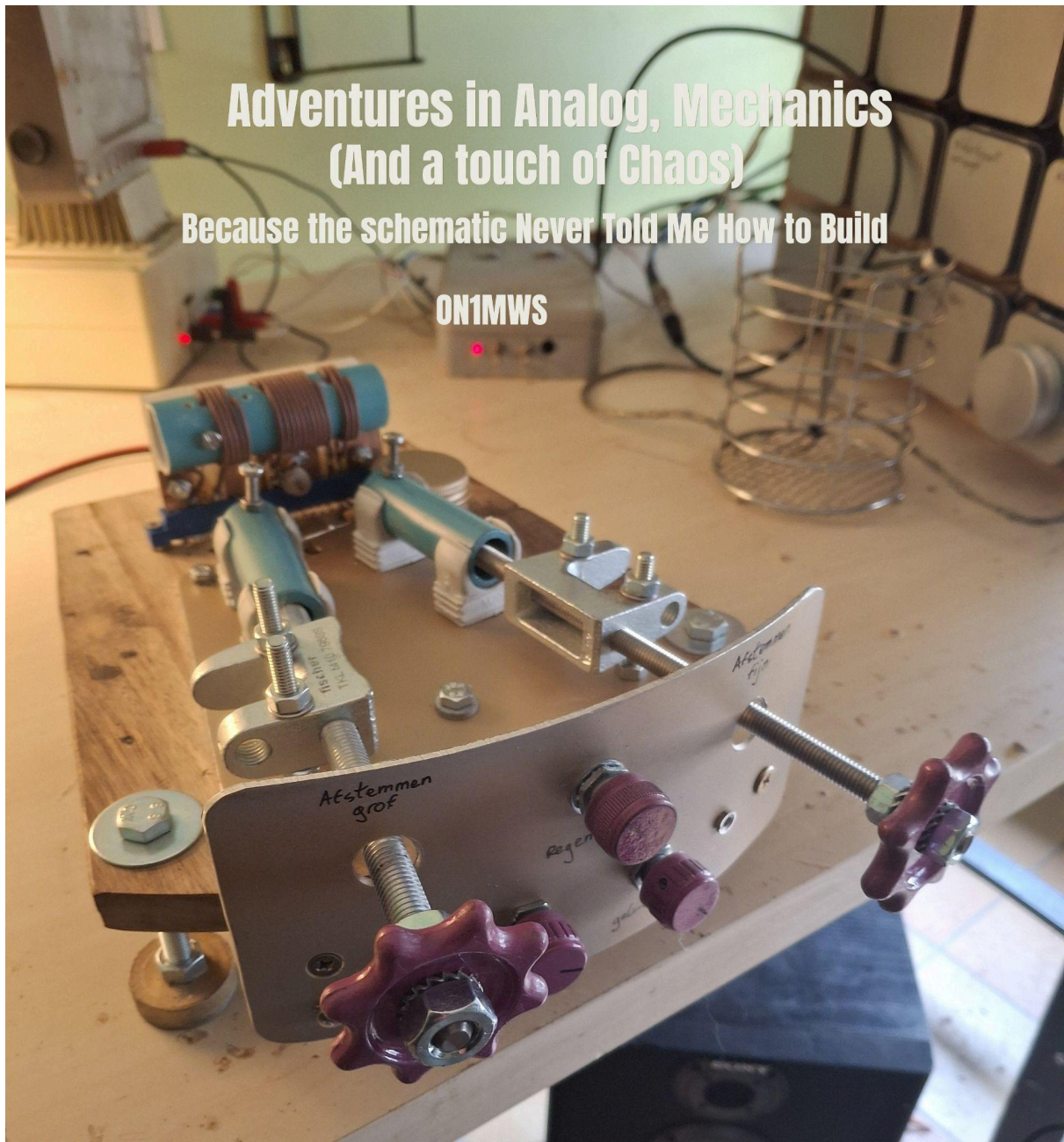




Adventures in Analog, Mechanics (And a touch of Chaos)

Because the schematic Never Told Me How to Build

ON1MWS

Revision 1, 2026.

Introduction.

'Ladies and gentlemen, welcome to the exhibit. Please keep your hands, feet, and existential questions inside the tour group at all times.'

'You are now standing in front of what experts, and I use that word loosely, call an ON1MWS radio. Yes, it works. No, we don't know why. Yes, we've checked for explosives.'

'Let's begin with the chassis. That's a **wooden cutting board**. Because when you think 'high-performance RF engineering,' you naturally think 'kitchen utensils.' The builder certainly did. This is what happens when someone looks at a ham radio chassis and says, 'Nah, I'll use something I can chop onions on.'

Behind it is a sheet of aluminium. Not aerospace aluminium. Not precision machined aluminium. Just scrap aluminium. Possibly from a road sign. Possibly from a baking tray. We don't ask questions.'

'Now, the metal cylinders you see? Those are **tin cans**. Yes, actual tin cans. Square tins, Nivea tins, Belgian chocolate thins, the whole supermarket RF department. Each can contains a different stage of the radio. It's like the world's most confusing spice rack.'

Visitors often ask, Why would someone build a radio like this? And the answer is, because the builder is following **RF physics**, not **aesthetic sanity**. And RF physics apparently said, 'Put the oscillator in a Quality Street candy tin and bolt it to a wooden daisy board.'

'Before we continue, please take a moment to admire the tuning system. Yes, those are **pressure-valve knobs**. No, they are not connected to any plumbing. These control a homebrew multi-tube tuning capacitor, a device that boldly answers the question nobody in RF ever asked 'what if frequency tuning feels like you're operating an industrial boiler?'

'Please admire the soldering. It looks like a family of spiders attempted modern art during an earthquake. This is called **ugly construction**, and believe it or not, it actually works better than the neat stuff. Yes, we're all upset about that.'

'Now, if you're thinking, This looks like something a Cold War spy would bury in a potato field, you're absolutely right. Future archaeologists will have a meltdown trying to classify this. They'll probably decide it's a ritual object used by a cult of mechanically inclined lunatics.'

'But rest assured, this is a real radio. It transmits. It receives. It talks to other radios. It does everything your shiny commercial rig does, and violates any visual and ergonomic expectation you might have at the same time.'

'Ladies and gentlemen, the ON1MWS rig'

'proof that with enough stubbornness, scrap metal, and strange decisions, you can confuse both historians and your local ham club'

Here's the general shape of what follows.

Chapter 1, where the itch begins.

This was the most difficult chapter to write. Why bother with building something inferior you can simply buy.

Chapter 2, The first challenge.

Here the story gets practical. Before anything else in this book can exist, you need a stable oscillator. This chapter is the tale of wrestling an analog VFO into behaving.

Chapter 3, discovering that the mechanics are half the radio.

At some point, every builder realizes that mechanics can ruin your fun. This chapter is about that realization, the moment you stop treating mechanics as an afterthought and start treating them as the actual architecture of the radio. Tin cans, ground plates, odd homebrew tuning capacitors, and improvised shields in my case...

Chapter 4, the part that no one advertised, failure as a learning curve.

This is the chapter where things fall apart, literally. It is about failed rigs that come before the successful ones. It is also about how a perfectly functioning rig can annoy you so much that you destroy it.

Chapter 5 , a complete station ecosystem.

Enough with failure. This chapter is the payoff, a series of working projects that actually work well. A superhet receiver, a CW transceiver, a power supply, a dummy load, an antenna, an SWR reader, a T/R relay, and a regeneration receiver, each one a functioning piece of gear from easy to more difficult.

Chapter 6 , the high peaks of analog scratch building.

Every builder eventually reaches the projects that feel like final bosses. This chapter is about those, a scratch built SSB transceiver, linear and a tube regeneration radio. These aren't just circuits. You join an exclusive club after you build these. I hope to prove that this club is too exclusive.

If you want to build radios from raw parts, and you'd prefer not to lose a decade learning everything the hard way, then you're in the right place.

Chapter 1

Who we are and how we're gonna do it

The mindset of a scratch builder.

on1mws

Who we are...

I found this section the most difficult to write. Why try to build a circuit, bend metal, drill holes, struggle with your creation for months if you could just buy it right off the shelf? Furthermore, the thing that you are homebrewing will never be able to compete with the performance of a commercial version. It can't be to save money. Certainly not to save time. There must be other reasons.

The joy of achieving something.

My current day time profession is maintenance mechanic. The factory luckily lays a heavy emphasis on preventive maintenance (I have also worked in factories where they let everything run until it blows up) From time to time there is naturally an emergency situation. The production stops. Production personnel stand idle, managers panic and profits stop. Then my colleagues and I get a call. We get the same treatment as surgeons when we arrive at the broken machinery. Not because we are super heroes, but because we are trusted to fix the problem or find a way circumventing it. In these situations we have no choice, we must solve the problem. Our reward is respect for our effort, knowledge, improvisation and problem solving. A feeling that feels good. So this must be the first reason for homebrewing. The satisfaction of mastering a problem.

Creativiteit.

My neighbor Hein likes gardening. His garden is weedfree. Every season he plants new stuff. His garden is evolving like his evolving taste. Some seasons he removes perfectly good plants because he does not like them anymore. His garden is his way to be creative. He creates a world that did not exist before he made it with his hands. I guess that **everyone** you know has and searches for a way to be creative. My way is to build radios. Gardening is not my thing by the way. Hein is a friendly guy and pretends he is not judging my garden, where nature runs a small democracy. I pretend I don't know he is judging me. We get along fine. His creativity grows out of the ground, mine grows from solder fumes.

Connection, meaning and pride.

When you buy something from a store, you will use it until it breaks. Then throw it away without any feeling at all. The thing has served its purpose. A purchased radio is a tool with no personal connection.

But you can endlessly admire your own homebrew radio. You planned the project. You made the enclosure, soldered the circuits, and understand how the electrons flow. You feel pride for your own work. No purchased radio (or anything else) can give you the same feeling.

Identity.

This is not a reason why I started to homebrew but it only occurred to me recently. Let me lose in a room full of **unlabeled** homebrewed HAM gear and I will effortlessly spot the rigs from K0IYE, PA2OHH, F5LVG... Each homebrewer has his own style. None of these homebrewers developed their own style. They just grew in it and have gear with their own DNA.

It's free therapy.

Long after you leave your bench you will still think about your project. Why does this not work, is there a plan B, How can I think up a test procedure for this or that circuit? Usually get the deepest insight after you leave your bench because you stopped doing useless tests. You unravel the problem with more clarity once you leave your bench.

Essential traits for a scratch builder.

To reach mastery in any field you will need, besides time, 3 traits, curiosity, persistence and being able to fail.

Curiosity is obvious. You will need to have the irresistible urge to want to figure out how and why something works. I can remember that I was looking through the ventilation holes in the back of our old black and white CRT television in the late 1970s. Our TV was still one with tubes. As a child I was fascinated by the glowing tubes, visible components and the smell of this huge TV. I knew it wasn't magic. I swore that I would one day understand how this all worked. Yeah, I'm still working on that one.

Trait 2 is **persistence**. A project like building a radio will take you some months. I work with deadlines. I will finish circuit block A by 3 weeks and circuit block B another 3 weeks from then. I am a very good employer for myself, I always set myself very easy deadlines.

Trait 3 is **Being able to take a loss**. Not every circuit or enclosure you'll touch will turn into gold. Especially when you start out. You will have to be able to accept that. For me it is no problem. In 2016 I did join our local chess club. I lost every single game in the first 4 years. But I kept going. (now I lose only 60% of the games) I just have that kind of personality. In chapter 3 you will read about a lot of failure, but how this led to a set of mechanical rules. In chapter 4 we will look at a notorious rig that failed many times. I hope it will be hilarious and that you will think 'why did this guy simply not give up'

How we're gonna do it.

I don't have enough math skills...

Welcome to my world, dear reader. I only have completed high school. I only master basic math. And, yet, here we are building radios. What I will show is that, thanks to the internet, there are shortcuts for us. There are online calculators for our needs. There are tank circuit calculators, Amidon coil calculators, crystal ladder filter calculators, plate capacitor calculators... You press in the numbers and the computer does the heavy lifting for you. No shame. We're here to build radios, not to derive Maxwell's equations on a napkin.

Limitations in physics knowledge and how to outsmart them.

Throughout this book you will notice how much I don't know. I will always be brutally honest about it. It also gets harder to learn as I get older. The way I learned to circumvent my limitations is to use **axioms**. When I read in many sources that this or that circuit works like this or that, but I don't completely understand it, it is time to put this wisdom in my axiom box. For example, a crystal ladder filter must have a matching impedance on its in and output. If not, the bandwidth and shape of the filter will be distorted. Do I really understand this, no. But it is in my mental drawer labeled 'true because smarter people proved it'. I am standing on the shoulders of others, enjoying the view.

Sifting through information.

Most classic books can be found for free online. The W1FB books and I also found 'Secrets of RF circuit design' from Joseph J. Carr useful.

But the classic is naturally 'Crystal Set to Sideband' from Frank W. Harris K0IYE. It isn't just a book, it is a journey. It's a story about Frank trying to understand radio by building everything from raw parts, slowly climbing from a crystal set to a full SSB station. Eventually he even built a working 2M station from scratch. It is not a dry text book but woven with funny stories. Frank also does not hide dead ends which is rare in a technical book. It is the book that made me think 'Hey, I could build transmitters too'.

To understand difficult RF concepts, nobody explains them better than Nick Wood, M0NTV. Check out his YouTube channel. Last year I was nodding the whole way through his video about impedance and how to use Smith charts. A truly impressive feat. Nick is a natural born teacher, and his understanding is on a completely different level than mine.

Standardisation, the secret weapon of scratch building.

After many years of tinkering, rebuilding, and discovering what actually works on a real bench, I ended up with a personal library. A set of circuits I trust completely. These are the blocks I reach for every time.

Here's what my toolbox contains:

One oscillator schematic

One frequency-stabilization circuit

One crystal oscillator design

One mixer circuit

One product detector

Two HF/IF amplifier stages

One AM detector

One audio-filter circuit

One LF audio amplifier.

One RF power amplifier circuit.

One gain distribution layout for receivers.

That's it.

These circuits appear in every project I build. They don't change. They don't need to. They are my **Lego bricks** — reliable, predictable, and endlessly combinable. Once you have your own set of "Lego circuits," everything becomes easier. Your builds become faster because the fundamentals are already solved. Your troubleshooting becomes simpler because you know how each circuit behaves. Your creativity increases because you're composing with familiar ingredients. Your rigs become more consistent because the building blocks never change.

Scratch building stopped being chaos once my tool box was complete. My "I know this won't explode" collection. This is the quiet superpower of the analog alchemist.

To have real R&D fun, you don't need a licence.

Okay, the transmitters and transceivers are out without a licence. Still, I will argue that analog scratch building can still be fun and exciting. You can become a specialist in DC receivers, like Onno Hoekstra PA2OHH. Onno has become a true master in small, capable DC receivers. Or dive in DC receivers with sideband cancellation, like Harry lythall SM0VPO. Or you could become the next Olivier Ernst, F5LVG, who has been building all sorts of regeneration radios to an impressive performance.

Or just maybe you could become a specialist in 'hybrid' radios. Hybrid radios that mix the shortwave frequencies to low intermediate frequencies like 455 Khz, followed by a regenerative detector. A combination of a superheterodyne and regenerative receiver. Such circuits did exist in the 1930s. Google 'super gainer radio'. Super gainers are largely unexplored territory and should be pretty capable receivers. Such radios haven't been built for many decades and you could become one of the **few people on our planet** who have hands-on experience with this type of radios. The point I am trying to make here is that to have R&D fun you don't need a license. You can design receivers that no modern commercial radio can replicate. Explore the corners of analog radio that commercial designers abandoned decades ago.

So let's leave the philosophy on the shelf for a moment. Time to roll up the sleeves and build the heart of the beast.

Chapter 2

The gateway challenge.

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Every craft has a gateway challenge. In radio building, you might expect it to be a friendly looking regeneration receiver, the schematic fits easily on one A4 page, right? Just a handful of components, a single transistor, a coil, tuning capacitor. How difficult can it be? A regen is not a beginner project. It is an **oscillator balanced on a knife-edge**, interacting with the antenna, the room, your hand, the weather... It is **one** transistor doing several jobs at once. It will hate its life and will punish you for your optimism. A regen is not where you start analog scratch-building. A regen is where you arrive after you've learned to tinker, to persist, and are very confident in your skills. If writing this counts as heresy, then so be it. The journey begins with something far simpler and far more important:

A stable analog oscillator.

If you can build an oscillator that stays where you put it, the rest of the book will open up. This chapter shows you how to get there; first the oscillator, then an unusual stabilizer to keep it in line.

The heart of any beast.

Every radio, transmitter and transceiver has at least one oscillator in it. When we look into the entire ecosystem of a station (chapter 5) we will discuss how this circuit is used. For now we can simply state that an oscillator is a circuit that generates a frequency. A power voltage is applied to the circuit and on the output a sinusoidal appears.

An oscillator is an easy build.

This book is about how to build and will avoid the basics. There are many YT clips that can show you the basics. What I use from the beginning is the Hartley oscillator. This oscillator uses a coil with a centre tap. Which avoids the capacitor divider of Colpitts oscillators. I find them much easier to build.

<https://youtu.be/Jf1rprWfVsA> SimplyInfo,

Is nice. This Hartley uses a transistor and the coils are to the collector. Not an exact replica of our oscillator but you will have a picture. So far I have not found a YT clip with the circuit I always use.

<https://youtu.be/MYGFWUmpe5Q> WA6BBQ

It is interesting to see what you can expect.

Hand-drawn circuit diagram of a frequency generator. The circuit includes a 12V supply, a 7805 voltage regulator, a 2N310 JFET, a 2N3904 or 2N3866 BJT, and a transformer. The JFET is biased by a 100Ω resistor and a 10V capacitor. The JFET's gate is connected to a 100pF capacitor, a 50026 diode, a 1N4148 diode, a 100K resistor, a 680 resistor, and a 10nF capacitor. The JFET's source is connected to ground. The drain is connected to a 47pF capacitor, a 100K resistor, and a 47 resistor. The output of the JFET is connected to the base of the BJT. The BJT's base is connected to a 1K resistor, a 10nF capacitor, and a 47 resistor. The BJT's emitter is connected to ground. The BJT's collector is connected to a 100nF capacitor, a 1K resistor, and a 1N capacitor. The output of the BJT is connected to a transformer with 10 turns of bifilar winding. The transformer's primary is connected to a 12V supply through a 100 resistor and a 10nF capacitor. The transformer's secondary is connected to a 10nF capacitor and a 47 resistor. The output of the transformer is labeled "Frequency Out".

The source resistor (680 Ohm) with the 10 nF sets the bias and keeps it stable. The 10 nF lets the RF pass unhindered. I've built these oscillators without the source resistor and they also work, but they start up less easily. Think of the resistor as the transistor's mood stabilizer. Less current means less heat and more stability.

The 100 pF into the gate feeds back just enough signal from the drain to keep the oscillation going. This capacitor must be as small as possible to avoid overloading the tank circuit.

That's it. The tank rings, the J310 feeds it, and the whole thing becomes a clean RF sine wave.

The second J310 is the first buffer amplifier. It takes as little signal as possible from the source and passes it through. Output impedance is 50 ohm. From here on, you can use 50-ohm cable if it's convenient.

The 2N3904 amplifier is the second buffer amplifier, the RF driver. The signal leaving the output transformer should be enough to drive a mixer. The 2N3904 is a 50-ohm-in, 50-ohm-out amplifier. One of my Lego bricks I always use in oscillators and linears.



This is the way it looks in reality. Neat soldering clearly doesn't play a role in building a working oscillator. There was enough room in this tin can to build the oscillator, buffer amplifier and RF driver. The tuning capacitor is located elsewhere and is connected in the shortest possible way.

In this oscillator and throughout the book we use Amidon toroid cores. They're easy to get, cheap enough, and the online calculators keep you out of trouble. The T cores are iron-powder. They have less iron than ferrite cores. They don't have much permeability, but they have high Q and they stay stable when RF current flows. That makes them perfect for tuned circuits like our tank: they ring cleanly and don't drift the moment you look at them.

The FT cores are ferrite. Very high permeability, very low loss, and they couple windings like glue. That's exactly what you want in broadband transformers and baluns: strong coupling and wide frequency range. But ferrite makes lousy tuned circuits, too much permeability, too much loss, and the Q collapses.

So the rule is simple: **iron-powder for things that must resonate, ferrite for things that must transfer energy over a wide band**. Once you know that, the rest of the book will feel a lot more logical.

What is my success rate when building this oscillator? **100%**. I've used this design since 2010 and every single one fired up right from the start. Maybe that's why I love this circuit so much.

Before we dive deeper into the details, we have another important topic.

The key to success

I've been an industrial electrician and mechanic for about 35 years. What is the secret of a good technician? We all make mistakes, but a good technician at least double-checks his work. After you build the oscillator and buffers, get your magnifying glass out. Check every solder joint. Go over your work again with the schematic next to you. Re-check the pinout of all semiconductors.

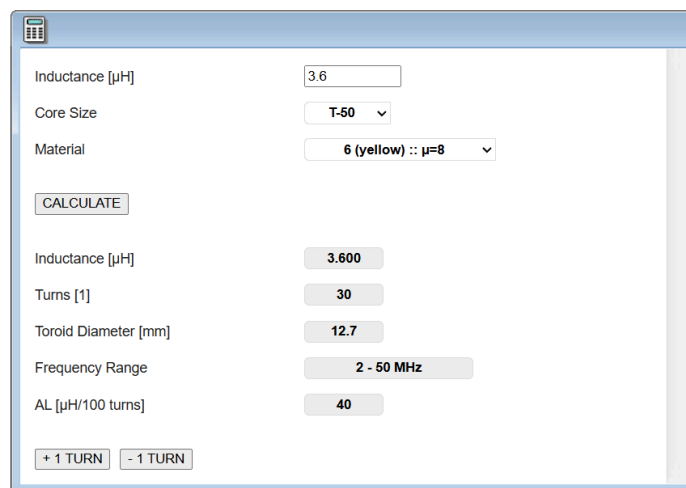
Be extra alert when we reach the logic ICs near the end of the chapter. Is the pinout correct? Are there no shorts between the many leads of the ICs? This is even more important with these ICs, because replacing them is a pain if you use the "dead bug" style like I do.

Keep this habit throughout the book. Double and triple checking your work before you apply power will save you a lot of time (and frustration).

What is the frequency range of this oscillator?

This is an excellent opportunity to demonstrate how someone, who only masters basic math like me, gets away with stuff.

To figure out the frequency range we need to know the inductance of the tank coil. Its 30 turns on a Amidon T50/6 core. Yes there are formulas....



The image shows a web-based calculator for determining the inductance and frequency range of a toroid coil. The interface includes input fields for Inductance [μH], Core Size, and Material, along with a CALCULATE button. Below the button, the calculated values are displayed: Inductance [μH] is 3.600, Turns [1] is 30, Toroid Diameter [mm] is 12.7, Frequency Range is 2 - 50 MHz, and AL [μH/100 turns] is 40. At the bottom, there are buttons for +1 TURN and -1 TURN.

Parameter	Value
Inductance [μH]	3.6
Core Size	T-50
Material	6 (yellow) :: μ=8
Inductance [μH]	3.600
Turns [1]	30
Toroid Diameter [mm]	12.7
Frequency Range	2 - 50 MHz
AL [μH/100 turns]	40

https://www.changpuak.ch/electronics/amidon_toroid_calculator.php

There are also online calculators. Just fill in the type of core and turns ... Our coil turns out to be 3,6 uH.

There is a formula to determine the resonant frequency of the tank circuit.

$$f = \frac{1}{2\pi\sqrt{LC}}$$

L in H and C in F.

But you guessed it, there are online calculators who do the heavy lifting.

<https://www.allaboutcircuits.com/tools/tank-circuit-resonance-calculator/>



capacitor tank circuit



Inputs	
Capacitor Value	20 picoFarad (pF) ▼
Inductor Value	3.6 microHenries (μH) ▼
Calculate	
Output	
Resonant Frequency	18.76 (MHz)

Inputs	
Capacitor Value	356 picoFarad (pF) ▼
Inductor Value	3.6 microHenries (μH) ▼
Calculate	
Output	
Resonant Frequency	4.446 (MHz)

The frequency will likely be tunable between 4 to 18 MHz. The frequency will depend on how you build it mechanically but we have a clear idea in which ball park we will end.

The schematic of the oscillator is the actual oscillator in my Holiday radio. It works from 6 to 22 MHz. I now realize that I was sloppy when I made the schematic years ago. There must be less turns on the coil. probably only 25 or so...

What if you want to wind a real air coil instead of a small coil wound on a Amidon coil. Yes there are formulas to do that, really complicated ones!

https://www.66pacific.com/calculators/coil-inductance-calculator.aspx

☒ Centimeters
☐ Single-layer coil
☐ Multi-layer, multi-row coil
☐ Multi-layer, single-row coil

(The following inductance formula requires units in inches.)

$$L = \frac{\text{Radius}^2 \times \text{Turns}^2}{9\text{Radius} + 10\text{Length}}$$


Turns:
 Diameter:
 Length:
 Depth:

Result: Inductance = 1.5 microhenries

But don't let that stop you, just find a calculator. There are calculators for simply everything. Even the law of Ohm. But my pride forbids me to use that one!

So, it's easy to build, not hard to calculate. Why isn't the world filled with analog oscillators?

Drift is the real gatekeeper.

For this occasion I disconnected the frequency stabilizer of the oscillator of my SSB oscillator. The oscillator is now 'on its own' The oscillator of the SSB rig is identical to the one above. It was configured for 40M so the frequency is about 18,1 MHz (pretty high) . I'm actually excited to know the result.

Why does an analog oscillator drift? Voltage changes, outside loads on the oscillator. and temperature.

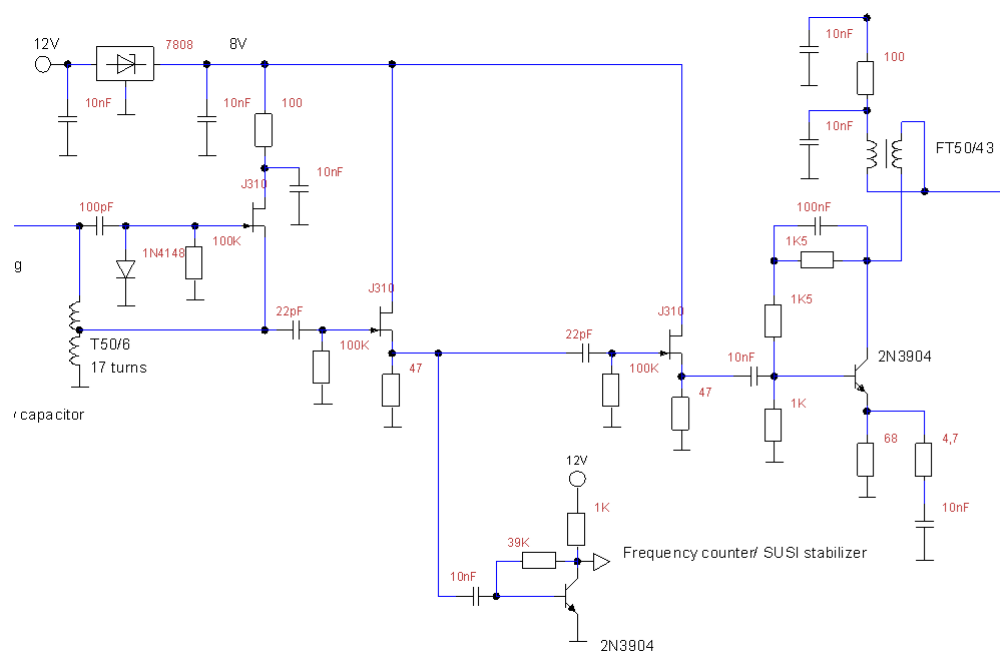
- If the voltage varies then the PN junctions will vary in the semiconductors. And thus the capacitance of the J310 and consequently the frequency. In our schematic you will see a 7805 voltage regulator. The output is always 5V. The voltage regulator is uniquely dedicated to the oscillator and 1st buffer stage. At least we did that right.
- The buffer stage and RF driver stage isolate the oscillator from the mixer. All sorts of stuff is going on in the mixer. The frequency will become unstable if this reaches the tank circuit.
- Another outside source is your body. That's why the oscillator is shielded. Eliminating the 'hand effect' is easy.
- The biggest problem is heat. Every component, the PCB, every solder joint, every wire, the tuning capacitor, everything has a temperature coefficient. This means that the capacitance of everything your oscillator is made of will change with temperature. Even the tiny currents that flow will heat the oscillator up. Internal heating is the silent killer for analog oscillators.

Just checked my free running oscillator. It's been running free for 50 minutes. The drift is 5 Hz/minute. What? That's not possible, the thing is playing a cruel trick on me. Now that it has to drift it does not want to. I'll do the test again and again until I have a bad result. I did the test the day after and the oscillator dropped several 100Hz in the first ten minutes. That's more like it.

Now we see that building and calculating an analog oscillator is easy but drift is the enemy. Before we look at the weapon we need to dive just a little bit deeper.

A Problem that only homebrewers know about.

Analog oscillators have a very dim view on T/R switching. All sorts of stuff will appear in the mixer when you switch to transmit. This will get into the tank circuit through the buffers. We are not talking about drift but a real jump. Your oscillator has just changed into a small angry trampoline. Our above schematic is fine for receivers but for transceivers we will use two J310 buffers.



Two J310 buffers in the oscillator of the SSB rig. And one transistor for the frequency counter. The extra J310 buffer protects the oscillator nicely from jumping when you switch back and forth from receive to transmit.

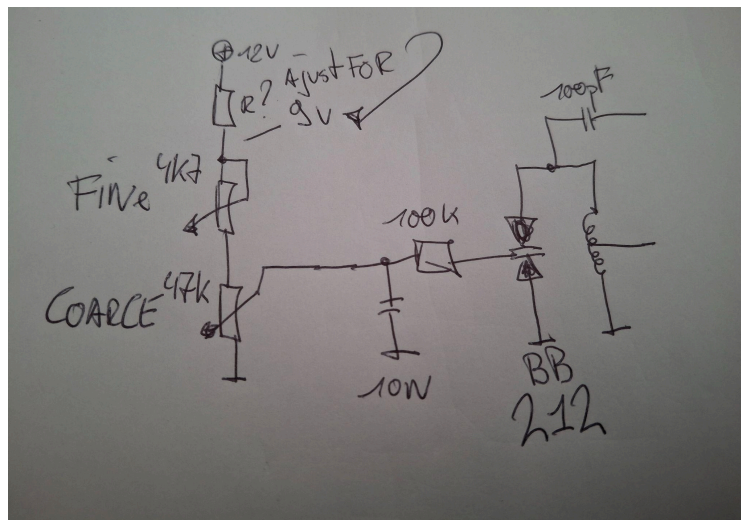
The many ways to tune the oscillator.

Old 1950s style tuning capacitors are harder and harder to get. So what do you do if you can't get hold of one? Fortunately, there are alternatives.

One alternative is varicaps for the AM band. Varicaps with a capacitance of 450 pF. These are now also scarce in the 2020s. Contemporary electronics are small cell phones, not AM radios. My local supplier Gotron stopped selling them.



But I still see them on other sites. 4,95 Euro. Fake? Maybe? Only one way to find out.

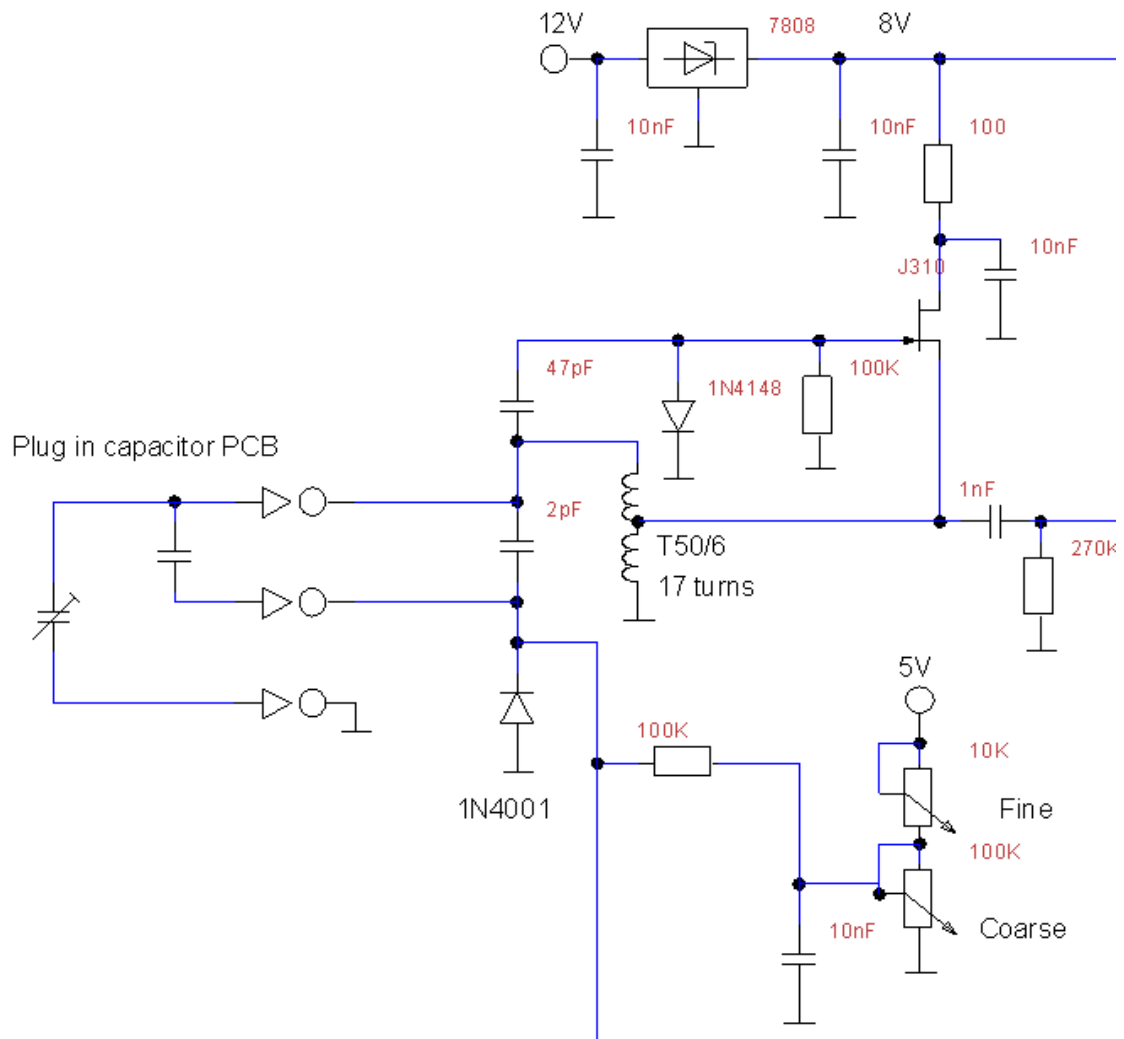


This is the way you replace the 1950s style tuning capacitor with an AM varicap. The Varicap has one huge advantage over the old style tuning capacitor. You get fine tuning for free with an extra potentiometer. The values of the tuning potentiometers are not critical. Just find values that feel right when you tune coarse and fine. The capacitor before the 100K is necessary to keep RF out of the tank coil.

Maximum voltage over a BB212 is 9V, so the resistor above the fine tune potentiometer will have to limit the 12V to 9V.

What if you can't find either of these solutions? There are more options, cheap ones.

Let's see how my old SSB did it.



Same oscillator. Same Lego block. But this time there is no 450 pF 1950s capacitor and no AM varicap in sight. How did I tune every band? With a humble 1N4001 diode. Yes, the classic rectifier diode. Misused as a varicap. Its capacitance is around 30 pF.

The PCB modules plug into cheap AliExpress edge-card holders. To tune a band, I simply plug in a capacitor PCB and tune a few hundred kilohertz with the 1N4001. It worked beautifully.

A 1N4001 can also be replaced by a real VHF varicap like a BB105. The capacitance is similar, but a real varicap gives more tuning range. A BB105 is built for this job; a 1N4001 is not, but it still works.

So yes, there are many options.

And the last one, the humble diode, is no problem at all.

Using the oscillator to get to know your oscillator and improve your tinkering skills.

This is the moment to have fun, especially if you don't have much experience with analog scratch-building. Build the oscillator and **play with it**. Try different tuning methods. Swap coils. Change the layout. Touch the coil. Blow on it. Watch what happens. This is how you learn.

And just as important: **get to know your measurement equipment**.

Oscilloscopes can be found second-hand for very little money. Put your probe in 1× mode on the source of the J310 and see what the waveform looks like. You'll learn more in five minutes than in five pages of theory.

Voltoid

✓Choice | Aideepen MinTool-Wholesale777 Store > 



Dc 8V-15V 0.1Mhz ~ 65Mhz 6 Cijfers Le
Blue
€18.29 x1
Gratis retourneren

Frequency counters can also be cheap, very cheap. I bought one from AliExpress: six digits, very sensitive, can subtract the IF if needed, and it's a steal. I've seen the same model for 12 euro, shipping included. I can't say anything bad about it. It just works.

This hands-on phase prepares you for the next step: understanding drift, the real gatekeeper.

How would K0IYE and F5LVG reduce the drift?

Chapter 10 of K0IYE's 'Crystal set to sideband' and 'Stability of LC oscillators' on F5LVG's website are the lectures you need to learn how the masters do it. This is just a **short overview**.

K0IYE's most important tips,

- Use FET's.
- Shield the oscillator. (hand effect)
- Use a single sided PC board.
- Varicaps are the most stable component.
- Use air coils if possible.
- **Precision voltage regulation** for the VFO supply is vital for precision frequency stability. Frank uses better regulators than the 7805s I use.
- The VFO should draw as little power as possible. In other words, the lowest possible voltage. Less current is less heat.
- Every component in the oscillator that dissipates power (like the 7805) should be outside the oscillator box.
- Use C0G fixed capacitors. I bought some super cheap NPO capacitors on Aliexpress and use them in my tube regen. Drift when down by 2/3. They seem to be the real deal

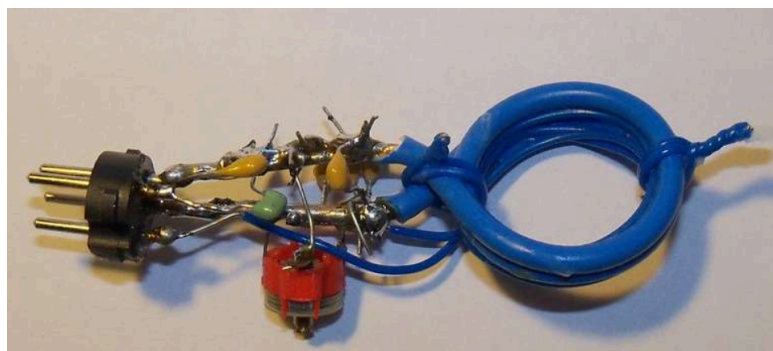


- And yes, Forget about tube oscillators. LOL.

Every single measure is important. In CSTSB there is also an explanation on how temperature compensates for stability, an art on its own. Frank got the drift down to 5 Hz/minute which is absolutely insane performance! All the oscillator designs are 5 MHz oscillators.

Discovering Olivier, F5LVG's work led to discovering more stabilization tricks.

- Use a large air coil. With as few windings as possible. The width of the coil should be less than the diameter.
- Olivier has an interesting way of building coils. I still need to try that.



- Olivier also claims that you should have as much capacitance as possible in your tank circuit. His reasoning is that temperature has the most effect on the capacitors. So if the overall capacitance is large, the impact is less.

There is a link to a page where he presents an oscillator which has a drift of 30 Hz/hour. Per hour! Olivier has been building regens and oscillators for 40 years and it is obvious by scrolling through his site that he is a master in what he does.

The closest I ever got to their work was my solid state regeneration radio. Many of the master's tips were used. And I was surprised by the result. The drift is maximum 20 Hz/minute in the winter and less in the summer. The regen runs at 7,15 MHz. I could still replace the capacitors with NPO types. The drift should be better.

Disadvantages of their approach.

The disadvantage of building super stable analog oscillators is that is only possible if they run on a relatively low frequency, and have limited tuning range. When you see the designs in Crystal set to sideband you will see that the stable oscillator frequency (5 to 5,3 MHz) is mixed with crystal oscillators to the desired frequency. This is a huge task. Mixers, many crystal oscillators and lots of filtering. Filtering out unwanted mixer frequencies is hard. Because of all that, every design in CSTSB ends up as a double-super. The effort Frank K0IYE put into those rigs is impressive. His radios are more analog pure than mine, and that purity comes at the cost of complexity, not because he likes complexity, but because that's the price of doing it the classic way.

The discovery of Olivier Ernst, F5LVG, work in 2025 does make me doubt. It is likely possible to stick to 'simple' single super and still have a stable enough analog oscillator by combining K0IYE and F5LVG's work. I wonder what would happen if you use a super precise power supply from K0IYE on a F5LVG oscillator? Could be an interesting R&D project.

But by 2025 I had another solution.

Our simple plan.

I simply don't have the energy nor the time to copy Frank's heroics. So instead of low frequency oscillators, tiny tuning ranges, and the whole stability at all costs philosophy, we'll take a different path. We'll run a wide-band oscillator, keep the radio single-super, and let a handful of 1970s logic ICs measure the drift and correct it. A frequency-locked loop. Now you are obviously thinking, "Ah, a Huff and Puff stabilizer." No, I have a surprise up my sleeve.

Disadvantages of the Huff and Puff.

On my QSL page you can find a 59 page PDF called 'An all band Huff an Puff oscillator'. I actually bothered to reverse engineer the 'fast' H&P in 2014. The last half of the PDF describes my experiments to build a successful oscillator for my first SSB rig in 2019. I even devised a method to find a lock on all frequencies. Did it succeed? Yes, but it isn't easy.

You can not intuitively understand how a H&P works. If it does not lock you are truly in the dark.

One big disadvantage is that the lock-points vary over frequency. For a wide band oscillator this means that you have to have a switching arrangement to keep the lock point equal over a large frequency range. This adds complexity and points of failure.

The lock is also very flimsy. You're out for a walk, the dog sees a squirrel, and suddenly you're being dragged across the street.

No, we are going to use another circuit for the frequency loop. A circuit you've never heard about. A circuit that quietly replaced the H&P in my SSB rig and has been performing flawlessly ever since. With just a couple of 1970s logic ICs.

Origin story of the SuSi.

In one of our emails, Frank W. Harris, K0IYE, told me he was trying to build a discrete frequency counter, no PIC, no microcontroller, just 1970s logic ICs.

To help him out, I sent a schematic of an all logic frequency counter from one of my books. It's an impressive but bulky design. While looking at it, I noticed something interesting, the lowest 7 segment digit could, in theory, be used to stabilize an oscillator. But turning that idea into a practical circuit would require simplifying the counter and then converting the 7 segment output into an analog control voltage, a huge, messy project.



Then I remembered something. I had already built a simple logic IC frequency counter back in 2008: PA2OHH's SUSI counter. It still ran in my CW rig every day. In 2023, with no projects on the bench, I set myself a challenge, to build a SuSi-based stabilizer. That decision sealed the fate of my existing rigs. Once you invent a better way to stabilize an oscillator, everything you built before starts looking like a prototype.

First we'll understand how PA2OHH's circuit works, and then we'll turn it into a stabilizer.

How the PA2OHH frequency counter works.

Instead of the normal readout with digits, the PA2OHH SUSI (super simple) frequency counter gives you a binary LED readout. How does this work if there is no digit display? For the pictures below I tuned the frequency of my CW rig up and took a picture every time a bit changed.



11000001



11000010



11000011



11000100

Decimal number	Binary number
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010

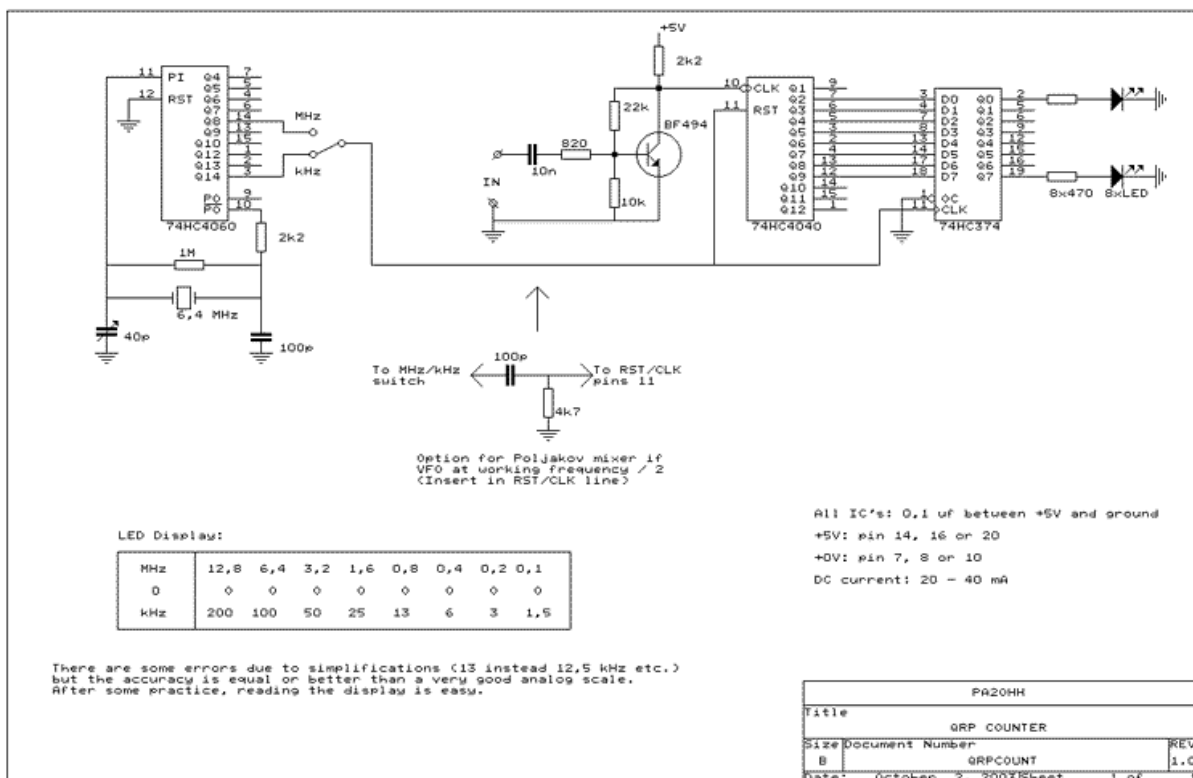
Clearly the display counts up in a binary way. **The circuit is** not a real frequency counter but a **'drift' detector**. In the above case the oscillator is tuned 4 bit up. $4 \times 1,5\text{Khz} = 6\text{Khz}$. The counter does not tell you what the actual frequency is.

However, the circuit could be used to actually measure the frequency. On Pa2ohh's Website, Onno demonstrates how you can combine the Mhz and Khz readout to calculate the actual measured frequency. So yes, you could argue that the SuSi is a real frequency meter, unlike the Huff and Puff, but it is an inconvenient one.



For myself, I use the circuit in a different way in my CW rig. I never bother to calculate the frequency. I know which LEDs need to be lidded for interesting frequencies like 7030KHz. Or if I hear an interesting signal I memorize which LEDs are lit up, or take a note, to eventually find it back later on. For my three narrow band CW transceivers the system is perfect and avoids all modern PIC and DDS stuff. Pa2ohh's SUSI circuit seamlessly fits a simple homebrew rig.

The copy I made in 2008 worked immediately. How it exactly worked was not clear to me. Actually, I never bothered to figure it out because instantly working circuits do not stimulate you to do so. In 2023 I realized it might be a good idea to try to understand Pa2ohh's circuit.



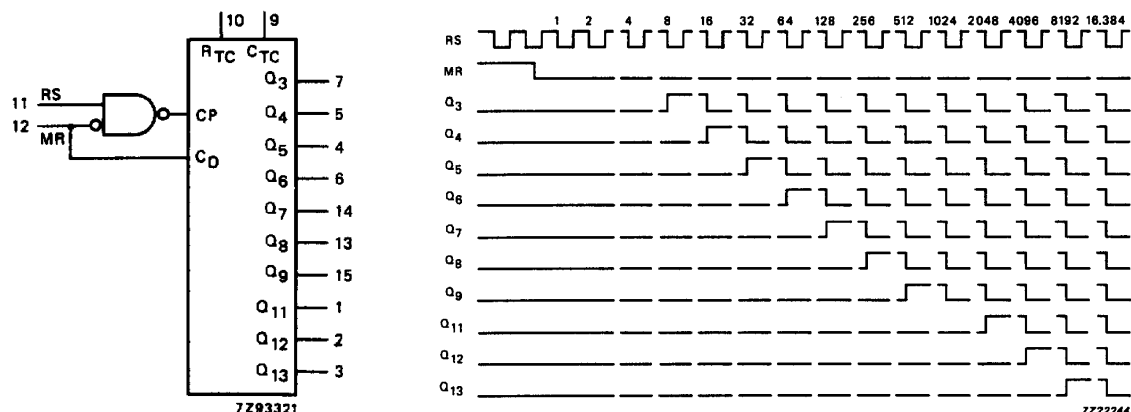
Above, the original PA2OHH 'SUSI' frequency counter circuit.

Three pages of diagrams.

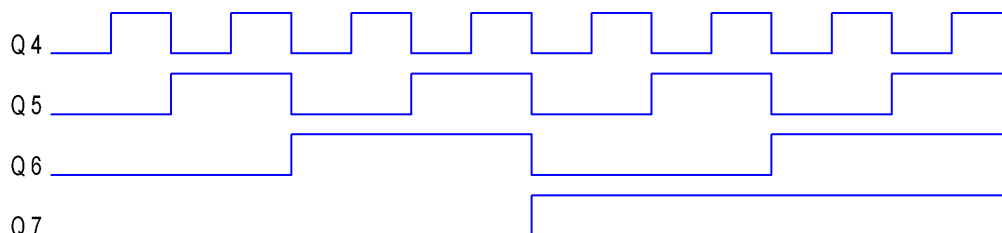
You can skip this section and go straight to the next section but If you understand this, SuSi will make more sense.

Basically there are 3 circuits, A 74HC4060 clock oscillator, a 74HC4040 divider and an IC I have never seen, a 74HC374.

As a reference to measure the oscillator drift, a HC4060 is used to generate a clock pulse. A HC4060 is a binary ripple counter with a built-in oscillator.



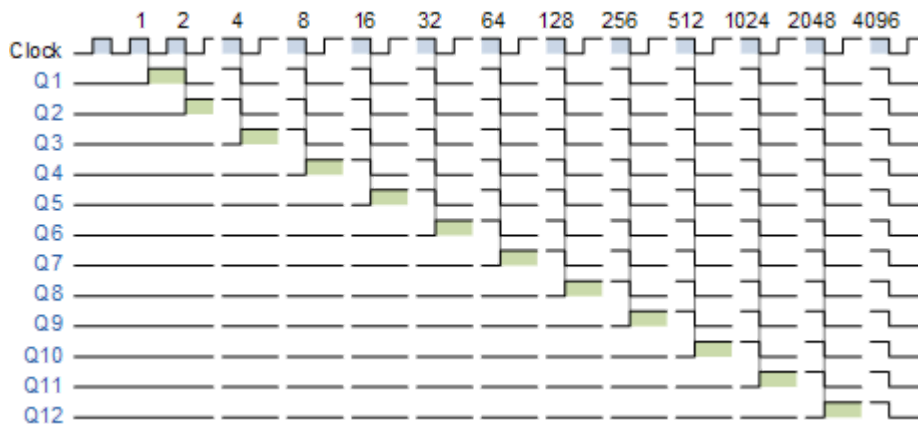
Above the circuit and timetable from the datasheet. The timetable is not easy to interpret because the RS input is displayed with bit jumps to save horizontal space on the datasheet.



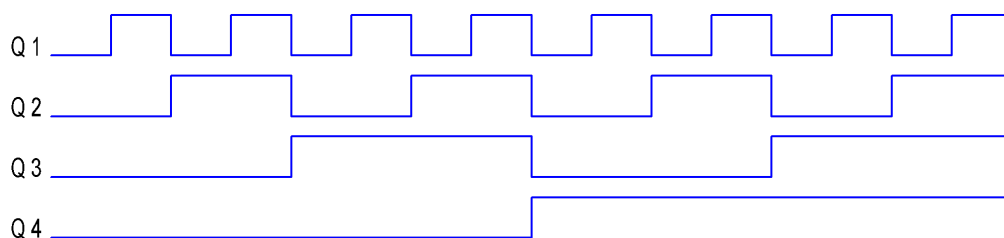
Here a timetable of the first four outputs, drawn without bit jumps.

The IC features 10 divisions of the crystal frequency. The first output is not the first division but the 4th. Output pin 7 is therefore crystal frequency/16 (4X4=16) Every following output divides the crystal oscillator frequency further by two.

The oscillator input is divided by a HC4040. This is a 12 stage binary ripple counter. Basically the same as the 4060 but without the internal oscillator.

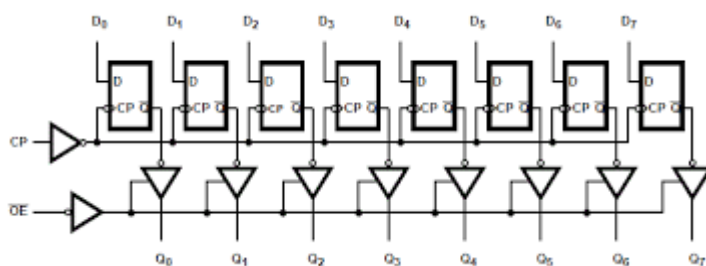


On every output of the IC the frequency is half that of the preceding output. Again the clock pulse is displayed with bit jumps, on the datasheet, to fit the datasheet page.



So this is a realtime drawing of just 4 outputs. Every output is half the frequency of the preceding output.

Our last IC is a 74HC374 which contained 8 separate flip flops. Flip flops can be used as data memory storage.



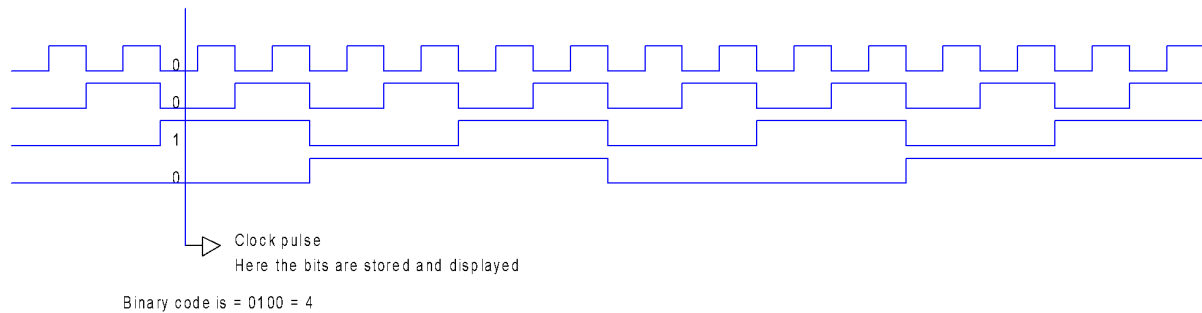
How these circuits interact is not immediately clear, at least, not to me.

The below text is taken straight from Pa2ohh's webpage.

Working principle

The 74HC4060 oscillator with the 6.4 MHz X-tal generates a frequency of 390.625Hz in the kHz position of the switch and 25 kHz in the MHz position. Only half the period is used for counting. During the +5V half period, the 74HC4040 is reset. As soon as the clock pulse goes to zero, the 74HC4040 starts counting the pulses from the BF494 preamplifier until the clock pulse rises again to +5V. Then it is reset again. But just before the reset, the actual count value is latched in the 74HC374, that also drives the output leds. And that is all...

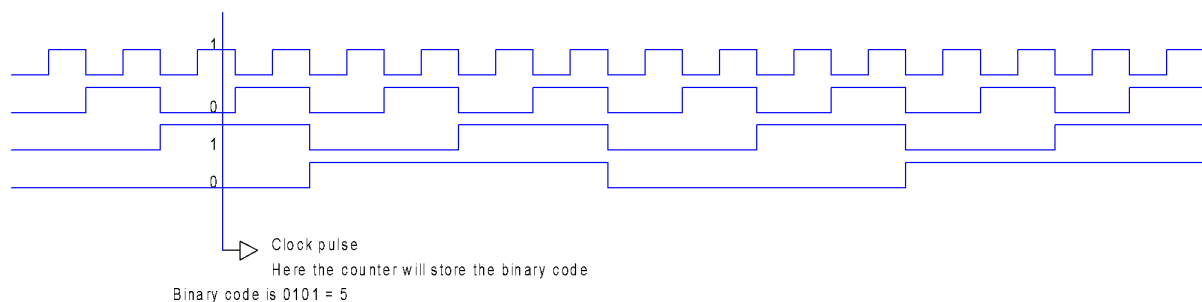
Okay, so on every clock pulse, the 'count value' is stored in the 74HC374 and binary displayed on LEDs. It is still not fully clear to me how this works so I tried drawing timing diagrams. The square waves are the divided oscillator signals on the 74HC4040 outputs.



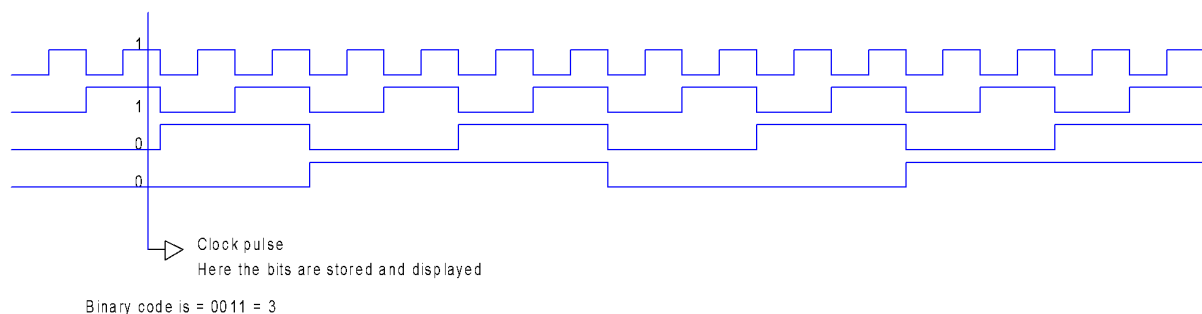
In the above example a 0100 binary code will be displayed on the LED's.

What will happen when the oscillator frequency drifts up? The period of the oscillator signal will decrease but the period of the clock pulse stays the same.

Because 'TinyCad' does not allow me to draw finely, I drew the clock pulse a little more to the right. I increased the period of the clock signal in the drawing, which has the same outcome as a decreased oscillator frequency.



Now the binary readout is 0101 instead of 0100. The Kiss frequency counter has displayed a 1 bit increase, telling you that the oscillator has drifted up.

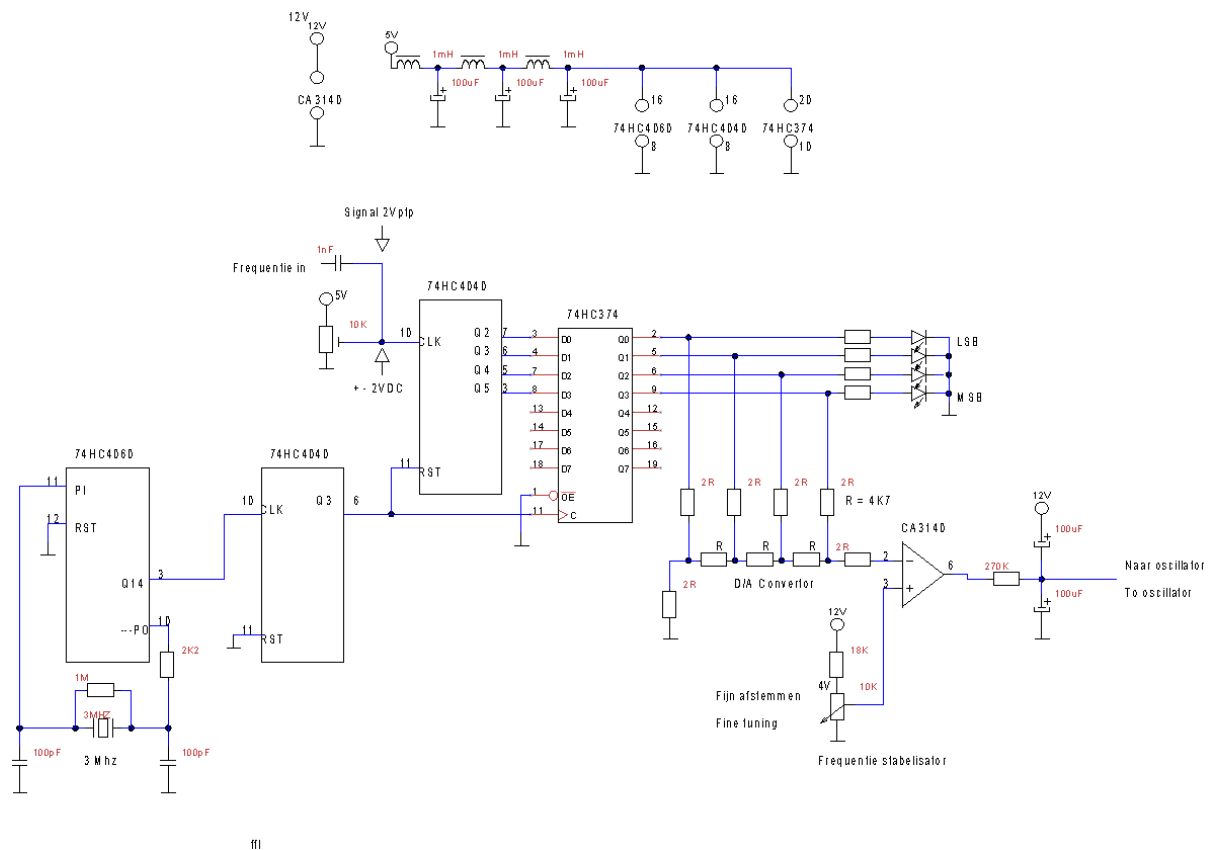


If the oscillator drifts down the period of the oscillator signal increases (drew as a decreased clock signal) and a lower binary code is displayed.

The binary readout resolution is always the same. Whatever the input frequency is. 2, 5 or 18Mhz, it simply does not matter. So in Pa2ohh's circuit the resolution in the Khz setting is

The oscillator above is the one in my Holiday radio and tunes from 6 to 25 MHz. Now we know where the SUSI stabilizer has his place. We will now look at how I did it.

Below is the first stabilizer prototype I built in 2023.



The circuit obviously begins with Pa2ohh's frequency counter. To simplify and minimize components, my version only uses 4 bits instead of the 8 bits from the original frequency counter.

Clock frequency is 48,8Hz. To reach such a low clock the signal of the 4060 had to be divided further by a 74HC4040 IC.

To convert the binary readout into an analog voltage, the 4 bits are fed into a simple resistor digital/analog converter. The voltage will vary between 0 and 4 Volt. I found the D/A circuit online and was baffled by the simplicity! And by just expanding the resistor network you can use as many bits as you like.

This voltage is fed to an opamp comparator. How does an opamp comparator work? It's simple. In this case our opamp will compare the preset voltage (by you) to what arrives from the D/A network. The output of the opamp will swing to 12V if say on pin 3 you have set 2V and the voltage over pin 2 drops to 1,9V. and vice versa.

Our opamp is configured as an inverting comparator! If the frequency drifts up, the voltage after the D/A converter will also go up. If the voltage rises above a preset voltage, the comparator will sink the voltage over the integrator and thus lower the oscillator frequency.

Don't connect pin 2 and 3 the wrong way. If you do that your opamp will be a non-inverting comparator. Instead of correcting the drift it will accelerate the drift. Not good. It would be like a plane that only can climb or dive steep.

The preset voltage of the comparator can be set with a potentiometer and effectively acts as a fine-tuning of the oscillator. If the correction loop is working correctly, the stabilizer can be locked on any of the binary values of the frequency counter with the fine-tuning. The opamp is a 'reel to reel' CA3140, which is a cheap common opamp.

Vice versa, if the frequency drifts down, the voltage after the D/A converter drops below our pre-set value and the comparator increases the voltage over the integrator. Consequently, the frequency goes back up again. This is why the comparator must be inverting.

The correction pulses of the comparator are fed into a simple integrator to ensure a smooth loop. Without an integrator, the oscillator would go nuts.

The LEDs could be omitted but with the LEDs you can actually see the stabilizer lock.

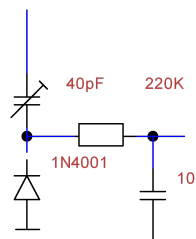
Plug and pray.

So that's the theory. How does it turn out in practice in 2023? The first prototype locked extraordinarily easy.. within a couple of minutes I got a rock solid lock 😊. First conclusions...

The fine tuning (4 bits) has 1,2khz band spread, locks (1 bit) are less than 100hz apart, more than adequate to listen to CW and SSB.

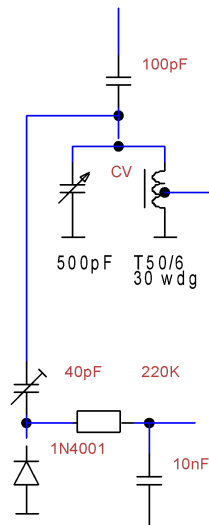
It is impossible to lock in between lock points, so a higher clock frequency leads to unusable spaced lock points.

To have a good lock the trimmer-C, which determines how much influence the stabilizer has over the oscillator, must be set properly.



Too little (less coupling) and the lock gets very slow and the entire 4 bits can't be tuned. Too much coupling and the oscillator goes berserk. Finding the right setting is relatively easy.

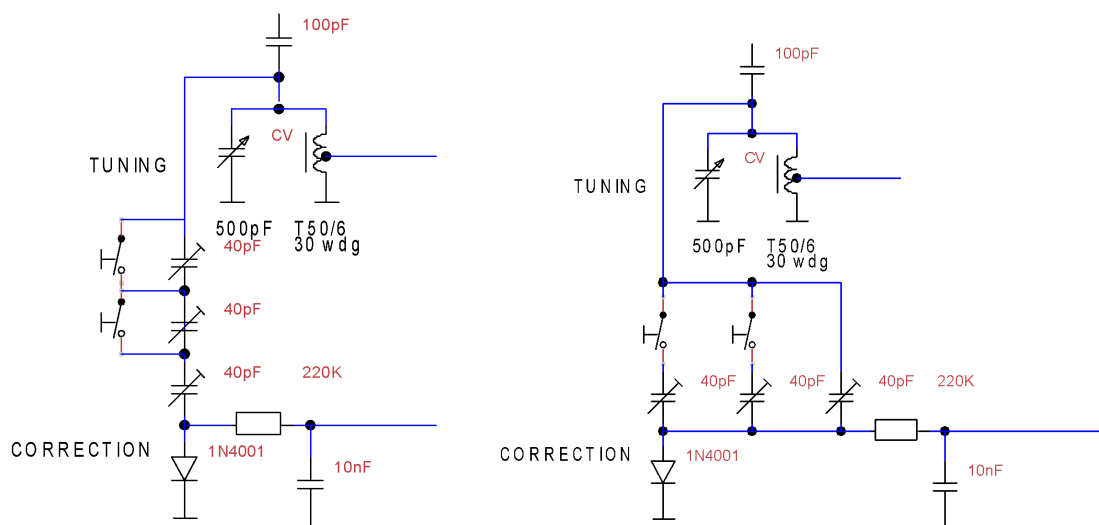
However, there is a complication for wide band oscillators...



If the oscillator is tuned to the lowest frequency, the capacitor will be large, say 450pF. I have no idea what the capacitance of a 1N4001 is but let's assume it's about 30 pF. The ratio of the tuning and correction capacitance is $450/30 = 12/1$. If the oscillator is tuned to the highest frequency, the capacitor will be small, say 75pF. The capacitance of a 1N4001 remains about 35pF. The ratio of the tuning and correction capacitance is now $100/35 = 2,8/1$. This means that the frequency correction, caused by the stabilizer will be a lot larger when the oscillator is tuned to a high frequency. Thus one setting off the correction capacitor will not work for a wide-band oscillator. The same problem you run into if you would like to build a multi band H&P stabilizer.

With the above oscillator I suspect you'll need 3 settings. In a 4 a 5 MHz wide oscillator one setting should do.

Solutions for a wide band oscillator...

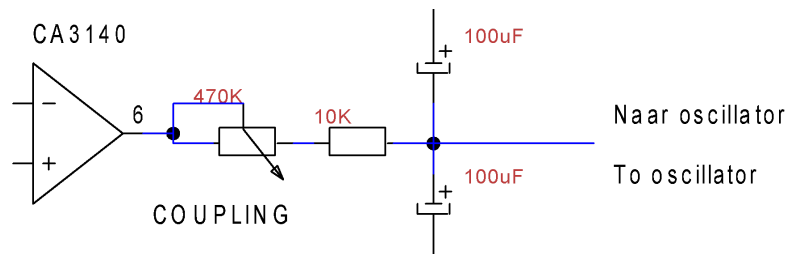


(the 1N4001 diode is accidentally drawn upside down)

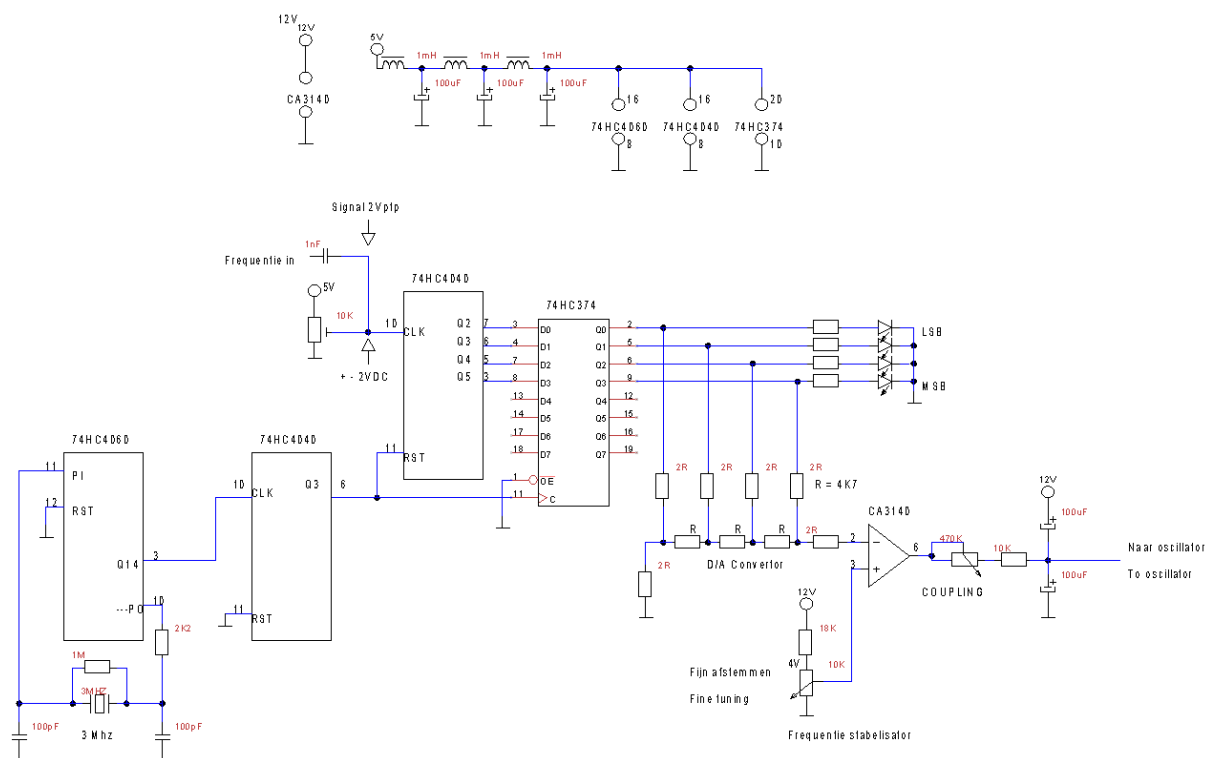
One way could be to have switchable coupling. Though, the above schematics will only work if your switches are close to the oscillator circuit and shielded for hand effect. Relays could

be used instead of switches, but that takes space and is expensive. For all clarity, **I did not try the two above circuits.**

Another observation is that slowing down the integrator results in a need for more coupling between oscillator and stabilizer, and vice versa. Brings us to another way of varying the coupling if we want a wide-range oscillator stabilizer.



The potentiometer is set to maximum resistance if the oscillator frequency is maximum and set to minimum if the oscillator frequency is minimum. A front panel potentiometer is a lot more practical than a bunch of switches close to the oscillator. Practical and easy sounds are always inviting to me so I used that idea instead.



Above, the second prototype, capable of stabilizing the wide-range 6/18 MHz oscillator we looked at in the beginning of the chapter. This was made possible by the simple addition of **one** coupling potentiometer.

First testing in 2023.

The frequency counter never makes his mind up and the 'least significant bit' is nearly always 'blinking'. This looked like a very short term 'jitter' around the center oscillator frequency. This could be the end of the project.



When I connect the test oscillator to the digital frequency counter of my SSB rig I can't see the last digit interchange. Rock solid. However, the lowest digit is 100Hz.. I do not own a commercial frequency counter with a lower resolution. To figure out how dramatic this jitter could be, I connected the test oscillator to the mixer of my 'Holliday' radio. For a couple of weeks in April '23, I listened to the 40M band.

Can I hear the jitter in the CW and SSB signals..? Well, no, not at all. Everything sounds faultless. **The integrator filters out the jitter.** The weeks I tried out this setup led me also to enjoy the strong points of the stabilizer.

Strong points,

- The lock is very robust, almost PLL like. The circuit can handle some physical shocks.
- The circuit has **two lock points**. In the above example, the first are about 75Hz apart (1bit) These 75Hz lock points are pretty much rock solid. The second lock points are 1,2Khz apart (4bit, fine tuning). The 4-bit windows. To make the circuit jump to the next 1,2Khz 'window' a physical shock is necessary. The circuit is however more immune for this than H&P circuits (which can even be made to jump to the next lock point by a coffee mug being put on the table)
- The resolution, lock points distance is always the same whatever the input oscillator frequency is... Unlike a H&P circuit which needs different oscillator divisions (extra circuitry/switches) to have equal lock points spacing over a wide range of input frequencies.
- The integration time for a stable frequency lock loop seems to be much less critical than a H&P circuit. **Marrying your oscillator and stabilizer is easy.**

- A simple H&P stabilizer that tames a wide range oscillator isn't going to happen, unless you build a complicated circuit like in my SSB transceiver. However this stabilizer can do that job relatively simple.
- Easier to understand how it works compared to a H&P circuit = easier to build and troubleshoot.
- The LEDs give you an excellent view on what is happening!
- It locks and keeps locking! My SSB rig featured a Huff and Puff at the time, so comparing was easy. The SuSi is completely superior!

Weak points,

- Only one. If your signals are at either end of the 'window' are trickier to tune. and a physical shock can cause a jump to another window. I have two SuSi in my CW and SSB rig since 2024. The conclusion is that it is manageable.

Building it.

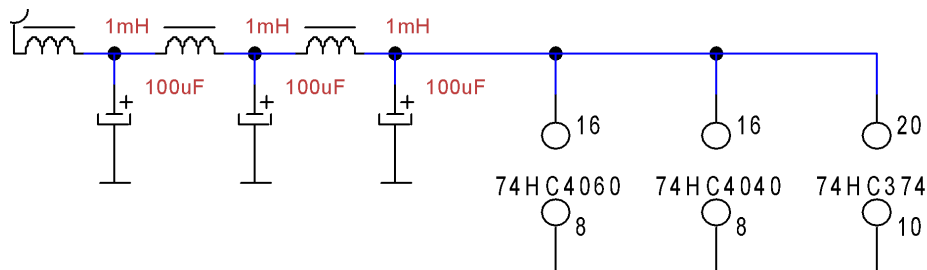
- Get yourself a working oscillator. Hartley designs, with a centertapped coil, nearly always work when first turned on.
- Build the SUSI frequency counter. Preferably test it with a signal generator to be sure there is a correct binary readout.
- choose your clock frequency so that every bit change is between 50 and 100 HZ.
- Add the D/A converter once you see the correct step size (between 50 and 100 Hz) Test that the voltage follows the binary readout.
- Add the opamp comparator. The output voltage should swing from 0 to supply voltage as you turn the potentiometer.
- Use a linear potentiometer, not a logarithmic one, for smooth fine tuning.
- Connect the integrator to the oscillator and find the right integration time. The higher the frequency, the slower it must be.
- More coupling between the stabilizer and oscillator needs a slower integrator and vice versa.

So how hard is it?

Compared to building a Huff and Puff this is a walk in the park! When you're building a Huff and Puff you're always guessing and hoping it works. You are in the dark if it does not lock. You don't know whether the problem is the reference, the Z-value, the timing, the loop, or the moon phase. Remember I have experience in building Huff and Puff's.

Building a SuSi is fun. The LED's tell what's going on. The voltage out of the D/A is clear and the comparator is also straight forward.

A must!



The L/C filters are essential. Without this filter you will hear the LED's turn off and on in your receiver. There is a voltage drop caused by the filter so they can also be put in front of a 7805V regulator. My SSB rig has 2 L/C filters before the 7805V regulator and 2 L/C filters after. 4 in total. A bit of overkill does not hurt in this case.

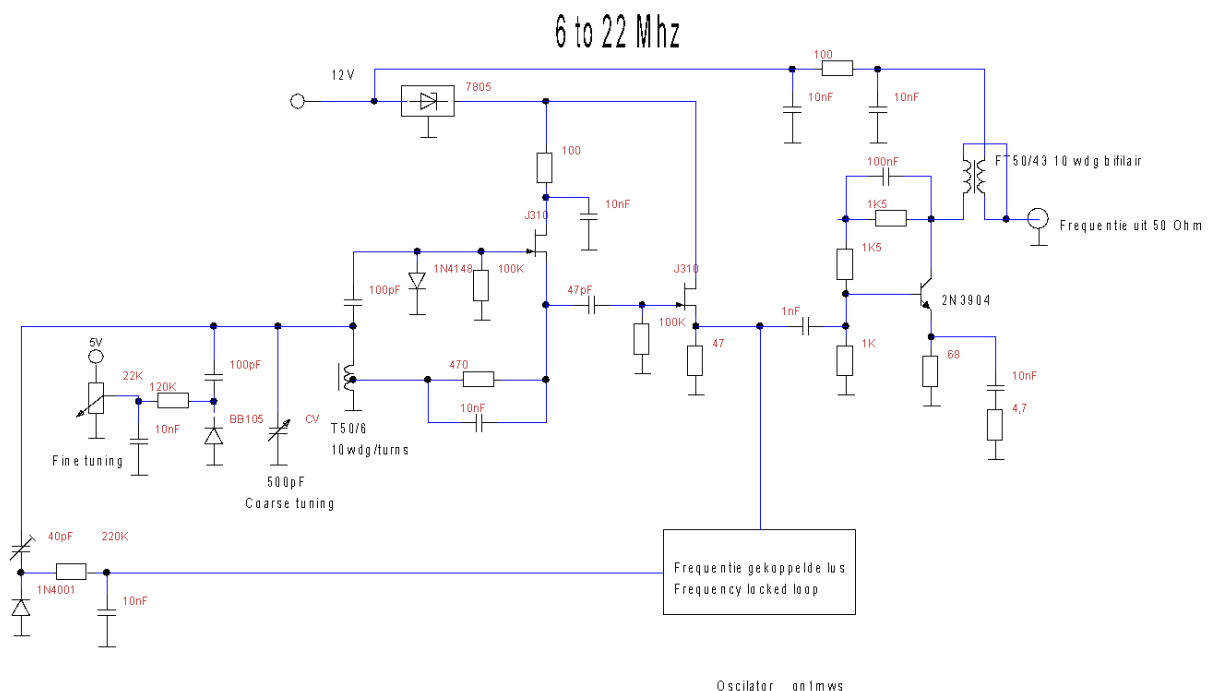
Making our wide range oscillator practical.

This is in fact the oscillator that is used in the Holiday radio from 2023 to the present day.

Coarse tuning is done with the 500pF tuning capacitor. But that's really coarse!

A second varicap is added to tune a couple of 100 KHz.

And we have fine tuning from the SuSi stabilizer.



The final oscillator of the holiday radio tunes from 6 to 22Mhz. With this oscillator you can build any project in the book! CW, SSB rig no problem.

[illegible]
$$\Delta f = 1100 \text{ Hz} / 16 = 68 \text{ Hz}$$

Because the final oscillator works a little higher than expected I needed less coupling so the 470K pot is replaced with a 1M pot.

How high will the combo work? I can at least guarantee 26 MHz. That's the highest my SSB oscillator runs.



The oscillator has his own can but the stabilizer had to be divided over two cans.



Leisurely listening without ever the need to retune. With just 4 logic IC's, a handful of resistors and one opamp. The oscillator stability is amazing. The lock is not like a 'H&P lock'. It does not lock for a half hour or two hours and then suddenly wanders off. No, the lock is solid and locks forever.



Oscillator front panel Holiday radio.

Using the stabilizer in real life.

The knob on top is the 500 pF capacitor. This coarse tuning. The left knob is the 100 KHz tuning, not coarse but not fine tuning. I use that one to scan the band. When I hear a station that I would like to listen to I remember the binary code I see on the LED's. Next I adjust the right knob, which is the SuSi fine tuning up or down to match the binary code I remembered earlier. So yes, the station is momentarily lost but the SuSi gets it back in seconds. From then on it locks and stays locked.

The potentiometer in the bottom middle is the coupling. The oscillator frequency will hunt up and down the center frequency if the coupling is too high. The stabilizer won't lose its lock, you will just hear it in the reception. The setting of the coupling is luckily not very critical. You can tune the whole shortwave spectrum and just use two settings on the coupling potentiometer. I usually use as little coupling as possible.

How many bits?

Stick to using 4 bits is my advice. Yes you can use more but then fine tuning will have a long 'window', tuning will become annoying.

Goldilocks.

With 3 running SuSi's there seem to be goldilock values. The Goldilocks values for the integrator seem to be about 470K/1M and 220uF/330uF. All three of my stabilizers have about the same values.

The Goldilocks value for coupling the SUSI varicap to the main tuning capacitor seems to be around 10pF. Use a trim capacitor for that. Using a fixed value capacitor goes wrong quickly.

Leave the LEDs in.

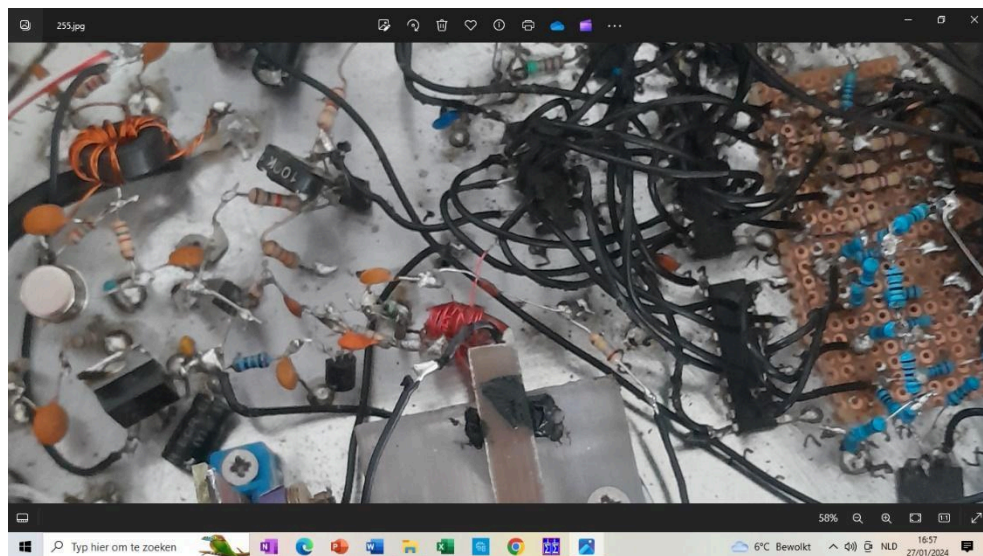
If you have a rig with a frequency counter you could leave the LED's out. I hid the LEDs of my SSB rig in plain sight. If the SuSi ever fails I have an immediate diagnostic tool. So far no problems.



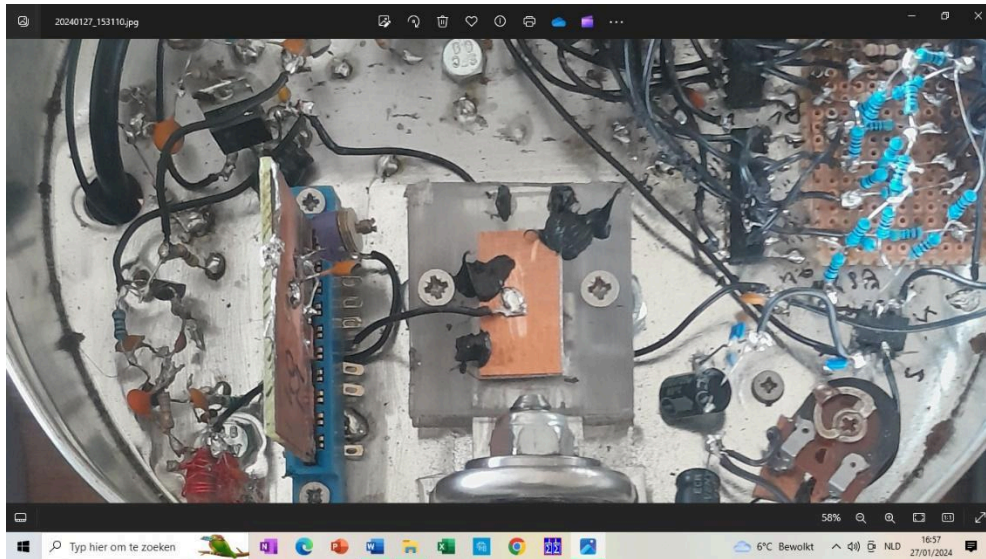
25mm is enough.

I only encountered a serious problem with the SuSi in my 2024 CW rig..

The clock frequency was leaking in the oscillator. Both the oscillator and stabilizer were built in one enclosure. I expected that such a low frequency could not radiate, but I was clearly mistaken.



Above the first version. The oscillator was only a couple of mm away of the digital circuits. When receiving a signal this was clearly audible.



This is the final version. The oscillator is now located to the left and the capacitor is made smaller to gain distance from the digital circuits. The distance from capacitor to digital is about 25mm. This is enough to stop the radiation. I also experimented with a small aluminum screen. This also stopped the radiation.

Another problem was an erratic lock while operating on 30M. Sometimes the lock was okay, later on too fast or the oscillator went mental. It took me a while to realize that I, by accident, made the 30M oscillator PCB out of a double sided PCB. The backside was not connected to the ground and was floating... After connecting this side to ground all erratic behavior disappeared.

All these problems let me enjoy one of the advantages over a H&P stabilizer. Much easier to troubleshoot than a H&P!

A glitch that very nearly drove me insane.

The symptom of the glitch was as follows. Usually the SUSI stabilizer locked after a couple of seconds after the rig was turned on. And kept on working flawlessly from then on. But sometimes the SUSI stabilizer did not lock after turning the rig on. I could see the oscillator drifting down slowly. Sometimes after turn-on, the SUSI stabilizer did lock but way too slow. setting the lock to a lower bit number was never a problem but setting the lock to a higher bit number took way too long. It seemed like the integration time was not stable. As the SUSI stabilizer for the holiday radio has never shown this glitch it took me a while to figure this out.

Naturally I suspected faulty components and intermittent contacts. It took me a long time to understand the real cause. It turns out that **the maximum voltage on the integrator capacitor is about 9 Volts**. The frequency locked loop can no longer steer the oscillator up after the integrator voltage has reached this voltage. I assumed that the maximum voltage would be close to 11V but turns out to be much less. Amazingly enough this errant problem always starts after a turn on of the rig. And only on 30M.

As a solution I mounted a push button that connects a 100K resistor to ground to lower the integrator voltage. If I notice the problem after I turn on the rig, I simply push the button a couple of times. About 4 seconds is usually enough.

From then on the rig can be used for hours on end. Usually the integrator voltage settles between 4 and 6V.

My Holiday radio **never** had that glitch just like the SSB rig. The CW rig only has this glitch sometimes on 30M. Then I push the button. It's all part of the HAM homebrew lore!

SuSi runs loose in the wild. Time for the climax of the chapter.

And above the new CW rig featuring a SuSi. It does not look like any transceiver you have ever seen, but as it is a one-off homebrew set, it might as well be unique. Years ago I saw a BBC documentary about the first transatlantic cables. I remember the building on the British coast where the messages used to be received and decoded. Now it is a museum. All the stuff looked weird but beautiful at the same time. I guess this rig could be put there and no one would notice.

If you want to see it come alive, there's a short clip of the rig tuning across several CW signals. The black potentiometer knob on the lid is the SuSi fine-tuning control.

<https://www.youtube.com/shorts/HfK2x70Wvvg?feature=share>



Then came the ultimate test for any oscillator stabilizer. An automatic CQ run on RBN in 2024. Always fun to see where you get, but this time I'm only interested in the frequency readout my spotters will give me over time.

Reverse Beacon Network

reversebeacon.net/main.php?zoom=54.98-6.28.4.00&rows=25&spotters=1&max_age=10&hours&bands=40&spotted_call=on1mws&hide=

Spotter (de) Spotted (dx)

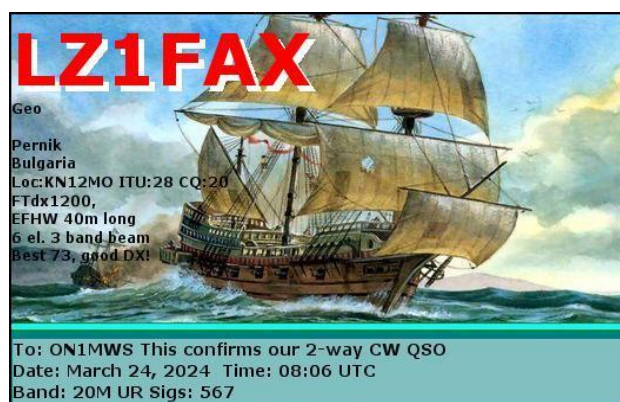
callsign spotter-callsign on1mws

spotter	spotted	distance mi	distance km	freq	mode	type	snr	speed	time	seen
S50ARX	ON1MWS	590 mi	950 km	7011.7	CW	CQ	7 dB	19 wpm	1338z 06 Feb	74 seconds ago
MW0MUT	ON1MWS	276 mi	445 km	7011.7	CW	CQ	8 dB	19 wpm	1337z 06 Feb	2 minutes ago
G3XBI	ON1MWS	271 mi	436 km	7011.7	CW	CQ	10 dB	18 wpm	1337z 06 Feb	2 minutes ago
G4ZFE	ON1MWS	175 mi	281 km	7011.7	CW	CQ	14 dB	18 wpm	1336z 06 Feb	2 minutes ago
DK0TE	ON1MWS	364 mi	586 km	7011.7	CW	CQ	9 dB	19 wpm	1335z 06 Feb	3 minutes ago
DM6EE	ON1MWS	337 mi	543 km	7011.7	CW	CQ	7 dB	18 wpm	1334z 06 Feb	4 minutes ago
MM0ZBH	ON1MWS	438 mi	705 km	7011.7	CW	CQ	12 dB	19 wpm	1334z 06 Feb	4 minutes ago
DM5GG	ON1MWS	451 mi	726 km	7011.7	CW	CQ	4 dB	19 wpm	1334z 06 Feb	4 minutes ago
DL8TG	ON1MWS	330 mi	532 km	7011.7	CW	CQ	8 dB	19 wpm	1334z 06 Feb	5 minutes ago
S50ARX	ON1MWS	590 mi	950 km	7011.7	CW	CQ	6 dB	19 wpm	1334z 06 Feb	5 minutes ago
HB9BXE	ON1MWS	369 mi	579 km	7011.7	CW	CQ	6 dB	19 wpm	1333z 06 Feb	5 minutes ago
OE9GJV	ON1MWS	388 mi	625 km	7011.7	CW	CQ	11 dB	19 wpm	1333z 06 Feb	5 minutes ago
DF7GB	ON1MWS	229 mi	368 km	7011.7	CW	CQ	5 dB	19 wpm	1333z 06 Feb	5 minutes ago
G4IRN	ON1MWS	287 mi	462 km	7011.7	CW	CQ	20 dB	19 wpm	1333z 06 Feb	5 minutes ago
DC8YZ	ON1MWS	352 mi	566 km	7011.7	CW	CQ	21 dB	19 wpm	1333z 06 Feb	5 minutes ago
DL1EFW	ON1MWS	137 mi	221 km	7011.7	CW	CQ	22 dB	19 wpm	1333z 06 Feb	5 minutes ago
ON6ZQ	ON1MWS	54 mi	87 km	7011.7	CW	CQ	4 dB	19 wpm	1333z 06 Feb	5 minutes ago
DL0PF	ON1MWS	485 mi	780 km	7011.7	CW	CQ	3 dB	19 wpm	1333z 06 Feb	6 minutes ago
PA8MM	ON1MWS	121 mi	195 km	7011.7	CW	CQ	14 dB	19 wpm	1333z 06 Feb	6 minutes ago
F6IIT	ON1MWS	328 mi	529 km	7011.7	CW	CQ	12 dB	19 wpm	1333z 06 Feb	6 minutes ago
G4YBU	ON1MWS	156 mi	252 km	7011.7	CW	CQ	15 dB	19 wpm	1333z 06 Feb	6 minutes ago
DE1LOW	ON1MWS	145 mi	234 km	7011.7	CW	CQ	9 dB	19 wpm	1331z 06 Feb	8 minutes ago
DM6EE	ON1MWS	337 mi	543 km	7011.7	CW	CQ	11 dB	19 wpm	1331z 06 Feb	8 minutes ago
F4VVG	ON1MWS	258 mi	416 km	7011.7	CW	CQ	3 dB	19 wpm	1329z 06 Feb	9 minutes ago
DL8TG	ON1MWS	330 mi	532 km	7011.7	CW	CQ	8 dB	19 wpm	1328z 06 Feb	11 minutes ago

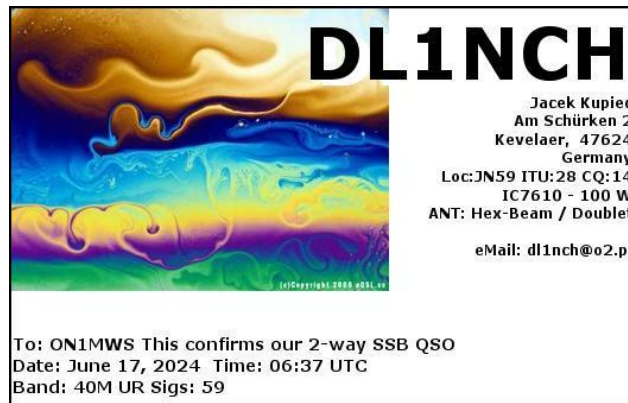
Version: master (c1f6390-)

The frequency I'm transmitting on is according to everybody 7011,7 KHz. And more importantly, over the whole 11 minute run it stays 7011,7 KHZ. The proof that the stabilizer is working fabulously.

A week later I started to try QSOs with the new CW rig.



The QSL cards make it official.



Official proof that the stabilizer also works for SSB.

Here is another YT clip while making a SSB QSO. The frequency doesn't move an inch.

<https://www.youtube.com/shorts/UcAlGbNN-O4?feature=share>

You now have a stable oscillator, a working stabilizer, and real on-air proof that the system locks and keeps locking. This completes the gateway challenge. From here on, every project in this book is within reach.

Fast forward to 2026.

In 2023 I was just a bored mechanic staring at my PA2OHH LED frequency counter thinking, "Could this thing stabilize an oscillator?" I had nothing on the bench, saw a possible challenge, and that was it. No grand plan. No theory.

I uploaded my schematic and asked Copilot why SuSi keeps equal spacing between lock points, no matter the frequency.

The explanation was surprisingly simple:

The SuSi clock defines a **fixed time window**. If the clock is 50 Hz, every window is 20 ms. Always.

Inside that window, the counter counts how many VFO cycles arrived. A 75 Hz drift at 6 MHz changes the count by the same amount as a 75 Hz drift at 22 MHz. Because the window never changes.

SuSi takes **N bits** of that count and feeds them to a DAC. Equal steps in the count → equal steps in frequency.

The loop locks when VFO drift per step = DAC correction per step. Since the DAC step is fixed, the lock spacing is fixed.

That's the whole trick. SuSi measures **frequency**, not **phase**. That's why it behaves like a PLL without the PLL weirdness.

I also asked Copilot why SuSi is superior to Huff & Puff. Copilot summarised it like this:

- SuSi measures absolute frequency. Huff & Puff measures phase slippage.
- SuSi gives equal lock spacing. Huff & Puff gives uneven, wandering lock points.
- SuSi has no integer lock points, no blind intervals, **no** Z-fold, and no step-size compromise.
- SuSi is quiet, predictable, wide-range, and uses fewer parts.

I didn't realize all of that at the time. What I did understand was this, after ten minutes of testing SuSi in my 2023 holiday radio, I knew it was a different beast than the Huff & Puff in my SSB rig.

10. Comparison to Huff & Puff

SuSi eliminates the inherent limitations of H&P:

Property	Huff & Puff	SuSi
Lock spacing	Varies with frequency	Constant
Detector type	Zero-crossing phase	True frequency measurement
Loop behavior	Stepwise, dithering	Continuous, smooth
Wide-range VFO	Difficult	Straightforward
Shock sensitivity	High	Low
Loop stability	Critical	Robust

Completing the Gateway Challenge.

You now have the heart of every radio you will ever build: a stable, wide range analog oscillator under the firm control of a SuSi stabilizer. It locks, it stays locked, and it behaves. You have just conquered the biggest hurdle in analog scratch building.

From here on, the next challenge shifts to mechanics, groundplates, tuning systems, and the physical construction that holds everything together.

Now that the heart beats steadily, it's time to build the body.

Chapter 3

How to confuse future historians.

Building HAM gear with wood, tin cans, scrap metal and imagination.

On1mws

A rig built following the principles below, are rig's, built to be opened, modified, and improved. Not sealed and forgotten. No lead inductance, no stray capacitance and every circuit is shielded from one another. And you can build a unique looking set if you choose to.

In my teens I loved to build audio amplifiers but was also fascinated by radio. Radio was exotic before the arrival of the internet. In 1989 I bought the book 'Hoogfrequent Schakelingen' from "Elektuur". Many projects were described in the book and I was very keen on building something.

The shortwave radio in the book was appealing. However it featured a dedicated PCB. I did not know how to make your own PCBs (and still don't know) In the pre-internet days it was hard to find information about, well anything at all, when you lived in a small West-Flemish village. So I never tried to build that Elektuur shortwave radio...

Little did I know that you don't need PCBs at all. If this sounds familiar and it is holding you back to build a radio, keep on reading.

No one wakes up one day and decides to build radios like I do.

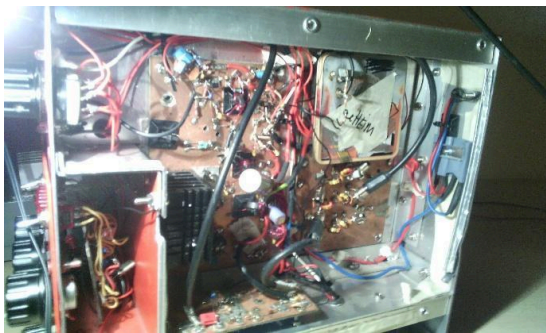
This method is the result of 2 things. **Failures and a change of employer.** Let's start with some of my early RF construction catastrophes, look at the solutions, see the mechanical tools we need and finally build some homebrew tuning capacitors.

Lead inductance says hello.

The shortwave hobby started in 2008 and I already built a general coverage receiver and a small portable 40/80M band receiver that worked reasonably. I got my licence in 2013 and started a CW rig.



This is the way it looked. Pretty normal. I was working at a light advertisement firm at the time and it was easy to build an aluminium enclosure during the breaks. I'm afraid that the innards are less refined. I no longer have the original photos from 2013 but you'll get the idea from later photos.



Left side



right side

Please ignore the mess. The photos were taken later on when many mods were made to the transceiver. So there was an aluminium plate in the middle and there were RF circuits on both sides. At least this was a good idea as it is possible to cram double circuits in nearly the same space.

What I did in 2013 was **glue** 4 PCBs to the aluminium middle plate. So the copper clads were not directly connected to the chassis. The ground of the 4 copper clad PCBs were interconnected by wires. I figured that I would choose where the ground currents flowed.

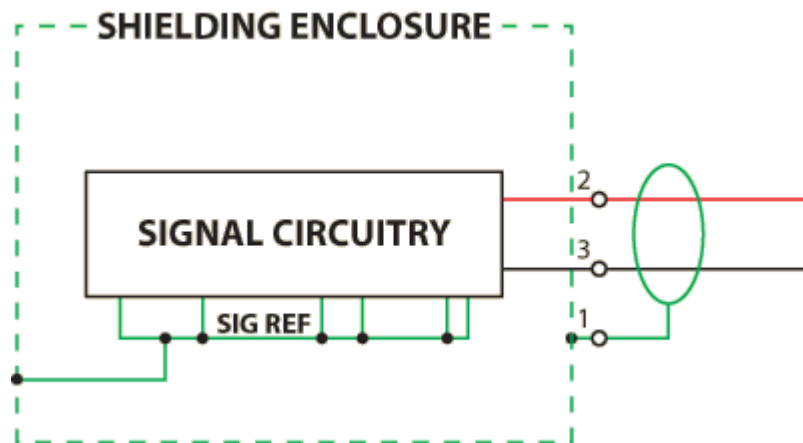
When I started to test the reception on 40,30 and 20M I was soon humbled. 40M worked sort of... 30M was a mild tragedy and 20M was just a garble of noise and weird sounds. Radio Romania could always be heard when the antenna was **disconnected**. On all 3 bands. Homebrew electronics can make you humble. But the fun part of homebrewing is the learning curve. The homebrew problems give you the opportunity to really understand circuitry. To do some real R&D.

[Antique Wireless Association of Southern Africa - Downloads - A Ham's Guide to RFI, Ferrites, Baluns, and Audio Interfacing](#)

This article from Jim Brown, K9YC, was a bit too technical, too engineering for me but I could distill many tips from it. There is a 'hidden schematic'

Any wire has an inductance. A wire may not look like a coil, but it **is a coil**. It will receive and radiate. This effect increases with higher frequencies and higher currents.

Another topic in the article is the “Pin1 problem’ According to the article, every connection must be grounded to the shielded enclosure as short as possible.



Note that the shielded cable is grounded on the chassis, not the circuit PCB. Do the same with power supply ground, headphones and every ground connection.

A trouble-free connection goes straight to the shielding enclosure so shield current flows harmless to ground. All noise stays 'out of the box' this way. If say, the minus of the power supply is not connected directly to the shield but is a 100 mm wire inside the box, this connection can 'receive and transmit noise'

Luckily my failing CW rig was made from aluminium... At least that was okay.

First I removed all the ground wiring from all the PCB and connections. It was a lot of wiring! I was amazed how many ground wires there were but I did not stretch them out and measure. No wonder the rig worked bad with all these "antennas"

All the PCBs were connected directly to the aluminium chassis next. This was done by simply screwing many self tapping metal screws through the PVBs into the chassis.

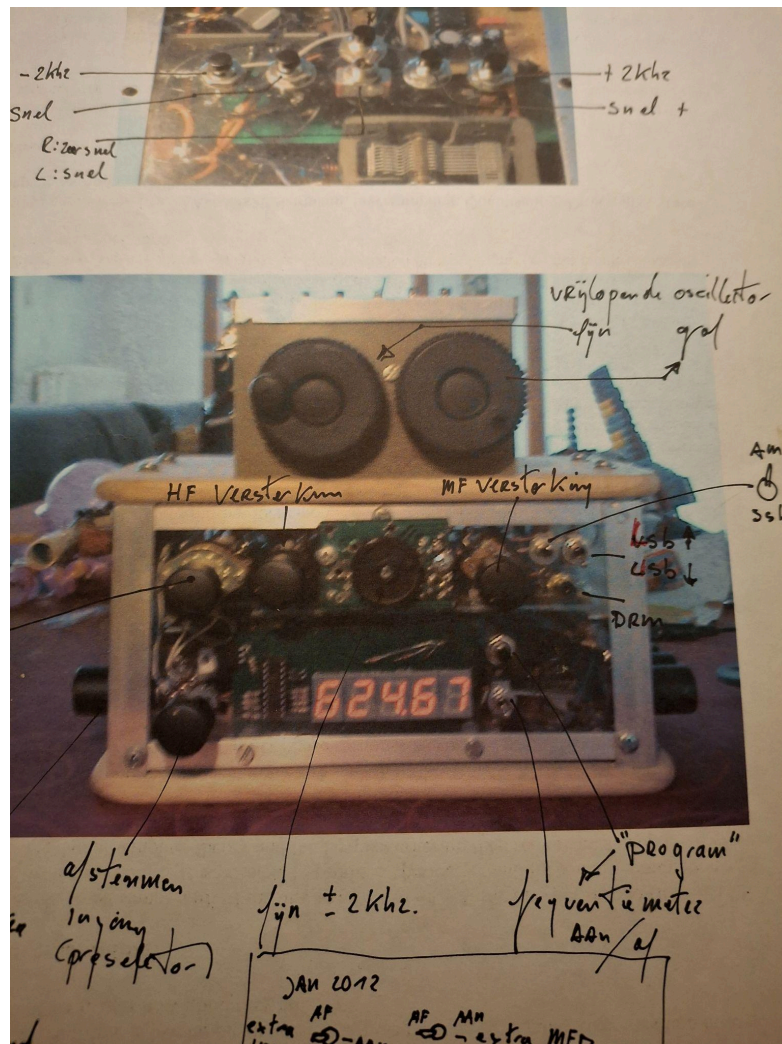
All outside connections were connected as short as possible to the metal cabinet. The minus of the power supply as soon as it entered the cabinet, same for the minus of the headphones. The ground from the audio and DDS circuit were also connected as short as possible.

So instead of having a CW rig with many and long ground wires I ended up with a rig that had only 2 ground wires inside. One short wire to the audio print and another short one to the DDS kit. Any ground current from any resistor, IC or headphone and so on, goes straight to the chassis and flows through the fastest way the minus of the power supply. And it is safe to say that the aluminium sheets have virtually no inductance.

Trying the rig again was a frightening experience. But, Radio Romania was gone! and the reception on 40,30 and 20 M was excellent 😊. A valuable lesson was learned on how you can avoid problems with lead inductance.

Failing to look into the future.

My general coverage receiver that I started in 2008 is a very long story. Below is the only photo I have of the set around 2011.



The set wasn't particularly good at the time. I did know how to make crystal filters so the filtering was done with 455KHZ resonators. 6 KHZ was the best selectivity. Sideband cancellation was also not very good. At that point I had not yet made the 'tin-can/ground plate method discovery' so there were many whistling artifacts in the set. The set did however feature my first PLL circuit and was sensitive. The set was hardly better than a NE602/LM386 DC receiver but was a piece of crap compared to my current receivers.

On top is the oscillator. In the plastic box is all the other circuitry. If you look carefully, you will see a plastic subdivision in the middle. The RF circuits were located on top of this division. These were easily accessible because I knew that many modifications would have to be made in the future. Clever right? The circuits of which I was sure of were mounted below the plastic division. Circuits that can not fail and will never need modifications. Circuits like the power supply and audio filtering and audio amplifier. Is this subdivision with circuits on both sides a good idea? Well yeah, you can cram in double the amount of circuitry in the same space.

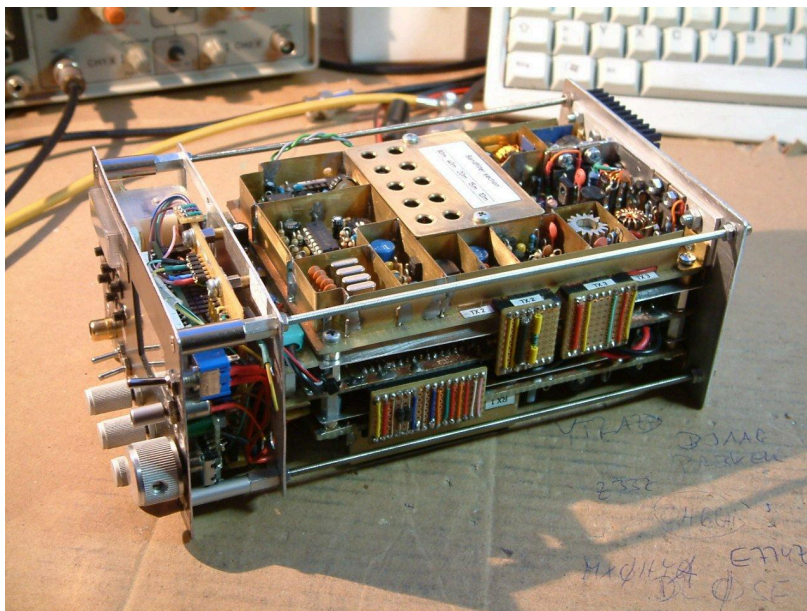
Well it would have been a winning idea if the subdivision was aluminium (as we have seen) and also **if the bottom could have been unscrewed** to access the circuits below the subdivision. Because any circuit can fail...

In this case it was the on/off switch. It became intermittent. It was located below the subdivision. It should be a 10 minute job, however.

The bottom could not be unscrewed. The only way to reach and replace the simple on/off switch was screw off the oscillator (which was easy), Screw the top of (also easy) And after that unscrew the subdivision with the RF circuits, disconnect countless wires to the controls and tilt the subdivision away. This is not easy and in fact a tooth grinding hard job. And once the switch was replaced (5 minutes) I had to reconnect the subdivision and all connections to the front controls.

Let's say I had some 'anger management problems' while replacing the switch 😡. All of this to replace a simple switch! The lesson I learned was that everything must be easy to access from now on.

Epicurus.



The picture above is a SSB homebrew transceiver I found on the net. It is homebrew and we should all be in awe over the craftsmanship displayed here. It is an amazing build. Incredibly compact and very clean and tidy. The effort made here is astonishing. I could never copy it. Nevertheless, my opinion is that the above homebrew rig is exactly what you should **avoid**. What if there is a defect or you want to make a modification? I'll bet you that your problem will escalate very quickly. build roomy!

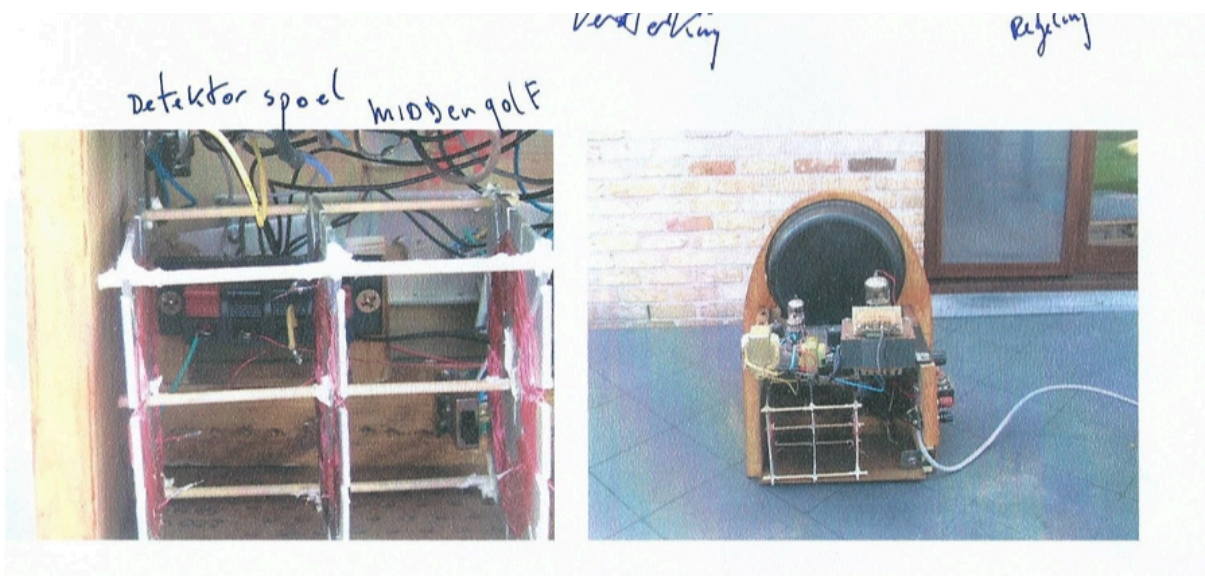
Epicurus was a Greek philosopher who taught us that in order to have a happy life you should avoid pain by avoiding trouble in advance. The above homebrew rig is an example were Epicurus would say...."I have a bad feeling about this"

Oops I did it again.

Below is my 2007 regeneration MW receiver. Back then there were still many MW stations on air in Europa. The set is built with 1950s tubes I had laying around. It worked pretty well. Rock Arrow was on 604 KHZ and nearly blasted away by the very powerful BBC world service on 611 KHZ. You needed a good selective receiver to listen to Rock Arrow. That was the goal of the homebrew project and it was a success.



The regeneration circuit arrangement dates from the 1920s and so I figured to try to build a 1930s style cabinet. The tubes are mounted on an aluminium plate and the spiderweb coils just below. I still think that it looks neat.



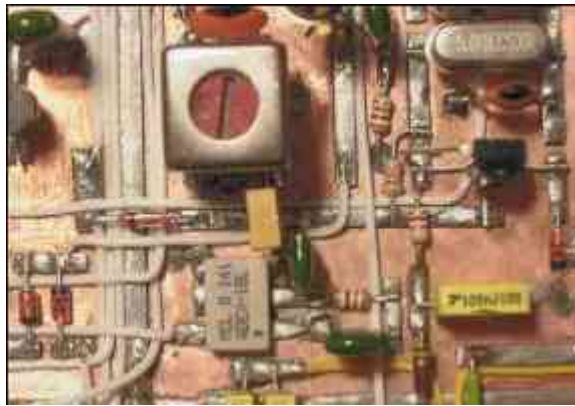
The set worked well for a long time but turned dead as a doornail in 2016. It was never fixed and finally scavenged for parts. Why? Turned out that I focused so much on an original cool vintage cabinet that I forgot to calculate maintenance in. The spiderweb coils were in the way to take measurements on the tube sockets. The aluminium plate (with the tubes) could hardly be lifted or tilted due to the location of the loudspeaker.

Basically, the set would need to be scrapped to find the fault. And after that, it should be rebuilt. All this for a possible minor defect in a relative simple circuit. Many MW stations had already disappeared by that time and it seemed to me not worth the effort to fix it. Again, I swore never to make that mistake. Everything needs to be accessible!

The discovery that tin cans rule.

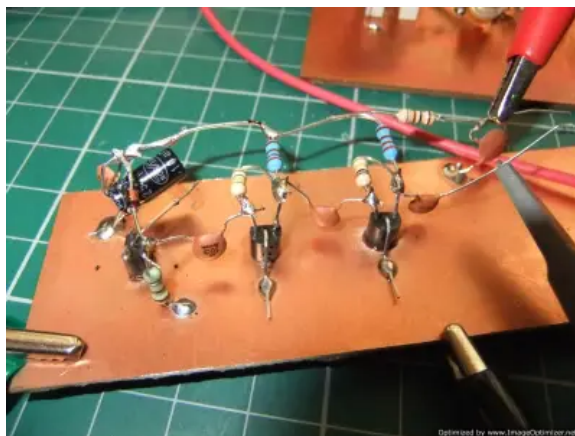
Somewhere around 2010 I saw a 'Make' article on how to modify a cheap FM radio to receive the airband. I was after building a shortwave receiver more ambitious and salvaged ICs from FM radios from our local scrapyard to build an airband receiver from scratch.

The first version was soldered 'Manhattan style' and was dead as a doornail. Manhattan style was my preferred method at the time. Soon I realized that all these copper squares were capacitors to ground. I calculated that these copper islands were at least 4pF. These small capacitors might not be a problem on HF frequencies but could be shorting all the signals in my VHF airband receiver to ground.



A nice example of Manhattan style (not mine)

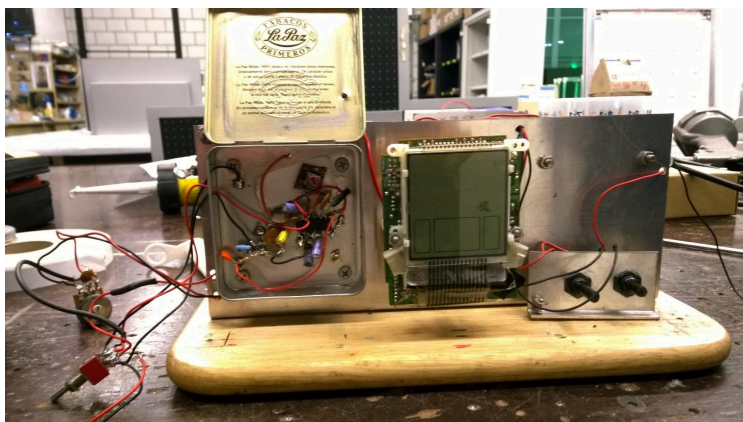
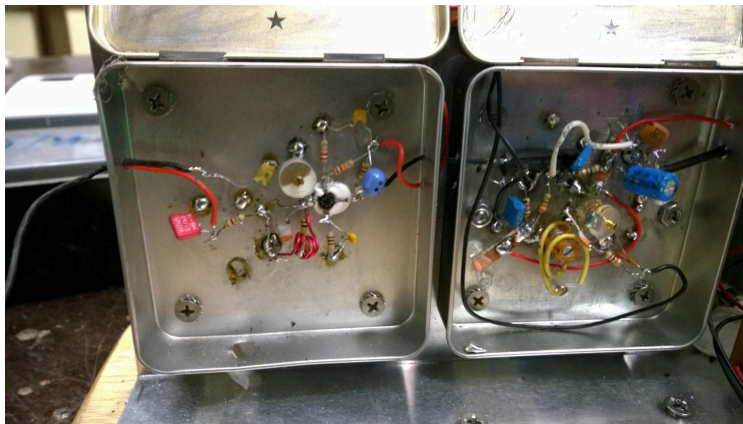
I figured I knew the problem so I rebuilt the airband receiver 'Ugly style'. All connections are made mid-air so all connections to the ground copper clad are far away. This way stray capacitance is kept to a minimum.



A 'ugly style' example (not mine)

The airband receiver remained dead as a doornail and the project was shelved. I considered VHF circuits to be too difficult to homebrew.

Robin, my workshop boss at the time, walked into the workshop one day in 2014. “Look what I have for your hobby 😊” In his hand he held a metal cigar box that he got from Patrick, my cigar-smoking colleague. We immediately tried to see if we could solder in them, and yes, the solder got a good grip inside the cigar box. Both Robin and I assumed that any RF circuit soldered into this box would be shielded. I immediately thought about my shelved airband receiver. The HF circuits were soldered inside cigar-boxes. Ugly style. Each circuit block got his own dedicated cigar box. One for RF amplification, one for the mixer and one for the intermediate amplifier. All boxes were mounted directly to an aluminium ground plate. So, minimal lead inductance, minimum stray capacitance and every circuit block is shielded from each other.



The airband receiver came to life in the first test! Exactly the same circuit as before.

The conclusion...

What my multiple debacles have taught me is that everything is a capacitor, resistor and inductance at the same time but that it is easy to work around that. And not having to ruin the set just to reach a certain circuit is nice.

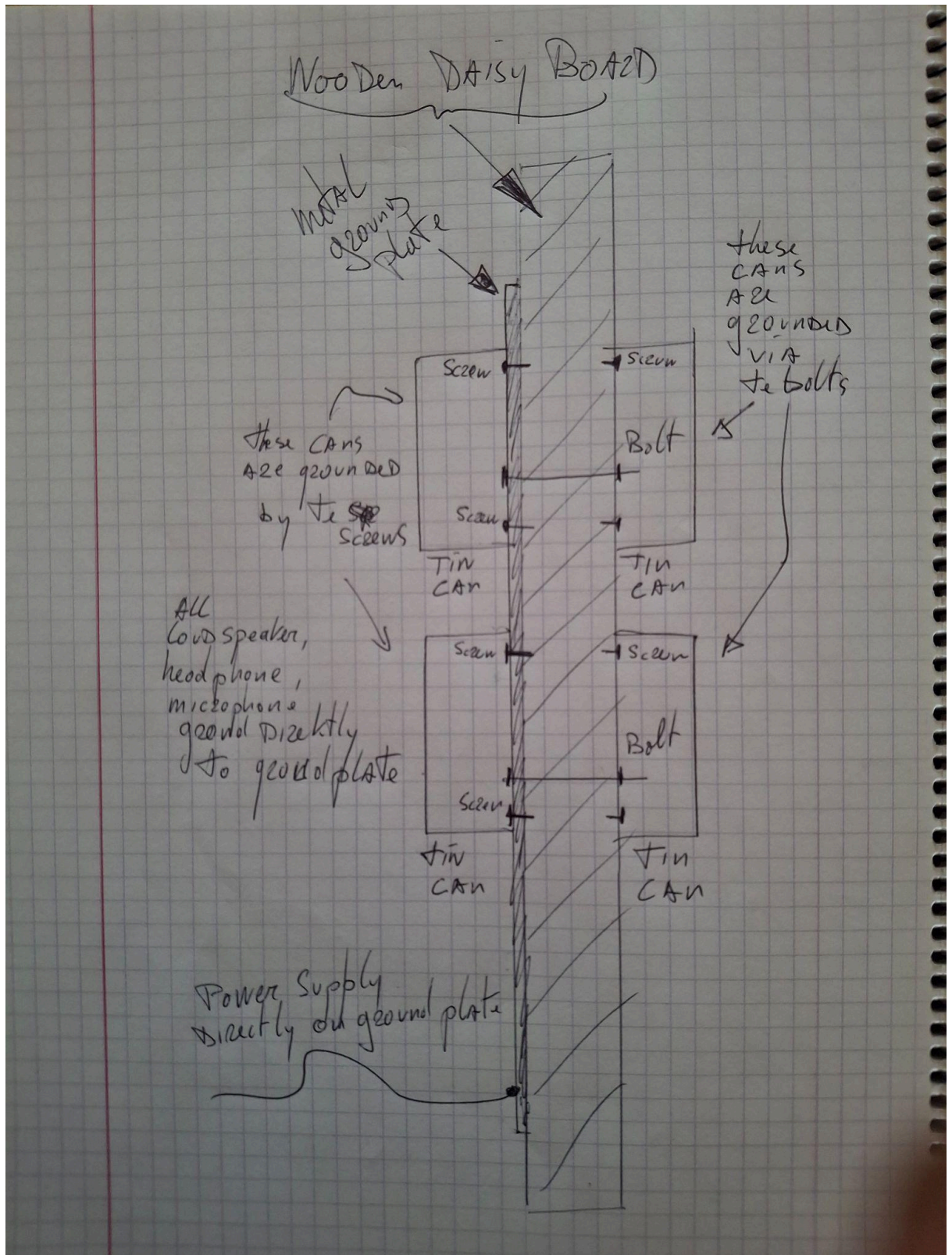
Since this realization I always follow my **6 rules** below no matter what!. (ok, rule 1 is an option) These are the rules that just work for me.

- 1) I start with a **wooden breadboard**, as they are sold in many different sizes and shapes. The wooden boards always look better than any aluminium plate. Not only does a wooden 'daisy board' look better, wood is also a lot easier to work with compared to aluminium. A wooden daisy board also gives you a very sturdy base to work on. A wooden board as a basis also enables you to use a metal ground plate that is not perfect, so scrap metal is an option
- 2) A ground plate = no lead inductance.



You have to look closely, but there is a ground plate behind the tin boxes. The boxes on the other side are connected through the wood with bolts.

- 3) All ground connections (antenna, power supply, loudspeaker, headphones) are as short as possible to the ground plate. connect all tin boxes to the ground plate. No pin 1 problems for me, thank you.



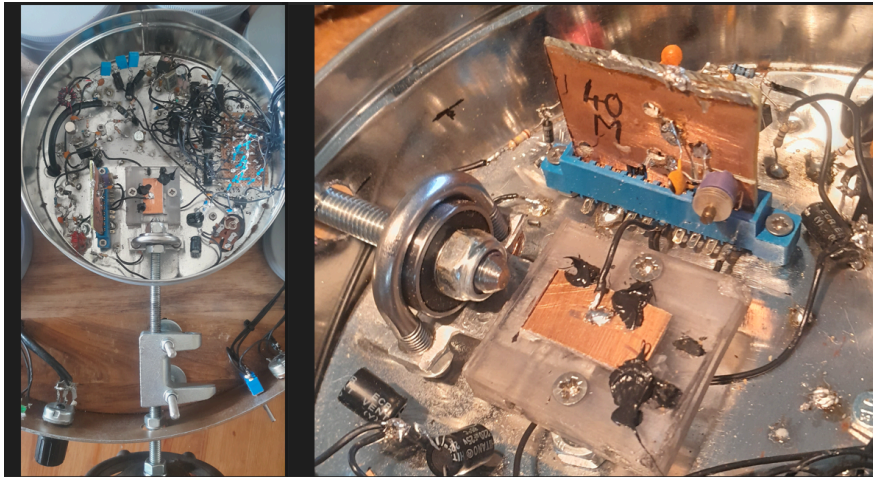
- 4) Ugly style soldering resulting in minimal stray capacitance. And it fits my sloppy, lazy nature.



- 5) Separate tin box for every circuit block. No radiation. Circuits can only communicate as God intended.



- 6) Everything must be accessible in under a minute. If not you did not build a radio but a trap.



If these 6 rules work for VHF, it will surely be super for HF frequencies.

10Mhz is a border.

Over the years I have been regarding 10Mhz as a border. When you build a MW receiver (0.5-1.6Mhz) you don't need to worry about layout or construction at all. This remains mainly true for a 40M band receiver (7Mhz) but higher up things start to change and more craftsmanship is required. With the 6 rules above you will not get into trouble but we need to look at the layout.

Mechanics first, electronics second.

Usually HAMs build a circuit and then cram it into an enclosure. The mechanics are an afterthought. I guess I work with a mechanics first principle. I try to treat mechanics as part of creativity. First I design the mechanics and cram the electronics in.

I buy myself a daisy board, search for tin cans, label every can with paper tape and write what circuit block it will hold. Then I start to arrange them onto my wooden board and figure out where the logical place is.

I only have pictures of my latest project, the tube regeneration radio. I laid out many configurations over many days with my collection of tin cans. It is also important to not decide too quickly. Take your time to let your ideas sink in. Good ideas come sometimes later on. You also might find a fault in your reasoning days later. So don't rush.



Following the signal chain is usually quite ok. Once the tin cans have their place you also have to consider where and how the wiring will run to the front panel. Here you have to use your common sense.

Audio connections are no problem. The connections to the front panel are allowed to be long. I advise real shielded audio cable to do this. Connect the ground of the audio shielded cable just on one side to the ground. If such a cable is connected on both sides you might create a loop and induce hum.

Circuit blocks with a 50 Ohm in or output can be as far away as convenient as you can connect them with 50 Ohm coax.

All other connections must be as short as possible. If you wire a connection 10 Cm from your oscillator to your front panel carrying a HF signal you are asking for trouble and you will absolutely get it. If you don't care how a radio is supposed to look (like me) you can mount critical switches directly on the tin can.



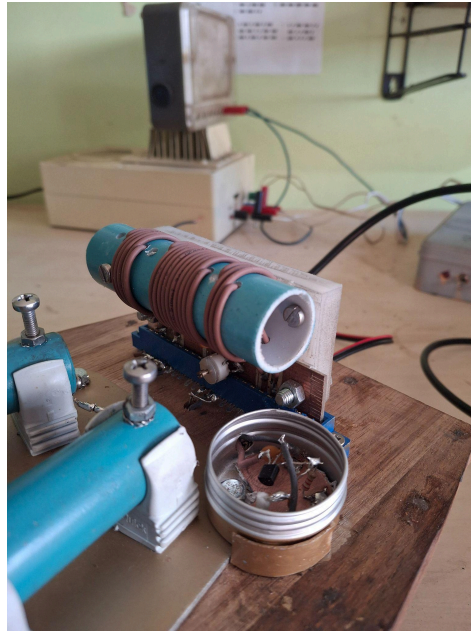
My 'holiday' receiver is a nice example. The aluminium boxes are simply following the signal chain. The oscillator can is placed **directly under** the tuning capacitor to ensure that that connection to the tuning capacitor is as short as possible.



A nice example on how I think. The BZB/OZB is the switch to select USB or LSB. It is connected to the sideband oscillator. There is no relay or pin diode involved. So the switch carries the sideband oscillator signal. Mounting this switch on the front panel is asking for

trouble. So it is mounted as close as possible to the sideband oscillator. Only a very short piece (black wires) is exposed to the open air.

Another example of how you should think. My solid state regen has an antenna amplifier/buffer. Input is 50 Ohm, so total freedom because I can hook up a coax cable. Output is on the collector of a transistor and is connected to a coil next to the main tuning coil. Not 50 Ohm. The connection between the output and coil must therefore be as short as possible.



The coil is the one right from the main tuning coil (middle) Antenna amplifier is in the tin can. This tin is placed so that the connection is as short as possible to the coil. The input signal comes from a coax so the length of this connection is irrelevant.

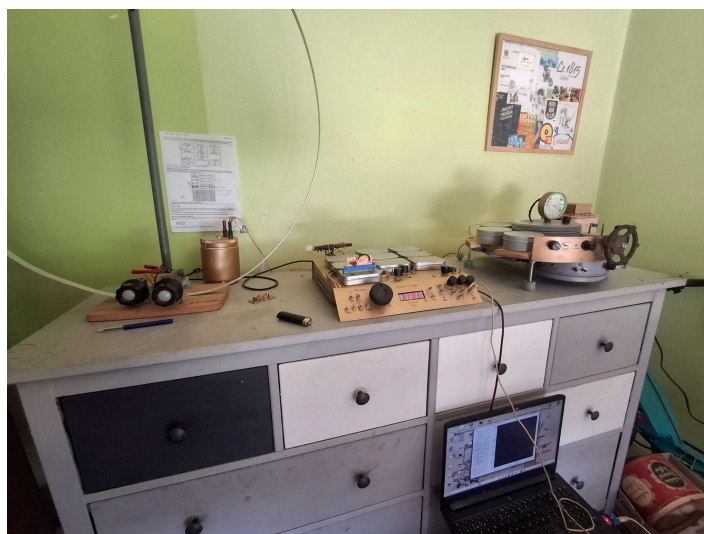
The SSB transceiver rebuild. Every circuit box follows the signal chain. All the longer connections are 50 Ohm so coax can be used. This one was also easy to lay out.

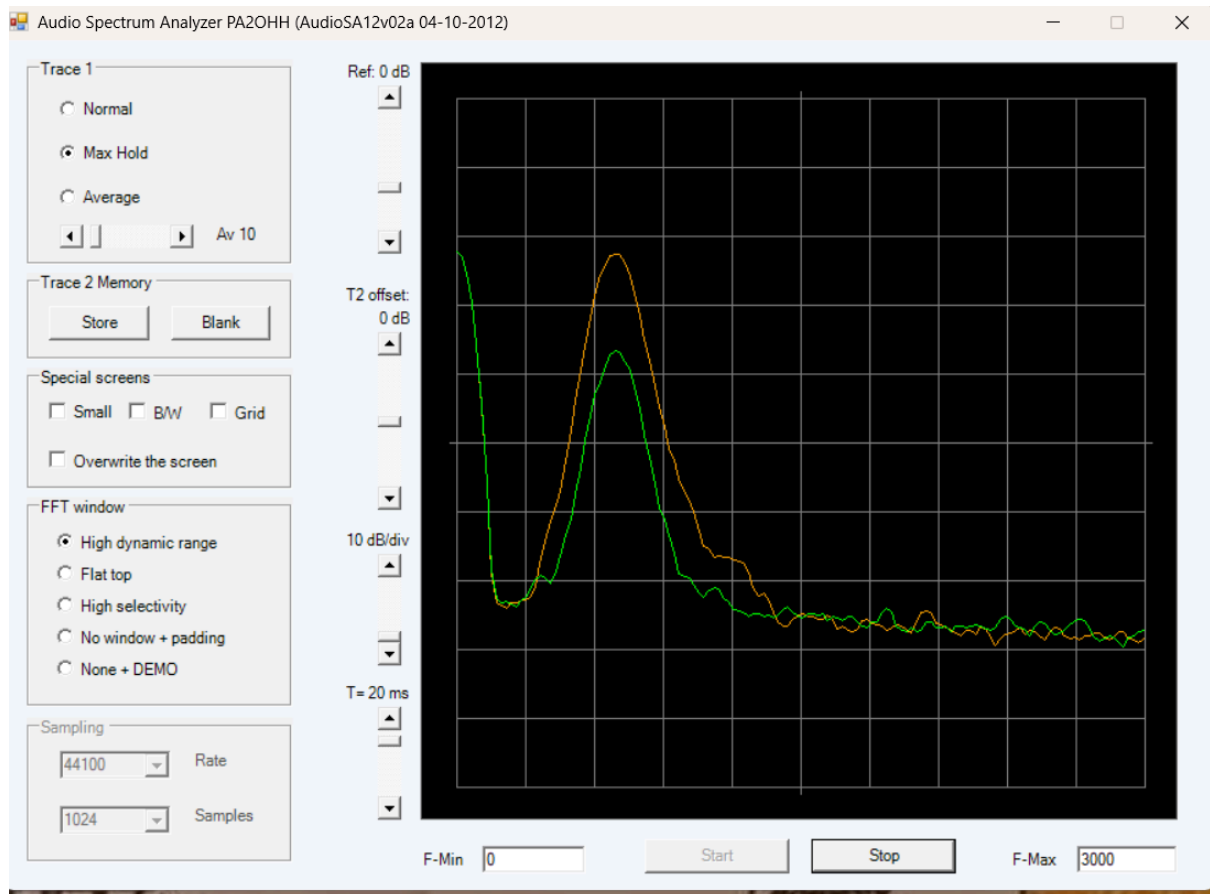


Some projects are infinitely more difficult to lay out than others. The tube regen was difficult. I had to consider the connections to the tank circuit, distance to the coil, a short connection from the HF amplifier to the oscillator and so on. None of these connections (besides the antenna) are 50 Ohm, so coax was out of the question.

So how well do these tin (alloy) boxes shield RF?

It took me until 2026 to really investigate how well tin cans shield RF. For this test I listened to the oscillator of my CW transceiver with my general coverage receiver. This oscillator is built in a Quality street tin box. Not pure aluminium but an alloy. What's in this alloy is a mystery but they are definitely slightly magnetic so I did not expect a perfect shield. I measured the output of the general coverage receiver with PA2OHHs audio spectrum analyzer to have a more scientific result.





Orange is box open and green is with the box closed.

The result was a bit disappointing. less then 20dB attenuation with the oscillator lid closed.... It is like it is.

My SSB transceiver is completely constructed out of alloy tin boxes and it works fine. No QSO partner ever complained about RF feedback, so the tin boxes are good enough.

The other circuits in my CW transceiver use round aluminium boxes that I bought from Amazon. I did not check these boxes. As they are pure aluminium they should shield 100%.

Always look out for boxes that are begging to be turned into a radio.



Many tin cans are simply for free. Larger boxes can be useful for larger circuit blocks or complete circuits. The Macintosh box will probably one day be turned into a tube power supply. The Glenfiddich box has been screaming to me for years but so far I have not found a purpose. The two Nivea cans are used in my regeneration radio.



Two Quality street cans were used for the CW rig. One for the iambic keyer and another one for the frequency counter/oscillator.



The PLL oscillator of my general coverage receiver is built in what used to be a Belgian chocolate tin can. **Needless to say that the Belgian chocolate was much more tasteful than the Quality street candies.** Belgium chocolate is so tasty that finding volunteers to eat it is easy, hardly an inconvenience. All of these food cans are not pure aluminium and the components could be soldered directly to the metal sheet.

Notice that every single circuit block can be accessed in a **fraction of time**. Year on I can safely say that this method is fantastic. Homebrew projects need constant tweaking and modification and **getting in and out fast is convenient**.

Whenever I am at my local hardware store I can't help myself looking at the kitchenware and think 'could I use that in a radio' And I'm glad I do. The power supply of my tube regeneration radio features two transformers. They got one great feature, they were free. 0 Euro! They were also horrible. They looked like they came from the depths. Fortunately I saw two cheap pieces of kitchenware. Kitchenware that whispered to me 'we can hide those hideous transformers for you, so you will never have to look at them ever again'



Painting is easy.

I found painting not so hard to learn. It is not a skill like bricklaying or welding that takes years to master.

The tin-cans must obviously be dry and clean. Cleaning it with degreaser will be helpful but not necessary. A little bit of sanding with a fine sandpaper is always a good idea.

First spray primer on the can or aluminium sheet. It is best to do this **indoors**. If you do this outdoors, which is tempting in the summer you can bet that insects will be glued to your paintwork. Which will result in a complete restart. Also try to paint in a **horizontal** plane. This way the chance on a leaker is reduced severely. A leaker is also a restart...

And thirdly, a difficult one, be patient and paint thin layers and always move your spraying can around. Apply one complete layer fast and **stop**. Resisting the temptation to quickly 'give a little extra on the spot that just lacks a little paint' is hard (at least for me) . Laying on thick layers or holding your spray can still result in a leaker.

If you do have the bad luck of a leaker, the only way is to sand off the paint bulge completely. Next you have to apply a new layer of primer over the whole sheet or can. Your sanded 'bulge' will always show up if you don't lay a new layer of primer before spraying your new paint. So, it is better to take your time and paint an extra layer and have a good result than rushing and having to start all over.



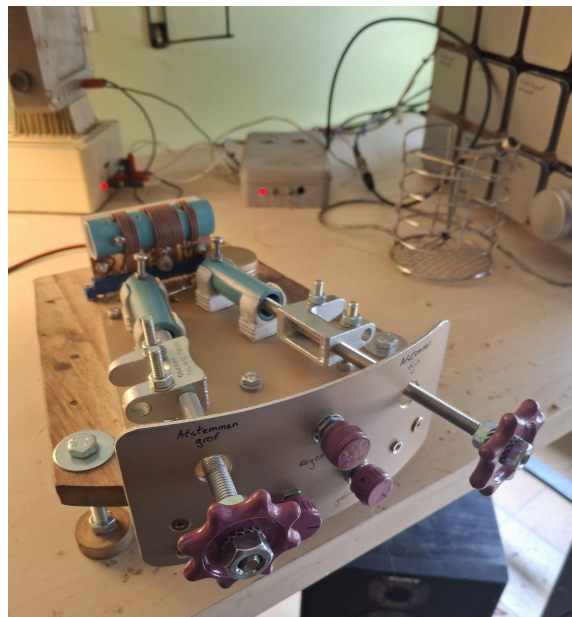
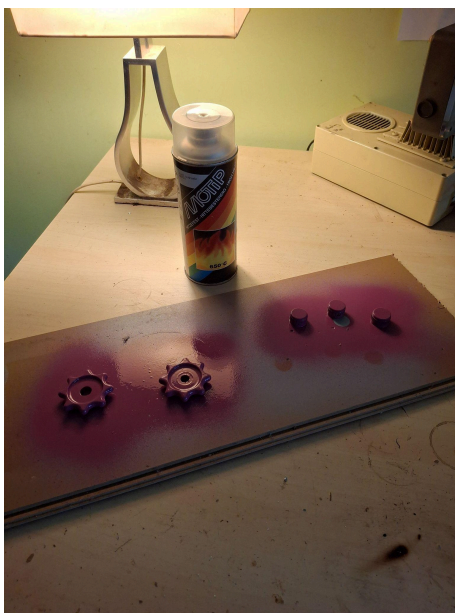
The first step is to spray primer. You can skip this step but this will cost you more 'real' paint which is much more costly. Usually, two layers is more than enough and in many cases one layer is quite okay. My primer has in fact a nice color of its own. Depending on the room temperature the drying time is usually only 10 minutes.



The next step is naturally the paint itself. Again, **don't rush!** Just apply a thin layer of paint and never hold your spraying can still. The chance that one layer is enough is zero. You can apply a second layer after the first layer is dry and that usually also only takes 10 minutes. You have to count on two layers minimum. 3 layers is nearly always more than enough for a very nice result. Et voila, that's all.

What I usually **don't do** is apply varnish. Varnish is also sold in spray cans. With a varnish finish your rig will be much easier to clean and more scratch resistant. However, your rig is not a car that has to resist all kinds of weather and other abuse.

But the main reason that I don't use varnish is that it is also that spraying varnish is much harder than primer/paint.



Surprisingly little! I am confident that I can build any project in this book with the few tools in



An electric drill,

A metal saw. I also have an electric swing saw but never use it. By hand you have a nice

A wood saw, if you use wooden daisy boards.

Measuring tape,

A file, I also have some smaller ones. At least one file is essential to clear up your drill and

A box with drills and bolts and screws. A Safran drill to clean up your drilled holes is once you have one nice.

Some wrenches,

Paper tape. The tape is used to tape off for instance the front plate to draw where the holes must be drilled. Once the holes are drilled the tape can be removed and your plate is ready for its paintjob.

Sandpaper, not in the picture.

A couple of clamps. I do not know the English name. In West Flemish they are called 'sergeanten' These are used to avoid having to buy a vise.



I clamp my piece on my table and do what must be done. These clamps are cheap, vises are not. Vises are called 'vijlstake' in West Flemish. The official Dutch name is 'bankschroef' Completely different. Because I work as a mechanic in East Flanders there is some confusion and very surprised looks from new colleagues when they hear the word 'vijlstake' . I don't have one at home as it is way too expensive for the few times it will be used.

Aluminium is not strong enough for threaded holes so you have to use bolts or screws. But in heath sinks you might have to drill and tread a hole for a bolt. Heath sinks are thick so a treaded hole will be strong enough. Treading isn't so hard but it needs attention. Drill a hole **1 mm smaller**. So for M6, drill 5mm, for M5 drill 4mm, for M4 drill 3mm. Then carefully start tapping your hole. Do not use a drill, your tap will break! Do it by hand. There are specialized tools to do this.



You really need to be careful and 'feel' when the tap is about to break, and stop in time. Your main worry is that your tap breaks off in the hole. It can not be removed like a drill and will be there until the end of times.

If the tap starts to complain, just turn back, clean the tap and continue. Do it **slowly**! Aluminum is infinitely easier than steel. If you have never threaded a hole you could practise on some scrap metal.

At home I do not use the special tools and use a Vise-grip.



Threaded holes are a rare occasion in my projects. Only some heath sinks have such holes. And the homebrew capacitors.

I don't have any professional, specialized or expensive workshop tools as you can see. You probably already have everything in your garden shed. If you still need to buy something, **buy cheap**, it will be fine.

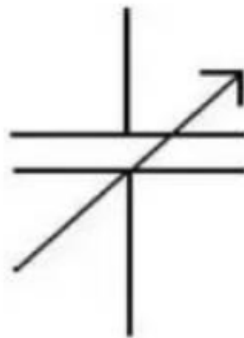
There is one exception, drills. You have to buy good drills or you are wasting your money. Using ordinary water to cool and lubricate your drill while drilling will increase the life of your drill significantly. Real cutting oil is indeed even better. If you ever have to drill in steel, drill **slowly**, and put as **much force** as possible on your drill. I am not very strong so I use my weight.

Reliability.

I've been doing this for nearly a decade. I can safely say that the construction is to be trusted. It works and keeps on working. I did learn one thing. Buy yourself a **magnifying glass**. Take your time to check every single connection after you finish a module. This good practice will save you time and frustration.

Why buy a tuning capacitor when you can build a contraption?

One of my main tasks as a maintenance mechanic is replacing broken pressure valves. The expensive bigger ones get repaired but we throw the smaller ones away. One day I saw this turning wheel of a pressure valve laying in our metal waste container. 'Hmm, could it be used as a tuning knob?' They look so wonderfully industrial. Especially rusted. I figured it would give a homebrew HAM rig a lot of character. My CW rig started to slightly annoy me at the time and the observation of the knob in the metal container sealed its fate. It would be rebuilt with the cool knob

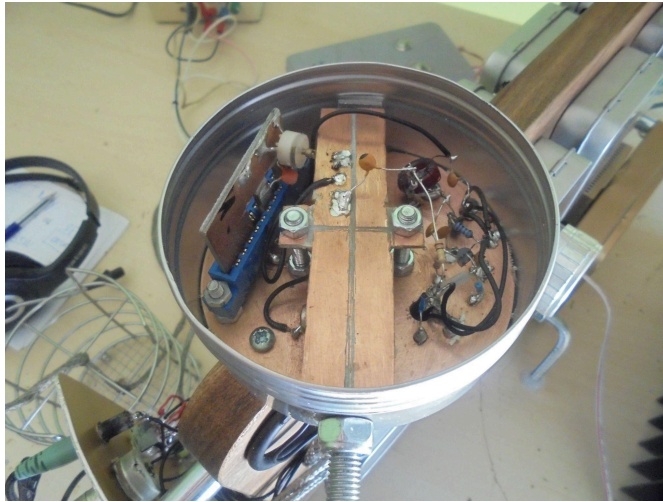


Variable Capacitor

Such a knob weighs about 300gr. Way too heavy to connect to a potentiometer. also a 1950s tuning capacitor would be destroyed by the weight. And even if it would be possible, you still don't have a tuning gear reduction. For weeks I thought about a solution to build a homebrew tuning capacitor with the scrap pressure valve knob.

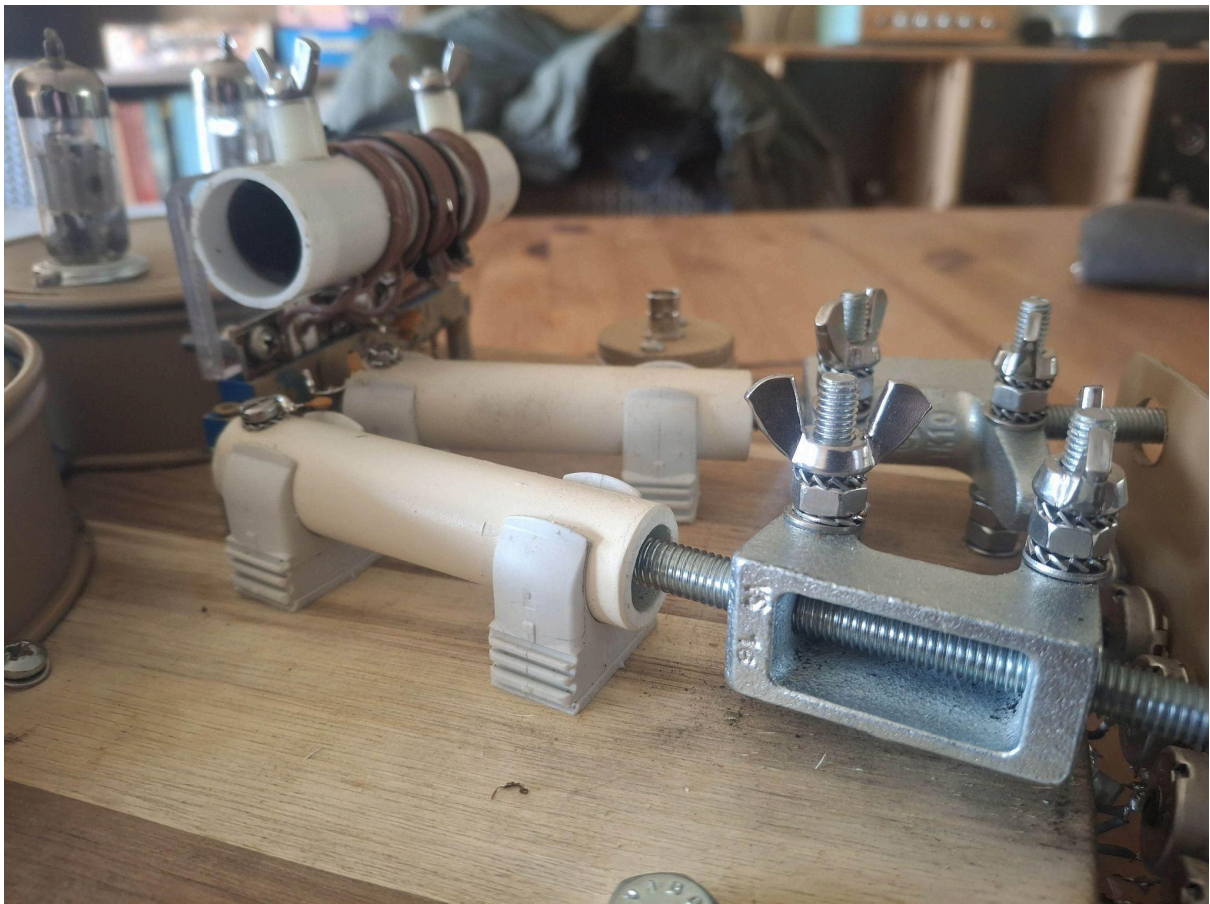
The version used in the CW rig was complicated, a metal plate that slips in a plastic sleeve. It also uses a ball bearing. We are going to skip over this version because it works, but true fine tuning is impossible. It will also be impossible to obtain ball bearings for ordinary homebrewers. The inadequate fine tuning was caused by friction but I did not realize that (yet)

My second version was much simpler. I thought that simplicity would result in better performance but was about to encounter reality.



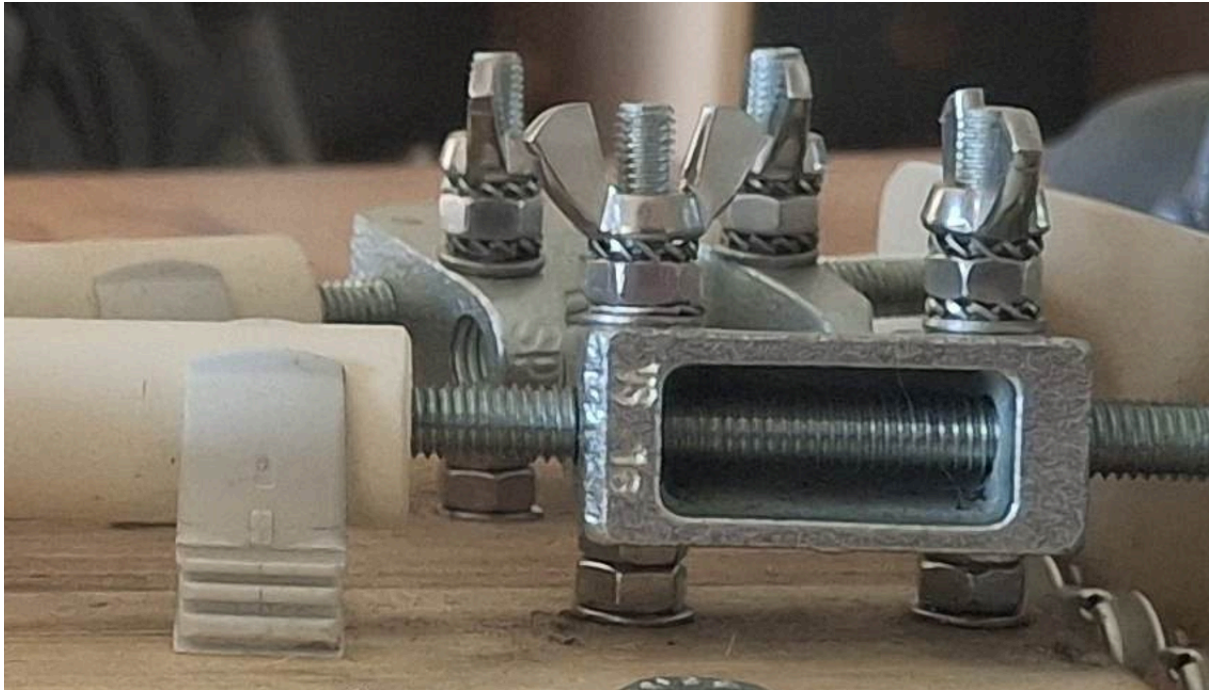
There is a metal moving under the copper PCB when you turn the treadeth rod. It was completely **useless**! What these two versions learned is that a tuning capacitor must have **no mechanical friction** or fine tuning is impossible.

Moving on to the version that works absolutely fine! There is no friction so fine tuning is possible. We will take the tube regenerative receiver as an example.



The M8 rod turns into a steel beamclamp. Not sure about the English name? They are cheap online. As you turn the threaded rod it will turn left or right, depending in which direction you turn. So the rod will either go in or out the tube and thus change the capacitance. The 'spood' of a M8 is 1.25mm. I haven't got a clue how 'spood' is translated in

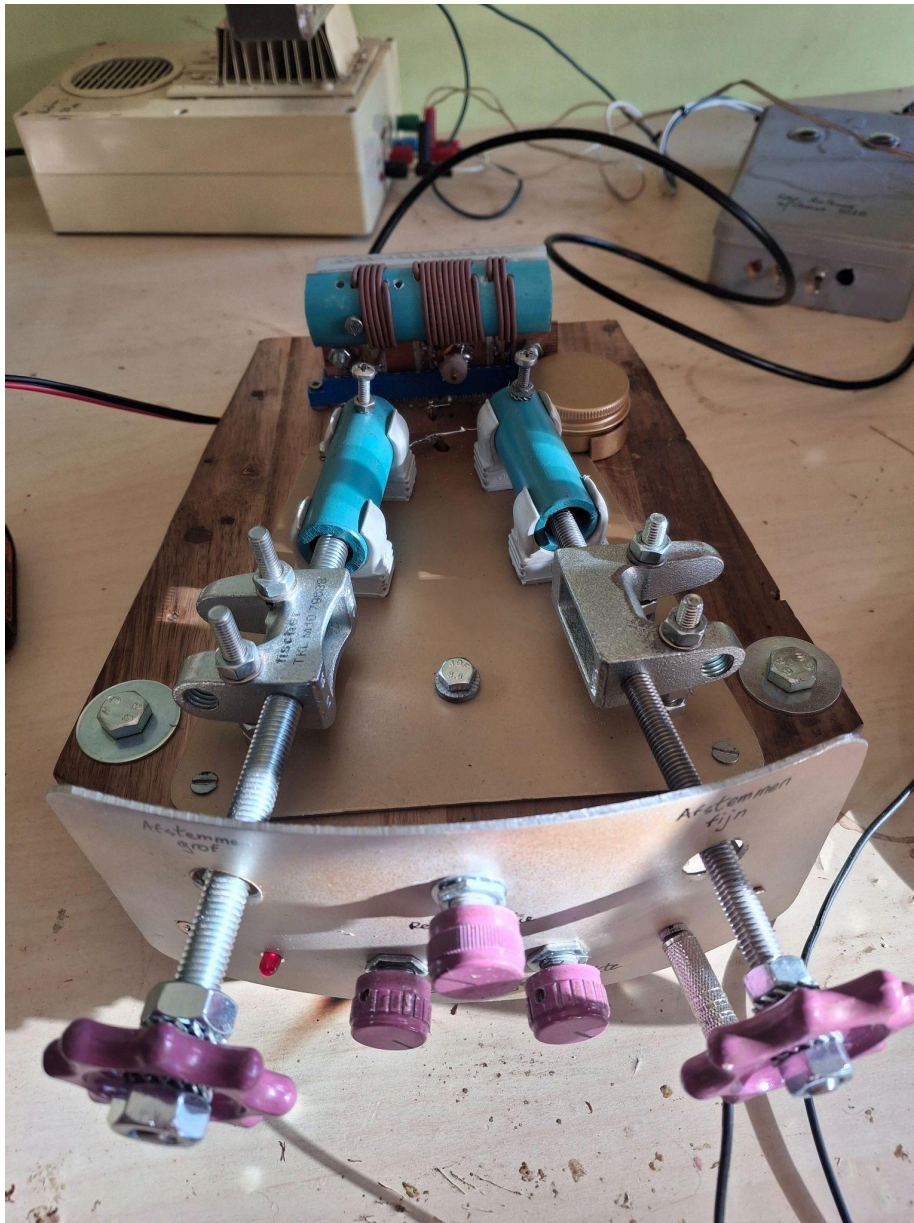
English but it means that one turn of a M8 bolt or rod will move 1.25mm. The length of the tube is about 80mm so we got ourselves a gear reduction of $80 / 1.25 = 64$. Nice! **The rod is the ground of the capacitor** and more than strong enough to carry the weight of a pressure valve knob or water valve knob. Two M6 bolts make a stand-off for the steel beam clamp.



The two holes for these M6 bolts have to be drilled by yourselves. The two M6 bolts are being used to fix the height and angle of the rod so that they do not touch the tube. **The two M6 bolts are connected to the ground plate** through the wood base. The metal groundplate is hidden beneath the wood base. The butterfly nuts have no function, I just wanted to add an industrial look to it.

The tubes are obviously the 'hot' side of the capacitor. The right one has an inner diameter of 10mm and the left one 14mm. The right is thus 'coarse' tuning and the left one 'fine' tuning. Be sure that your tube is isolated from ground!

The most difficult aspect of the build is lining up the rod and tube. They cannot touch when the rod is fully in the tube.



This requires that you must drill the holes of the steel beam clamps and plastic standoffs for the tube to near perfection! Use paper tape to mark your holes and take your time. Check the resistance of the capacitor with the rod fully in. The resistance should be infinite. If not, you will have to tinker until it is infinite. It is a bit of work but boy are they cool! You can also use anything else for a knob if you can't get pressure valve knobs.

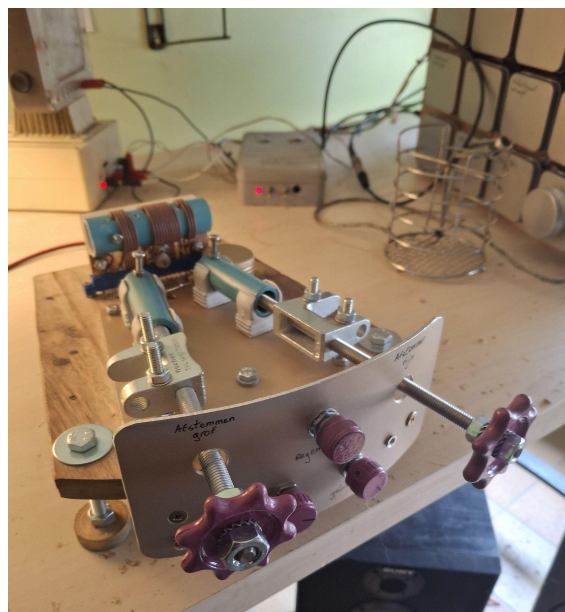
Tnx to my experience with the regen receivers I can safely claim that they are just as good as commercial capacitors and temperature stable.

I got a huge kick out of building my own homebrew tuning capacitors! At least half of the comments I get are praise about these capacitors. They can be made without special tools but require some persistence to build.



The single tube version in the SSB rig. Expected capacitance is below 30pF but that is enough for a one band.

Tips to insure your rigs end up in a museum with a label 'function unknow'



On the left, a Spoetnik regenerative kit receiver and on the right my comparable regeneration radio.

The SSB transceiver started in 2018. It was **not intended to be a tin can construction!** At the time I worked in a light advertising company and could easily build 'normal' enclosures during lunch breaks.



2020



2024

My plan was to build a chassis, use cigar boxes (from Patrick, my cigar smoking colleague) to shield every circuit block. The next step **would have been** to mount two side panels and a top panel when the SSB rig was working. I however left the firm early 2019 so completing the panels was no longer possible. Now what?

My solution was simply to paint the cigar boxes and chassis. To my surprise it did not look so bad. Over time the shassis/cigar boxes grew on me.

It was the first time I started to realise that radio should not resemble a commercial radio at all. When you homebrew you get given freedom! For some years I considered this transceiver my most beautiful creation so far. Well, until the rig started to annoy me and was scrapped and rebuilt.

I am still a maintenance mechanic but my current employer does not allow us to build for ourselves during lunch breaks so normal square boxes that resemble commercial gear are still out, which is a blessing.



My 'holiday' radio around 2018



Holliday radio anno 2023

My portable shortwave radio has had countless versions since 2011. In fact I have lost count! All the versions up to 2023 had the same feature. They looked as you would expect that a small homebrew radio should be. But the new version does not.



CW rig 2013



CW rig 2016

The most extreme evolution must be my CW rig. The versions up to 2023 were commercial grade looking stuff.



CW rig in 2023

But then I had moved on to building rigs that no longer resemble how a rig is supposed to look like. I don't have the tools to do so at home but, more importantly, I no longer want to. After posting my CW rig on the FB group 'the art HAM radio homebrew' in 2023, Steve Fabricant noted 'It could be a radiosonde that they sent down from a saucer to detect intelligent life, and failed.' LOL, I found that very funny actually.



Side view of the tube regeneration radio 2026.

My radios and rigs do not look minimalistic or retro or steampunk or modern. They look like mine. The mechanics were born over the years out of necessity. They were born because

my simple tools can not produce a neat commercial looking radio, and my employer does not allow 'home work' . And I am glad my road went this way and made truly unique homebrew stuff.

The reactions on air are usually one of two. Compliments (that actually happens), or hearable confusion. The confusion comes due to my rigs breaking every visual and ergonomic expectation modern hams have. The confusion vanishes usually and I get compliments. But not always.

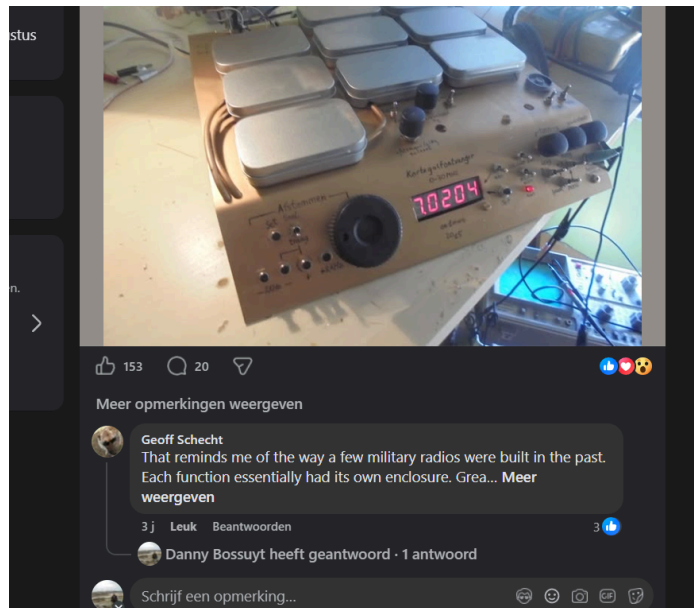
When I'm homebrewing I am in a way pretending that radio hasn't been invented yet. In many ways I have taken the step to pretend that how a radio is supposed to look like is **also not invented yet**. And I am inventing it myself. I build strange things because I started to enjoy it.

What if you feel that my rigs go way too far?

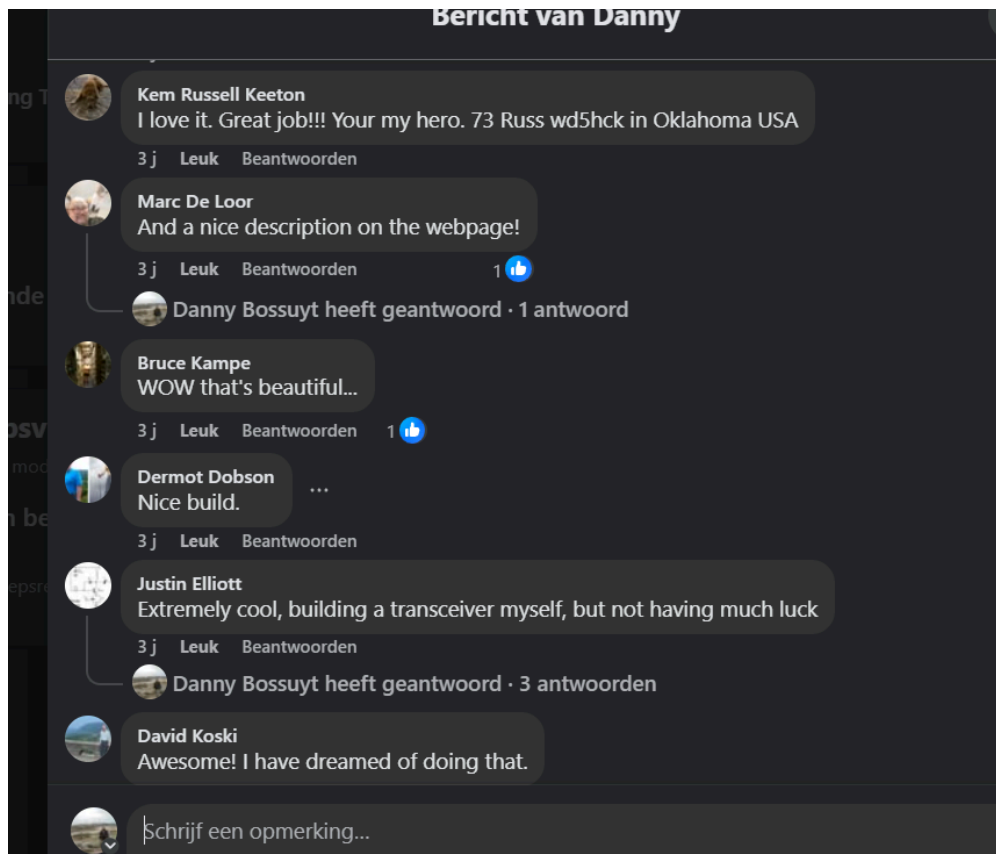
Fair enough. You can't argue about taste. But with the tin can method you can also build rigs that look oddball but within reason. Below pictures of my 2022 general coverage receiver. The chassis is aluminium instead of wood.



This radio has been used for a while in my living room. Every single visitor walked up to it and started asking questions. I posted it on the FB group 'The art of radio HAM homebrew'



153 likes, which is massive for a small niche group.



Just look at the comments. See, you can build a tin can radio that people love. A little weird is charming. Personally, I love my weirder rigs more, but taste is taste.

Short resumé, for guaranteed success.

A ground plate, no lead inductance. I usually buy myself a beautiful wooden breadboard. And hide the aluminium groundplate at the bottom.

All ground connection (antenna, power supply, loudspeaker, headphones) as short as possible to the ground plate

ugly style soldering resulting in minimal stray capacitance. And it is great for modifications. And if you are lazy like me, it goes fast.

separate tin box for every circuit block. No radiation. Circuits can only communicate as God intended.

Everything accessible in under a minute.

Our next stop is the graveyard. The failed rigs. We are going to follow just one goal, one rig, and look at what went wrong along the way. As we will see some of the problems were also mechanical....

Chapter 4

The escalation machine.

Getting annoyed by your own creations
on1mws

This chapter does not deal with analog or mechanics. You will not learn anything useful. It is simply the story of how a small, harmless goal slowly turned into a long, spiraling project. It also explains why people rebuild things that already work, and why rigs have to fear their siblings. Nothing in here will improve your station, and if you're looking for a laugh, you will not be disappointed.

You remember that Elektuur shortwave receiver from 'Hoogfrequent schakelingen' the one I mentioned back in Chapter 3? The radio I never built because I didn't know how to make PCBs. Early 2000s came along, the internet arrived, and suddenly the whole RF underworld opened up. Copperclad construction. Manhattan islands. Ugly style. Dead-bug. All things I did not know existed in the 1990s.

If I had known that in 1990, I could have built that Elektuur radio. But the world before the so-called information age was a different planet. Anyone born after the internet has no idea how hard it was to get information. You didn't "look something up." You simply did not even realise what you should be looking up, or where, I digress.

By early 2008 I needed a new hobby. So I decided to build a shortwave radio. Eighteen years after the Elektuur disappointment. This time I was going to get even.

The first mock-up went together in the garden shed. Nothing fancy. My goal was modest,, receive world broadcasters, hear a few HAMS, maybe catch some nautical weather. That was it. No grand ambitions. No "ultimate receiver." No "laboratory-grade performance." Just a working shortwave radio. That's how it all started, with a simple, innocent goal. I knew that building a shortwave receiver is not a walk in the park but I wasn't going to invent nuclear fission in my garden shed, right?

I dug up the book to write this chapter. First we need to find out what the goal was.



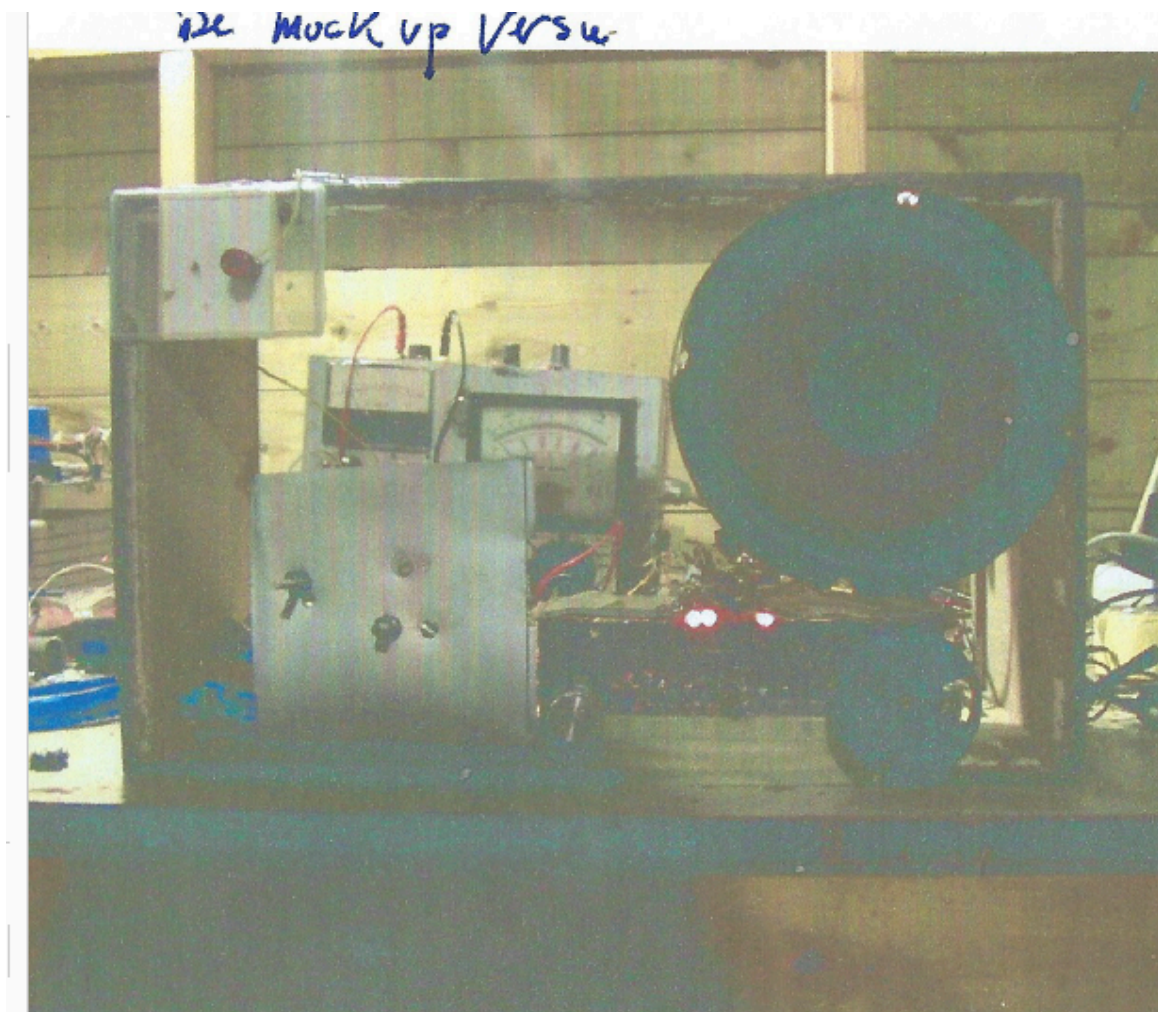
What were its specifications?

- receives from 3,5 to 12 Mhz.
- AM.
- Bandwidth 8 Khz (ceramic IF filter)
- Can it receive long wave, no
- Can it receive medium wave (AM), no
- Can it receive CW, no
- Can it receive SSB, no

It is a very modest AM shortwave radio. If we were to compare this radio to the first receiver featured in chapter 5, it would be like comparing a WW1 biplane to an F16.

The Mock up.

The original schematic was dug up and discarded. It was not possible to add a second mixer to receive SSB and CW. The IF strip was built around an IC, and it was obsolete anyway..



This is kinda how it looked like. It is my only picture. This was my test bed. The goal was to try as many circuits as I could and when I had a finalized receiver build a final version in a nice enclosure. And enjoy success. I was also planning on taking my time. It was a kind of 'test factory'. Professional approach is it not?

I think that the oscillator is in the lower right and on top of that PA2OHHs LED frequency counter which I built before the summer of 2008.

My local electronics shop had lots of BF981s for sale. Dual gate mosfet's. They are easy to work with. The gain can be controlled by the second gate making tinkering very convenient. Much more experimentally friendlier than transistors. The same BF981s could also easily be used for a mixer. So I started to set up a superheterodyne receiver.

I hardly knew anything. What is a 50 Ohm antenna? What is the best gain distribution? That the frequency has to be reasonably stable for listening to the HAM bands was a question I did not even consider.

However I had lots of fun. I had a notebook and took careful notes of my experiments. I kinda pretended that radio wasn't invented yet and I felt like an analog alchemist. The notebook was thrown away many years later and I would love to read it back.

Success came early. Many world broadcasters could be received with a meter of wire. In those there are still many good ones like Deutsche Welle.

Now my excitement grew, would I be able to receive HAMs? There were spots where I could hear garbled sounds that only could be HAMs. The next step was a second mixer and a sideband oscillator.

And yes, in August 2008 I was listening to two German radioamateurs. No idea which band, I did not have a frequency counter, just PA2OHHs LED counter. That circuit is a blinking suggestion, and mine held the wrong crystal. But who cares, I did it, boy was I over the moon.

The next day I rushed to my garden shed to listen again. This was difficult as my oscillator and sideband oscillator drifted like two drunks. They did not only drift, they sometimes drifted in opposite directions. When your frequency is just a tad off in SSB the voice goes from Donald Duck or Helium voice before disappearing completely. So I was very busy retuning on my second try.

I experimented a little more to seek for improvements. One of the improvements I tried was to build a Huff and Puff stabilizer. The result was that my drunk oscillator now went even more berserk. Of course it did, what was I expecting. I declared further improvements impossible and announced the 'test phase' completed.

Everything that I wanted had succeeded.

I could listen to world broadcasters.

But my mock-up **could do more** than the Elektuur radio.

I could listen to long and medium wave stations.

The reception of HAMs was icing on the cake.

Mock up

- receives from 0 to 30 Mhz.
- AM, yes
- CW yes
- SSB, yes
- Bandwidth 8 Khz (ceramic IF filter)
- AM antenna loop stick
- frequency counter, rudimentary.
- Hifi tone control, yes

Elektuur radio

3,5 to 12 Mhz
yes.
no
no
8 Khz
no
no
no

By the end of 2008 I declared victory. The time had come to think about a final beautiful enclosure and search for a new tinkering hobby.

It turned out later on that it was a premature victory. I had no clue that the radio was a child's toy. I did not realize that I enlisted in a war.

Version 1, The one that was naïvely optimistic.

So here we are, my plan was simply to build a final receiver. Somewhere in Crystal Set To Sideband, Frank K0IYE writes 'don't be embarrassed with the crude appearance of your homebrew rig, first and foremost, it must work well' For once I disagree with Frank. Yes it must work well, but you should also make an effort to build an attractive rig. Some readers might think 'but his rigs look like artisanal clutter'. I find them beautiful. It's my clutter. In 2009 I was inspired by the panel radios from the 1920s and I also wanted that my circuit, built Manhattan style, were visible. I wanted to admire my work. Even back then I liked exposed technology.

I only have one picture left. It is no longer my DNA but it can hold its ground. The front panel is painted aluminum, at an angle. The side, back and top panel are plexi. So my circuits are visible. So for looks; passed.

And there is the second line in Frank's sentence 'first and foremost, it must work well' Yeah, about that....



Did it receive longwave stations, yes.

Did it receive mediumwave (AM) stations, yes

Did it receive shortwave stations, yes

Could it receive morse code and SSB stations, again yes.

Has it **more capabilities than the Elektuur** shortwave radio, yes

Does it has a nice looking front plate, yes

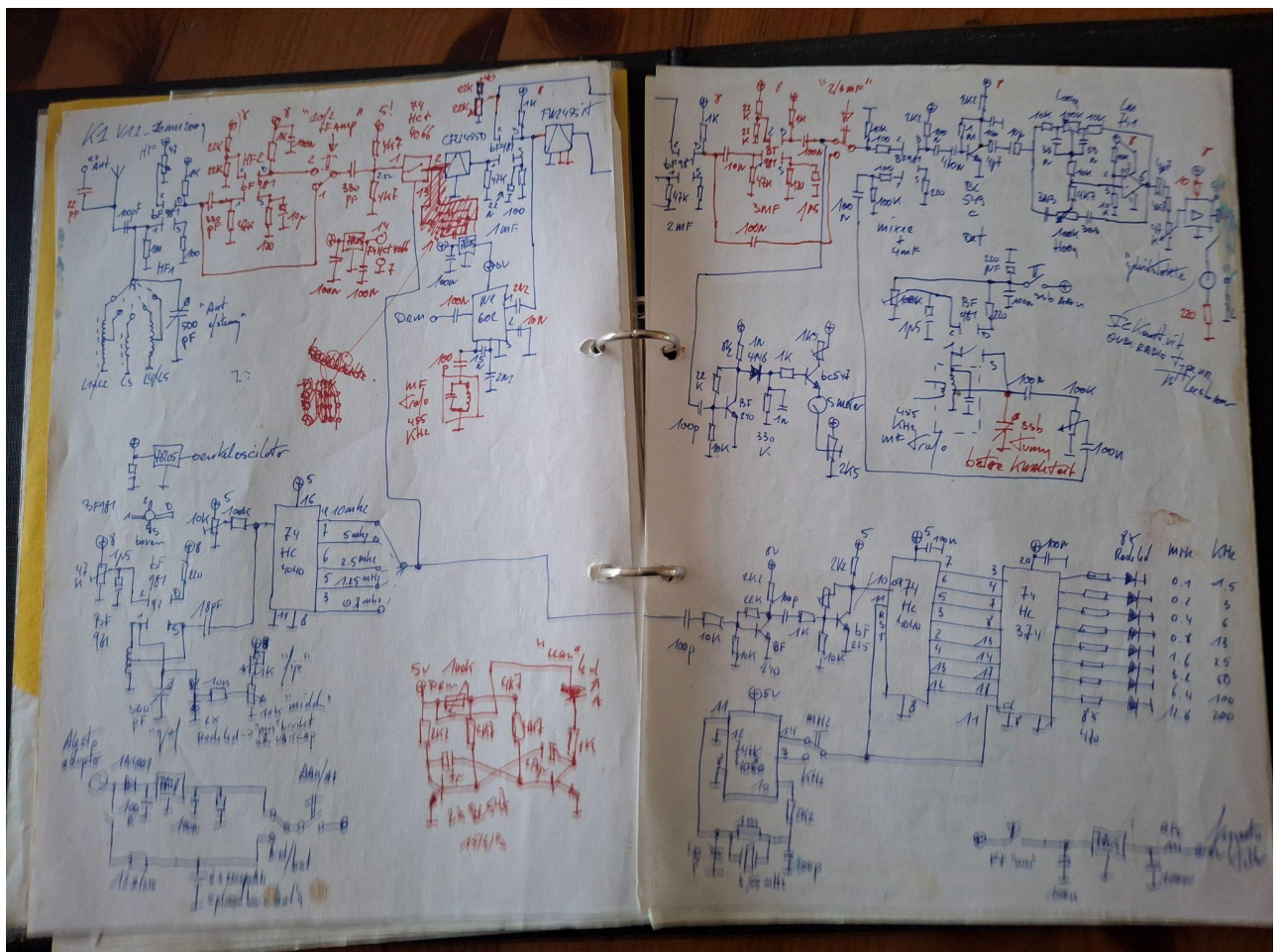
The problem lay not in what the receiver could do or not do, but **how it did it**.

Homebrewing crystal ladder filters was a capability that lay many years in the future and the receiver used ceramic filters. 455 KHz filters salvaged from radio from our local recycle park. The bandwidth was probably 8 KHz, so listening to SSB (2.5 KHz spacing) was 'challenging'. Listening to morse code (500 Hz spacing) was 'interesting'. You basically listen to 10 morse code stations at the same time. This was the least of the limitations of the radio. This is the kind of limitation you might be able to live with.

The oscillator was a free running analog oscillator. No DDS mobo jumbo for me, thank you. No huff and puff, no SuSi. Just a BF981 dual-gate FET flapping in the breeze, literally. The frequency drifted like a loose wheel. The 'mock up' had its oscillator in an old metal car radio enclosure. It was shielded completely by accident. I had unintentionally done something right and only realized that years later.

The oscillator was 'out in the breeze' in my new shiny receiver. Making the drift worse. I had a chore in the garage in 2009 and took the radio with me. My plan was to lighten my boring chore with my favorite radio station, BBC world service. The gate was open and the draft

caused the oscillator to drift so much that basically I was more re-tuning then doing my chore. Finally I turned it off. It was nearly 17 years ago and I can still remember the realization at that moment. My fancy homebrew radio was a beautiful useless machine. Now I started to realize why an oscillator must be stable. I started to read more about tricks to do this. I could not implement any of them. You are not going to believe this. The oscillator circuit was virtually impossible to reach. Oh yeah, the oscillator was built around a BF981 dual gate FET. No one does that for good reason. On certain frequencies it just stopped. I nearly forgot that issue.



I still have the original schematic.

My 2026 eyes see,

Too much RF amplification = distorts the mixer

Too much IF amplification = instability and distortion.

The oscillator is fed with square waves = harmonics and distortions

But hey, it has a cool S-meter, a feature never to be seen again in on1mws rigs.

Professionals do it all the time.

In my daytime profession, maintenance mechanic, I am regularly amazed how many faults there are in machines. Especially new equipment. We are not talking about stuff that breaks but about misery that can be avoided by some sensible design. Points of failure that shouldn't be there. My colleagues and I sometimes get annoyed. 'How did these engineers not foresee that we will need a half day to strip this machine for a ten minute fix' 'How on earth could the engineers be so stupid that they introduced such a weakness in their design'. While writing this chapter I am becoming much more mild. Apparently I also can't look into the future and avoid obvious mistakes. I am doing the same things in my shack.

The lesson here is, don't get mad at yourself. If professional engineering teams can't foresee the obvious you, as a one-man show, won't either.

Accept that you are human and see the mistakes as part of your journey. The goal is to not repeat mistakes 3 times and see the mistakes as a tool for mastery.

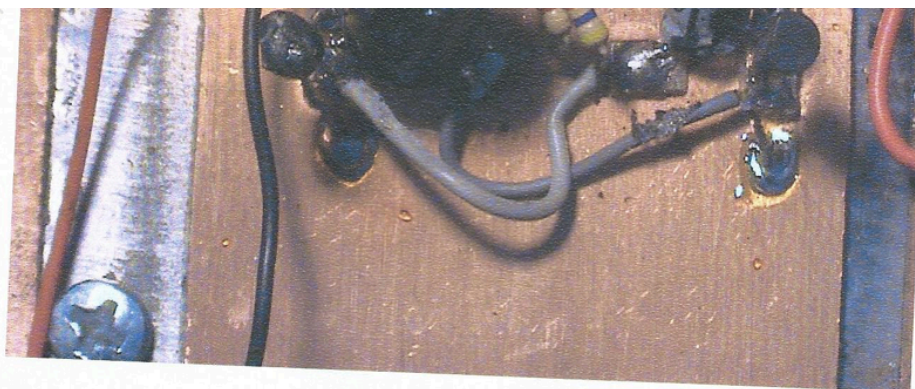
Version 2, The one that should have solved everything.

Realizing that my 'naive optimism' receiver wasn't going to cut it I scrapped it. I don't have any pictures of the 2nd receiver. The only thing I remember is a wooden plate with circuits, a plexi plate on top of that with circuits. And above that a plexi top panel. That's the most I can remember. The electronics were probably identical as before.

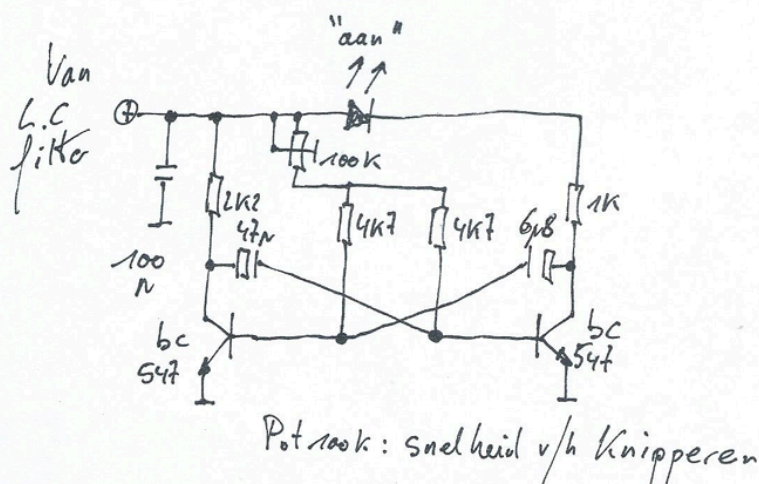
But it featured a homebrew copy of DL5UHF's PIC frequency counter. Instead of trying to guess the frequency on PA2OHH's binary LED counter (which only has a resolution of 1.5KHz) I now could read the frequency straight off 7 segment displays. Progress!

The least significant bit display displayed the 100Hz. This readout stood never still. I was such a luddite at the time that I did not realise that is not normal. It means the oscillator frequency is absolutely not stable. Remember the 'hand effect' from chapter 2? When I walked to the radio the frequency dropped, when I slowly backed off it rose. This oscillator did not suffer from 'hand effects' but from '**body effects**'. Remember that this radio was made from wood and plexi. The only metal to be found in the radio were the screws and bolts.

It might be a good time to bring up 'my cool on/off LED'. I'm not sure if it was in this version or the next. The receiver obviously featured an on/off LED. I had the brilliant idea to make this ordinary feature much cooler. I envisioned an on/off LED that would blink. One second on, two or three seconds off. The LED would not only display that the receiver was 'on' but also 'there is something exciting going on here' So I homebrewed an analog multivibrator.



Knipper led "aan"



Yes it worked! And yes it was cooooool! Until it wasn't. I noticed that the oscillator frequency continuously dropped 300Hz and rose back up again 300Hz after my victory rush. The oscillator did not have any form of stabilisation at the time. Yep, you guessed it. My super cool blinking LED caused a tiny voltage drop over the oscillator and made the already appalling frequency stability a complete disaster. O dear... Okay, at least I learned that oscillators have a dim view on changing supply voltages.

This version should have solved the problems of the previous version but was in fact... worse. It was plagued with the same issues and looked horrible. I don't have any recollection of how long this receiver existed but I'll bet you it was only a couple of months. I was disappointed, how on earth could I make the same mistakes twice. This is without a doubt the most embarrassing version.

Version 3, The one that almost worked.

By the time I reached Version 3, any normal company would have called a crisis meeting. What to do? How did we get in this mess? And more importantly, who's head is going to roll? I needed a good strategy.

Now is a good time to ask an obvious question.

Some readers must likely ask themselves 'why didn't this guy simply give up? 'admit defeat?' 'Throw in the towel?' Fair question, as I hit rock bottom in 2010. And probably already spend more money than just buying a decent shortwave receiver. I have given this a lot of thought. Never along the journey I had doubts.

Normal motivation.

If you want to achieve a goal, whether it is to build a guitar or run a marathon you will need motivation. There is normal motivation. The goal is in sight and you just need some extra tweaks. Or if you train for a marathon just do some extra KM's to get to your goal. That kind of motivation is easy as you are nearly there.

When the going gets tough.

Now motivation gets a lot more difficult. like here in this situation. To survive these kinds of setbacks you need to really want your goal **and** believe you will do it. In my case both questions are answered with yes.

Sunk cost fallacy.

I must admit that this also played a role. Keeping it up may seem not so sensible. But I invested so much time and money that giving up was simply no longer an option.

Make or break moment.

The journey toward the goal is the real fun, not reaching it. Not at this moment. This was the moment where the whole thing stopped being enjoyable. Either you bite the bullet or you quit. Whatever you're building, you can hit such a moment, and there's no sugar-coating it. It isn't fun. It's the point where stubbornness has to pull you through.

Back to the crisis meeting.

What was the strategy I came up with?

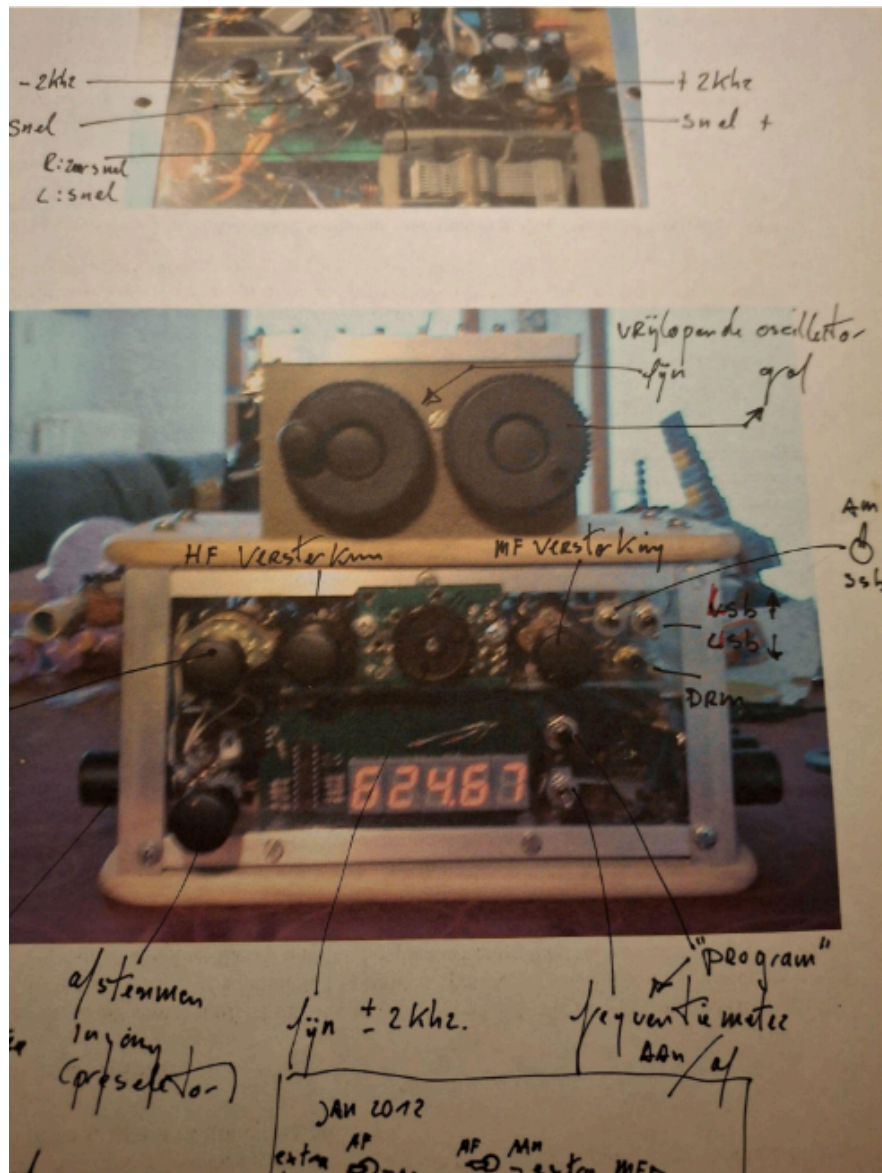
Step one,

- rebuild the enclosure, this time a beautiful one.
- Make sure that all the circuits that **needed tweaking** would need **easy access**.
- The circuits that were finished, audio and power supply could be placed in places where accessibility was less critical.
- Shield the oscillator right from the start

Step two,

- Find a way to stabilize the oscillator frequency.
- Enjoy success.

I only have two pictures left of version 3. It is a square box made from a plexi panel but the top and bottom are made from two identical wooden daisy boards. On the top daisy board is a box made from PCBs. This is where the oscillator is located and is very roomy as I expected a lot of tinkering on that location.



I haven't looked at the 2 remaining pictures in a long time. It looks great. What I love is that the plexi allows you to look inside the radio.

It's weird in just the right way. It isn't just your usual rectangular box with knobs on. No it is a device that looks at you and whispers 'guess'

I don't have any schematics left or notebook so here we will have to guess a bit. The electronics must have been identical and plagued with the same flaws.

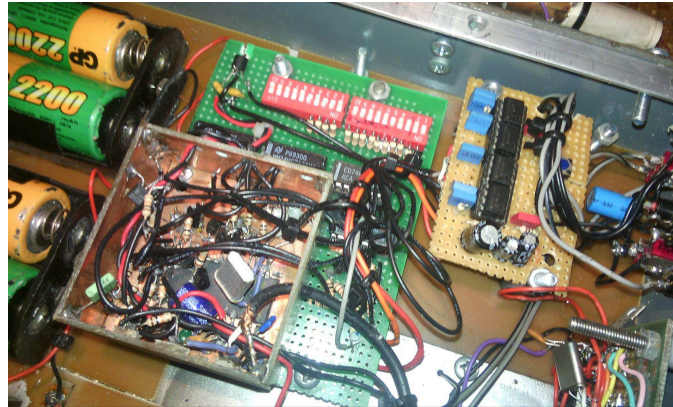
However the **'body effect'** of the oscillator was gone (oscillator is shielded now) progress!!

Phase one of the plan was done and a success. Now comes the tricky bit, how to stabilize the oscillator? A huff and puff was out and did not yet invent the SuSi.
So I homebrewed myself an actual PLL oscillator.

It was me against 7000 transistors. I had to read the whole data sheet of the MC145151-2 to make sense of it. Design the loop filter (tricky) The IC begs for microprocessor control, but I

did not know how. So I designed a 14 bit counter with 1970s logic ICs. I also had to make debouncing circuits for the push buttons with 555 timer ICs. To tune fast I had to make multivibrators with 555 timers.

It was a wrestling match and I won.



PLL.

The push buttons are clearly visible on the top panel of the oscillator. Again we can see that the enclosure looks unusual. I think it's unusual in the right way.



I also still have the block schematic. Pleased to say that the radio from this time on apparently has a normal amount of gain, not the insane amount as before. I did not know how a PLL does finetuning. My circuit did steps of 2.1 Khz. How to fine tune?

The radio underwent a **serious refit**. It was changed from single super to double super! Coarse tuning was done with the PLL and fine tuning by the second oscillator, which probably was a Xtal oscillator that could be tuned a couple of Khz. It all worked, boy was I proud!

Version 3

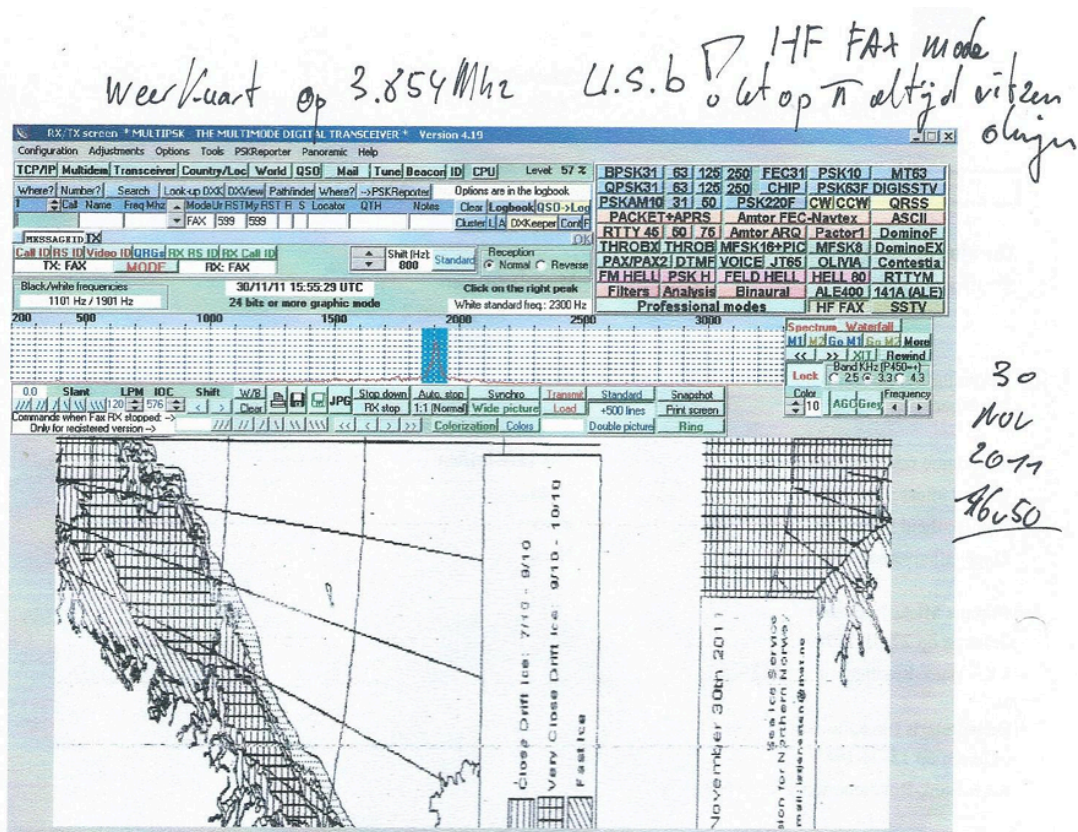
- receives from 0 to 30 Mhz.
- AM.
- CW.
- SSB.
- Bandwidth 8 Khz (ceramic IF filter)
- AM antenna loop stick
- frequency counter.
- PLL stability
- Hifi tone control.

Elektuur radio

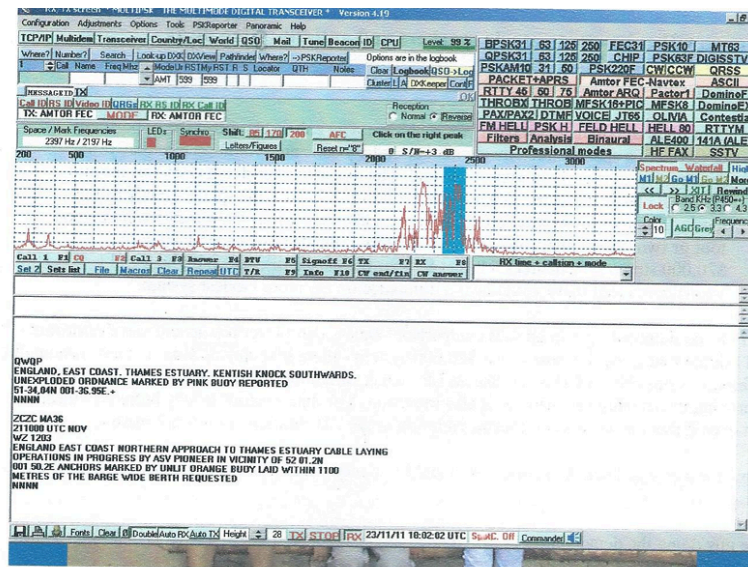
- 3,5 to 12 Mhz
- yes.
- no
- no
- 8 Khz
- no
- no
- no
- no

There had been a lot of tinkering done on this version. Changing it into a double super with a PLL is a really huge refit. Hundreds of hours of work. But there was a payoff. Modified version 3 was another level compared to the previous models and the Elektuur radio.

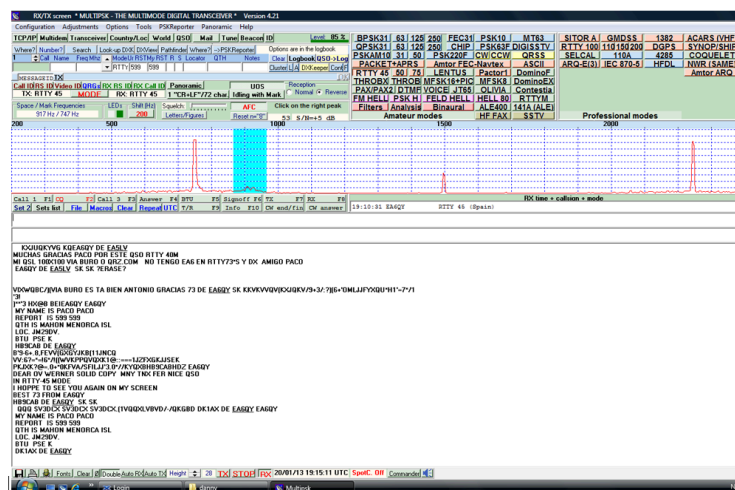
I could now listen to music and HAMS without constant re tuning. It could do other cool tricks. I could suddenly decode digital modes!



Above a weather chart.



Naval information.



RTTY

So this radio is no longer comparable to the modest Elektuur radio. This thing can do some neat things!

But the title of this version is 'the one that almost worked'? About that.

Reason one, you can read about the on/of switch' in chapter 3.

But there is more. Yes it is superior to the Elektuur, frequency stable, all modes... But there was a hidden flaw.

Only the oscillator was shielded. The rest of the radio was not. The sideband oscillators, mixers IF strips were out in the breeze. The whole box was wood and plexi. The only metal were the screws and bolts. No ground plate. Everything, including ground, was connected via wires. The result is that the circuits could communicate in ways they should not be able to do. They are not supposed to communicate via power supply lines and radiation.

Birdies! and other weird phenomena.

Behold, I had created a radio with an internal antenna park.

But hey, it was cool that you were able to look inside the cool techniques.

Version 3 was the version that almost made it. It was way beyond V1 & V2 (which were really bad) and the Elektuur radio.

There was one limitation that you could forgive. The 8 Khz bandwidth. My regens are just as bad. But you don't mind because they are so cool. Version 3 also has a cool factor. The birdie problem however was too annoying to be ignored.

Could version3 been saved?

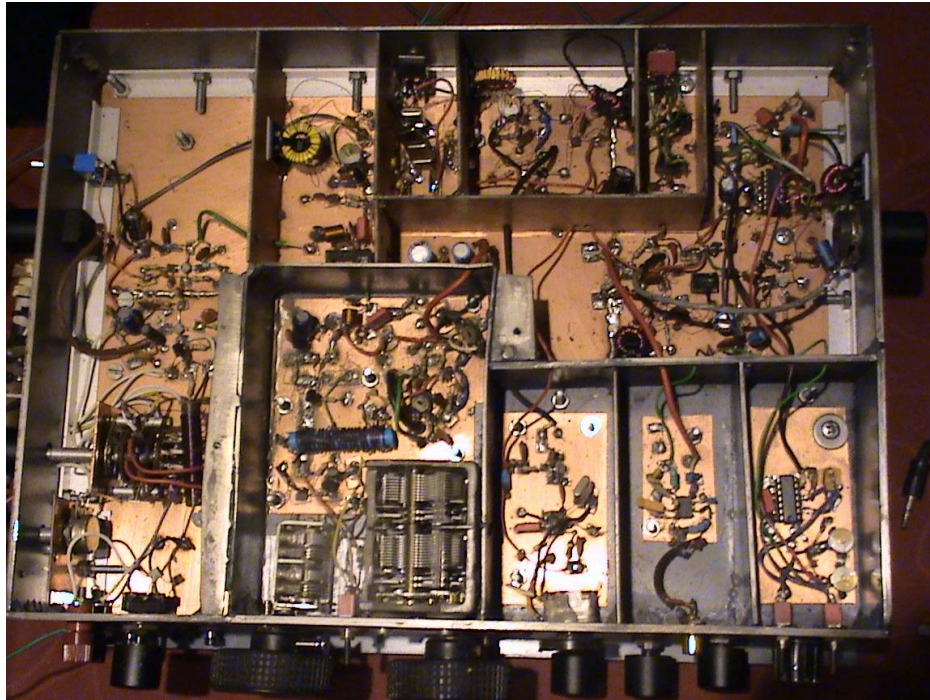
Now I realize that if you would retrofit the plexi subdivision with a metal plate instead all ground wiring would have been eliminated. All these 'antennas' would have been gone. There would be a proper ground plate. Shield the sideband oscillator would also help. So likely, yes, it could have worked. But in 2010 I did not yet understand the 'lead inductance' phenomena. I did not understand how important mechanics are.

Version 4, The one that eventually worked until it annoyed me.

This rebuild happened by chance. I followed a 3 month welding course from my employer (I still can't weld) The exercises were very boring. I told my teacher 'I have this weird hobby' 'I build radio's' 'That's not weird' he answered. The answer surprised me honestly. I asked him if I could weld an enclosure for a radio. He liked the idea and so version 4 was born. In 2012 in a school on evening nights. I am so bad at welding that the teacher helped me out.

It looks exactly how you would expect a homebrew rig to look like. A rectangular box with knobs on. I kept the idea of subdivision and putting circuits on both sides. The bottom could be unscrewed this time! I also welded subdivisions for the HF amplifiers, oscillator, and IF filters.

Exactly the same analog circuits were built in. **The birdies were gone.** More progress!!



Above the internals. Notice that the chassis is also ground. No groundwiring and unnecessary wiring. It's perfect. I can't remember if it is on purpose or by accident.



The internet keeps insulting me, and possibly my radio.

We have discussed how before the arrival of the internet we were all starving for information. When I started out I had just that 'hoogfrequent schakelingen' book. Now we drown in information. Gathering information takes time. It also takes some time to process new information in my head in my case.

Every time I thought 'okay, that's sorted' the internet told me that my receiver is in fact an inadequate toy. It reminds me of the chess.com games I play. I win an online game. I think I played super and run the game through the game analysis afterwards. The game analysis tells me I'm an idiot who should have lost twelve different ways.

My usual tactic was ignoring new information on how to improve the radio. However you can't stop the sound of a bell ringing in your head can you? Every time again I had to bite the bullet and adjust my design.

The last hurdle.

There are too many modifications to mention and honestly, I have no old notebook or schematics to help my memory. Let's say I tried many types of mixers, impedance matching, 50 Ohm inputs, and so on.

But the main limitation to make version 4 a truly capable general coverage receiver was the bandwidth. All my receivers so far used ceramic filters in the IF chain. 8 Khz at best. SSB reception, yeah it works but you are always hearing the station up or down frequency. Your fun is always spoiled. CW, well you are hearing 10 stations with a 8 Khz bandwidth.

K0IYE's 'Crystal Set to Sideband'.

Crystal set to sideband is a deserved classic homebrew book. Frank K0IYE has built everything from homebrew transistors, crystal sets, QRP CW, SSB rigs and even a homebrew 2 M station. The book is not a boring textbook but a journey of a guy who retires and gets his 1967 homebrew rig from the attic, discarded it and built a complete 100% homebrew station. The book is funny and many personal stories are woven in the technical details. The book also tells about his failures. Everything is explained from component level up. The book is free online, **get it!**

In his book I discovered **how to homebrew crystal ladder filters.**

Crystal filters.

Inspired by the book I realized that my radio needed crystal instead of ceramic filters for sure. One problem, my second IF was 455 Khz. There are no crystals on such a low frequency. So I bought the lowest value possible, 3 Mhz. For this I also had to change the frequency of the sideband oscillator. All in all, a serious refit.

How did the first test go? For the first time I could hear one, just one CW station. Instead of ten at the same time. Progress, but you are sensing where this is going.

After the initial victory rush I realized that the bandwidth was now too small for SSB, even with one single 3 Mhz crystal. Listening to music was impossible. I had just discovered that lower crystal frequency = less crystals for a given bandwidth, and vice versa.

I was the proud owner of the **only 'CW-only'** general coverage receiver in the world. A radio that said 'It's CW or nothing, my friend'.

A new sunk cost moment.

The above line seems funny but it wasn't. I was struggling. I've been at it for 7 years, just done a serious refit and had nothing to show. It was a lowpoint just like the lowpoint after version 2. For the second time I reached a point where only stubbornness pulled me through. It is too long ago to remember my mental state at the time but my luck was about to change.

A huge gamble.

Time to throw the dice.

Change the receive back in a single super.

10,7 Mhz crystals in the IF strip.

Fine tuning must now be done with the PLL (fine tuning was done by the 2nd Xtal oscillator before)

The only problem was that I needed a way to fine tune the PLL, I just had a wild hunch how.

It was a gamble and a radical one. I had no plan B.

For once my ideas worked out and the fine tune PLL worked right from the start. The single super structure also resulted in a much more relaxed receiver with a noticeably better S/N ratio

I can not empathise enough what a breakthrough this was. For the first time since the start of the project I could,

Listen to music.

Listen to **one** SSB station.

Listen to **one** CW station.

I was over the moon.

I did it!

In 2015 I was the proud owner of a capable general coverage receiver.



Version 4 vs. Elektuur — the Humiliation Table

Version 4	Elektuur radio
receives from 0 to 30 Mhz.	3,5 to 12 Mhz
AM, CW, and SSB	AM only
Adjustable crystal filter from 10 Khz to 300 HZ!!	8 Khz
Sideband suppression +40 dB.	0 dB
HiFi tone control,	no
Audio filters for SSB (voice)	no
4 audio filters for CW.	no
Frequency counter.	no
PLL stability.	no
50 Ohm antenna input.	no
AM antenna loop stick.	no

Put that in your pipe and smoke it, Elektuur radio!



Getting annoyed by my perfect creation.

The Elektuur radio was a tiny AM-only toy. Version 4, by contrast, is a general-coverage, SSB capable, CW capable, PLL stabilized beast. There is no comparison. If they ever got into a fight, Version 4 wouldn't even attack, it would just orbit the Elektuur radio out of boredom until the poor thing fell apart by itself. That's the level of mismatch we're talking about.

Version 4 survived seven years. Technically flawless. But slowly over time the receiver started to bother me in ways no schematic can explain.

Entering a new psychological problem.

Version 1 was a disaster, version 2 was so disgusting that taking it out of its misery was the only humane thing to do. Version 3 had limitations and some faults that were difficult to correct in its enclosure. They were scrapped. The destruction is reasonable. Technically they failed.

Now we are entering a new phase of destruction. We are talking about destroying perfectly good rigs.

Having brothers and sisters is an existential threat for homebrew rigs.

When is the most dangerous time for a rig to be alive? The moment I finish another rig. My new love sits in the shack quietly humming and doing its thing. My eyes start to wander off to its older siblings. Now it's time for the older rigs to **duck and hide**. Attracting attention can be lethal. I start comparing. Suddenly I start to see 'problems' where there were none before. What usually happens is that my attention gets drawn to one rig in particular. The rig does not know it but it gets evaluated. But why? Why do I suddenly see problems?

Mastery makes older work unbearable.

Every version is clearly better than its predecessor as we have seen our quest for a shortwave receiver (ok, except version 2) . Is it failure, yes, but the failures help you to reach mastery. Every version is slightly or a lot better than its predecessor. Version 4 isn't fighting version 3. That match would be easy. No, it is competing with his siblings. The CW rig, the SSB rig, the holiday radio.. Every time I finish one of these, version 4 gets 'evaluated' . Newer builds are naturally better, more elegant, look more like I want, more elegant analogs, better S/N ratio, whatever. The older version 4 can not keep up. It becomes more unbearable to look at over time. Version 4 did not become worse, I got better.

Identity change.

If you keep at something long enough you will develop an identity, where you want to or not. But taste evolves. The problem for your older rigs is that they no longer represent your new identity. If they were commercial I would not mind. Some other guy designed them. But my homebrew rigs are mine, they must represent me. If they do not they become unbearable to look at.

Anyone who ever built something, a guitar, a model plane, a piece of software, a painting, will recognise themselves in my escalation machine.

The Subtle Signs a Rig Is About to Annoy me.

Pinpointing the tipping point? When was version 4's faith being sealed? It's difficult to pinpoint. The signs are indeed subtle in the beginning but escalate quickly. Definitely after the first SSB rig was finished. Tins cans right. My new identity.

So my main annoyance was that version 4 looked like your regular homebrew radio. It did not share the DNA of my new tin can SSB rig.

We have an idiom in Flanders. If you want to beat a dog, a stick is easy to find.

And yes, it was easy.

The circuits were not elegant, the oscillator amplifier had 3 different transistors. Yes it works.

No, I don't see them. But still it annoyed me.

The Rf and IF amplifiers are not elegant, same problem. It is like I sneezed in my part drawer and the parts landed on the copper clad.

Too many whistles and bells. Even the side panels have knobs and switches.

Too much dust inside the enclosure. A really pathetic reason, yes.

The frequency readout is in an awkward place. Another pathetic reason.

None of these things are the real reason.

Version 4 just stopped being me.

Version 5, The one that could be final.

We are gonna keep it short on this one. The new receiver was built in 2022. It is basically the same receiver as version 4.

Analog improvements,

It had a new product mixer. One of my standard lego bricks. S/N ratio is maybe slightly better.

The BF981s were kept but all the amplifiers from antenna to detector are identical and elegant.

The oscillator amplifiers are now streamlined in identical amplifiers.

A lot of unnecessary and useless whistles and bells were scrapped without compromising capabilities. Version 5 has all the stuff you want, and the stuff you don't use isn't there. I think I found the exact right balance between simple and complex up to this day.



Mechanical,
A new aluminium chassis.
Every circuit block in tins I got from Amazon.

Version 4 looks like all homebrew rigs, version 5 looks gorgeous. It is indeed a tin can construction but for most people it will look more familiar than some of my other builds. It was used for a couple years in my living room. Every single visitor walked up to it to check it out.

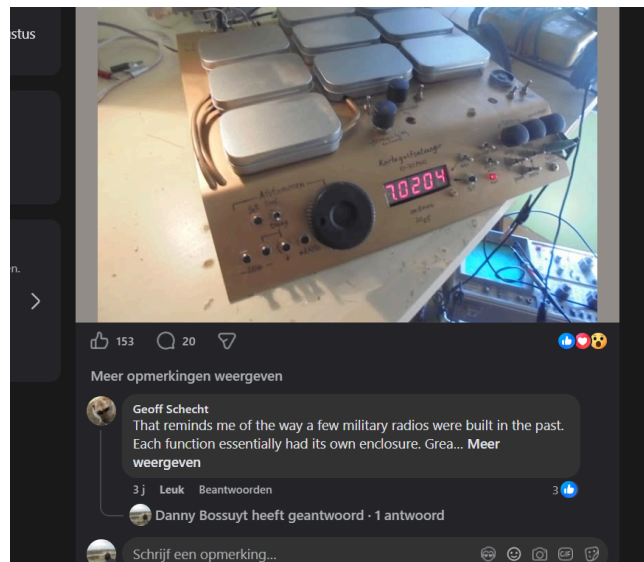


Just look how beautiful the RF circuits can be if you open a tin can.

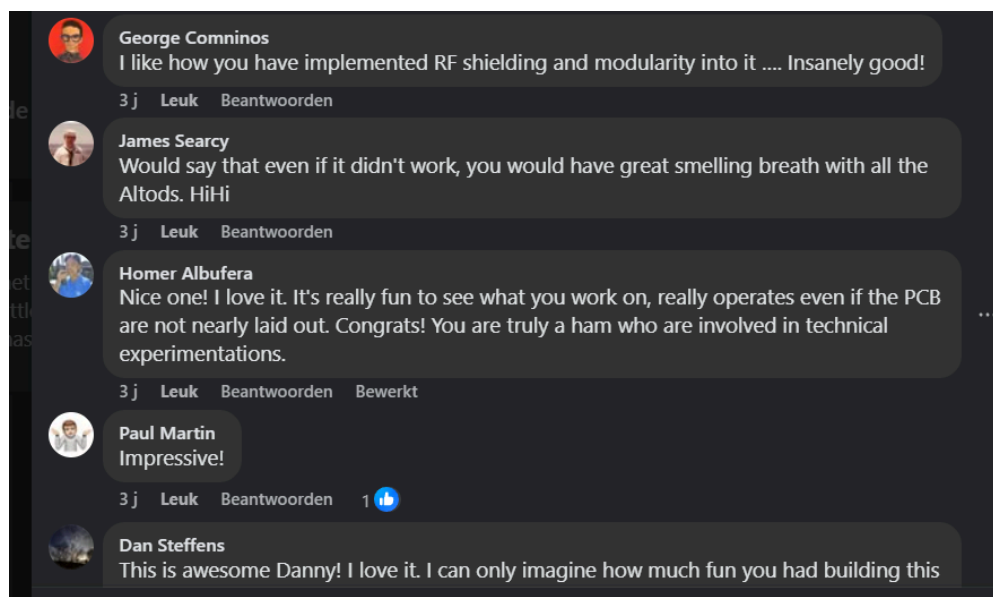
What is the best way to describe the difference between version 4 and version 5? Version 4 is like a hippo trying to ballet dance, version 5 is a prime donna that floats over the stage and knows it.

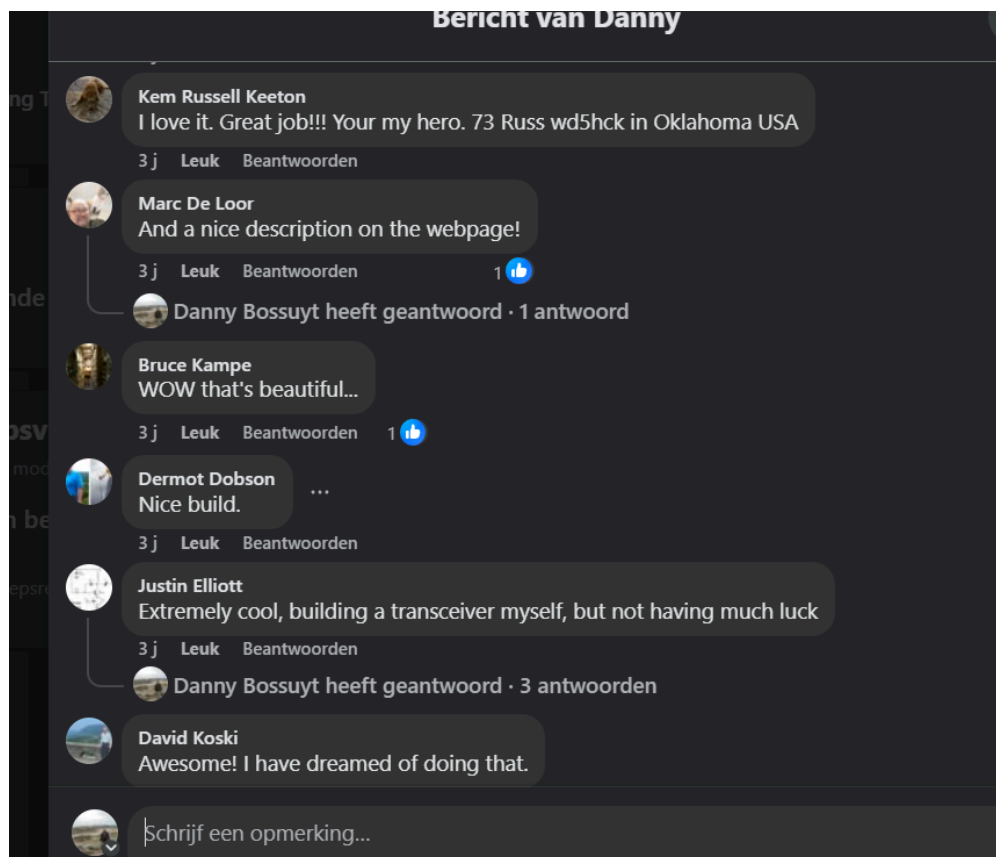
Version 5 is all elegance, both mechanical and analog.

There is nothing wrong with version 4, version 5 is simply in another league.



The new receiver was posted on a couple of FB groups. None of these groups ever see stuff of this level. In fact, posts of the level of version 3 are never seen. I did get a lot of likes on all of them with version 5. One of the groups is 'The art of HAM radio homebrew'. It got 153 likes. That might seem little but is in fact a huge number.





Just read the comments, 'Extremely cool' 'awesome' 'love it, great job' 'insanely good' 'you're my hero' 'impressive'. Dare I say it, version 5 is a hit.

The escalation machine might have finally stopped.

Version 5 never had the cool homebrew tuning capacitors like the rest of the station. It has always been the odd one out, a PLL, BF981 everywhere, a different DNA entirely. But while writing this chapter and sorting through the photos, I noticed something unexpected. It has grown on me. That's a good sign, four years on.

The other rigs have had their share of rebuilds, but nothing like the general coverage receiver. And yet I'm sure that the Holiday Radio, the CW rig, the SSB rig, and the regens are done. They've reached their final forms.

I'm at the end of the road. There's still a moped in the garage waiting for restoration, and that alone will keep me busy for a long time. A different kind of R&D.

So this is where the touch of chaos ends. No more heroic battles, no more adventures. Just circuits that work, from simple to complex, without quirks, and more than adequate for real use.

Chapter 5.

The Part of the Book Where Things Behave

This is the payoff, working projects from easy to difficult.

on1mws

You now have a stable oscillator. Time to build the world around it. In this chapter we will look at a complete ecosystem. We will not look much into the basics but **how** to build, how to use your builds and what to expect to maintain it.. The first project will be an easy but very good superheterodyne receiver.

Followed by the CW rig and finally a solid state regeneration radio. Sprinkled in between are projects like the power supply, dummy load, SWR meter, T/R switch and loop antenna. We will also take a look on how you can get around not having morse code skills.

The Superhet Is Just Lego With RF

A superhet looks complicated on paper, but it's modular. Each block does **one** job. Each block can be built, tested, and sworn at independently. When you finally stack them together, the whole thing snaps into place like RF Lego. So let's get started.

The block diagram of a superheterodyne looks strange at first glance. But if you go back to the early days of radio, the whole thing becomes obvious. The superhet wasn't invented because someone wanted to annoy beginners, it was invented because early engineers were searching for **selectivity**, **stability**, and **gain**, and the only way to get all three was to shift to a fixed intermediate frequency.

Useful theory only.

'How does a superheterodyne radio work' from Warren Parks gives a nice historical background of how this circuit was developed. The super heterodyne principle became crystal clear to me after I read it in 2002. Find it.

https://antiquiradio.com/post_how-does-superheterodyne-radio-work.html

'Introduction to the superheterodyne receiver' from Lloyd Butler skips over the history fast but gives a lot of more indepth information about superheterodyne receivers.

<https://www.scribd.com/document/62749354/Introduction-to-the-Superheterodyne-Receiver>

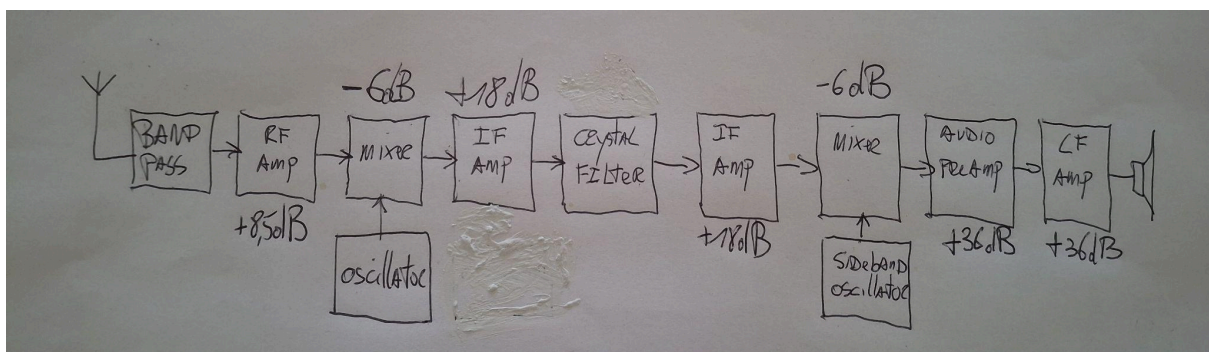
I have not checked but there must be countless YT clips explaining the superheterodyne radio circuit.

Gain distribution.

This is a bit where I struggled with when I started out. Connect the antenna directly to the mixer or via an RF amplifier? How many IF amplifiers do you need? Is a mixer with gain (like a dual gate mosfet) to be preferred over a passive mixer. If a passive mixer loses signal, does the loss have to be compensated with an extra IF amplifier?

These questions are the swamp every beginner walks into. For nearly a decade I followed the gain distribution scheme of the BITX20. It works. It's stable. It's predictable. And it avoids the two classic beginner mistakes.

- Too much gain in the wrong place, all sorts of weird glitches.
- Too little gain, that's an obvious one...



I took the dB's straight from the BITX20 schematic. Overall gain = 104dB which is spot on. More than enough but not too much either.

Presenting the compact general coverage receiver.

This radio is presented as 'The Holiday radio' on my QSL page. This unfortunately suggests it is a bit of a toy. However, it is absolutely not. If it were a toy, it wouldn't have 100 dB of gain and a crystal filter that can slice a CW signal out of the ether.

The name refers only to the size. It is compact in contrast to my general coverage receiver.

It tunes from 1,7 to 18MHz. AM, SSB and CW. Crystal filter bandwidths suitable for AM, SSB and even CW. And frequency stability. If you adjust the oscillator it can easily receive AM on what we in Europe call the MW band. From 500 to 1600KHz.

How does it compare to the many NE602/LM386 radios on the net? There is no comparison. Same with the 'Elektuur' radio from chapter 4... No comparison. This radio is superior in every meaningful respect. We are comparing mopeds to motorcycles.

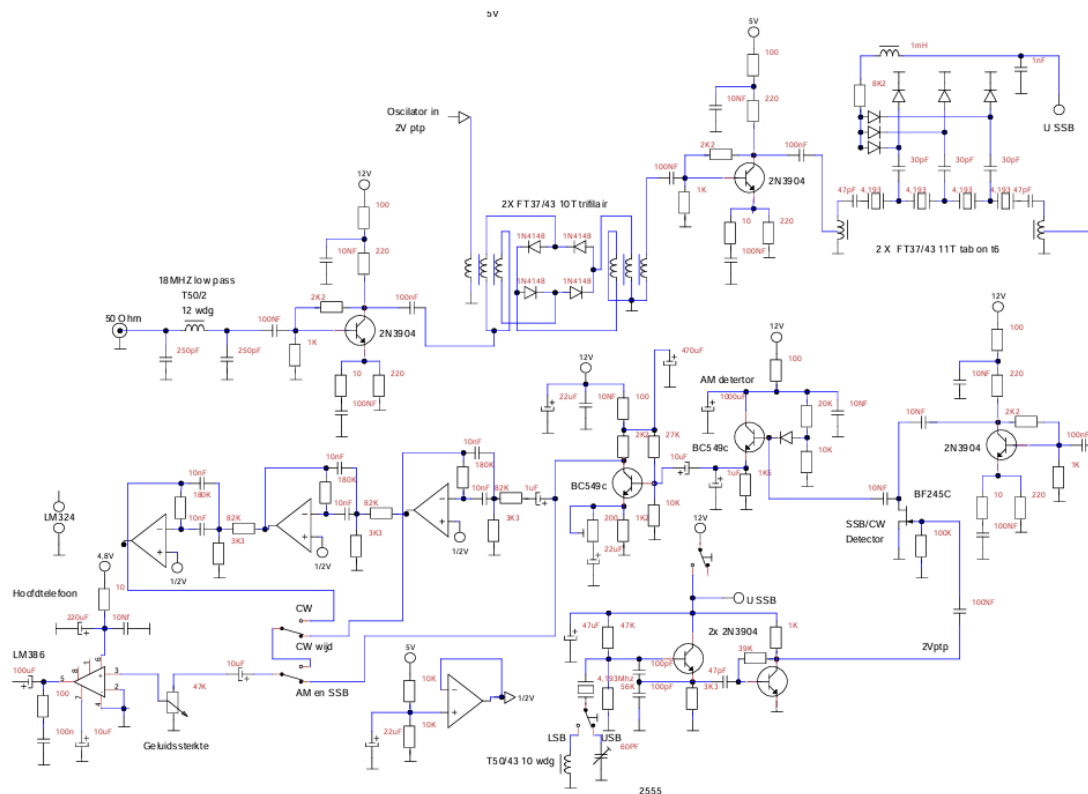
The NE602/LM386s are **great** beginners radios, I had one too. But you can do so much better and still keep the easy challenge.

My fancy general coverage receiver is surely superior to this radio? Version 5 from chapter 4. Well it has a HiFi tone control for music, a LF amplifier capable of powering a

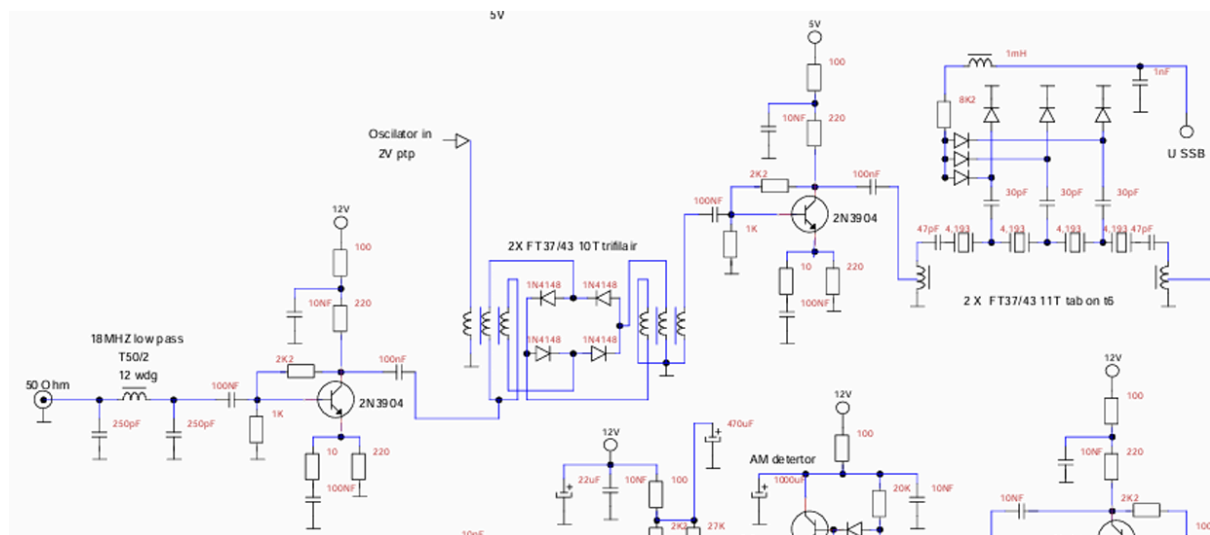
loudspeaker, an AM loop antenna, a wider tuning range, a real frequency counter, but superior overall? Yes, a bit, but at the cost of greatly increased complexity.

Could you use this receiver as your main receiver? Yes. I did even use it in some QSOs, that's how good it is. It has another thing going for it, simplicity. The amplifiers don't use fancy BF981s and tuned circuits. No, it uses dirt cheap 2N3904 broadband amplifiers, no coils, no alignment, no nonsense. This radio is superior in building friendliness.





The schematic nicely fits on a A4 page. The antenna signal first passes a 18MHz band pass filter. There was not much room on my chassis. This can be improved a lot and we will look into that later. Next comes the first amplifier. The original circuit from the BITX20.



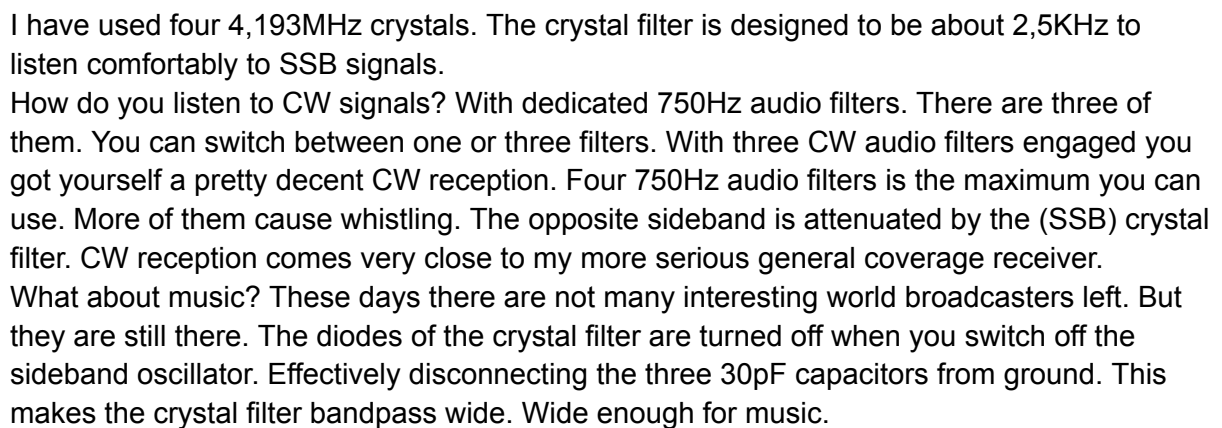
Next comes the double balanced mixer which is also an exact copy from the BITX20.

MONTV does a great job explaining how the mixer works and how to build it.

<https://youtu.be/m4rOJNQg2y4?list=PLIrK21HoQpvXradVQPtSlibSxGaH9ShOI>

Take great care in building the mixer and in winding the coils. They don't have to be beautiful but must be connected the right way.

The signal from the mixer goes through the first IF amplifier, which is identical to the RF amplifier on to the crystal filter.



My general coverage receiver uses a tunable crystal filter with AM varicaps and impedance switching to get to the same result. Better? Hardly and much more complicated to build.



Crystal filters.

My first encounter with homebrewing crystal filters was via 'Crystal set to sideband' Frank K0IYE builds his filter empiric and tunes them by ear. So yes, you can build them without theory or measurements. That was a surprise.

More capacitance on the nodes = narrower bandwidth.

Less capacitance on the nodes = wider bandwidth.

'Designing and building simple crystal filters' from W7ZOI (QST July 1987) gave a lot more theory. I can't seem to find the PDF 2026.

My takeaways were that the shape of your bandwidth is determined by the impedance matching on the in and output of the filter. Terminating too high results in increased bandwidth. Terminated to low, results in ripples in the bandwidth.

Luckily there are Crystal filter online calculators. The problem is that I don't know many of the parameters, so I've 'improvised somewhat'. It is useful as you can at least have a **ballpark** number for the capacitors you need and a rough idea of the impedance matching.

← <https://www.giangrandi.ch/electronics/xtalfilters/xtalfilters.shtml>

allowed the filter will be Chebytheff one with much stop-band and ultimate attenuation characteristics. The higher b
compromise.

Quartzes are used in their fundamental mode (even if they are overtone) and in their series resonance (even if they v
It's also important to select crystals with very similar characteristics; the resonance frequencies should be within a n
The target bandwidth is the bandwidth the filter should pass; the maximum possible bandwidth depends on all the d

Crystal series resonance frequency: f_{s3} = 4.193 MHz
 Crystal parallel resonance frequency: f_p = 4.205 MHz
 Crystal series capacitance: C_s = 20.1 fF
 Filter bandpass ripple: RP_{PB} = 0.5 dB (0..3dB)
 Number of poles: N = ☐ 2 ☐ 3 ☒ 4 ☐ 6 ☐ 8
 Target bandwidth: BW = 2.5 kHz @ -3 dB

Calculate

Calculation result:

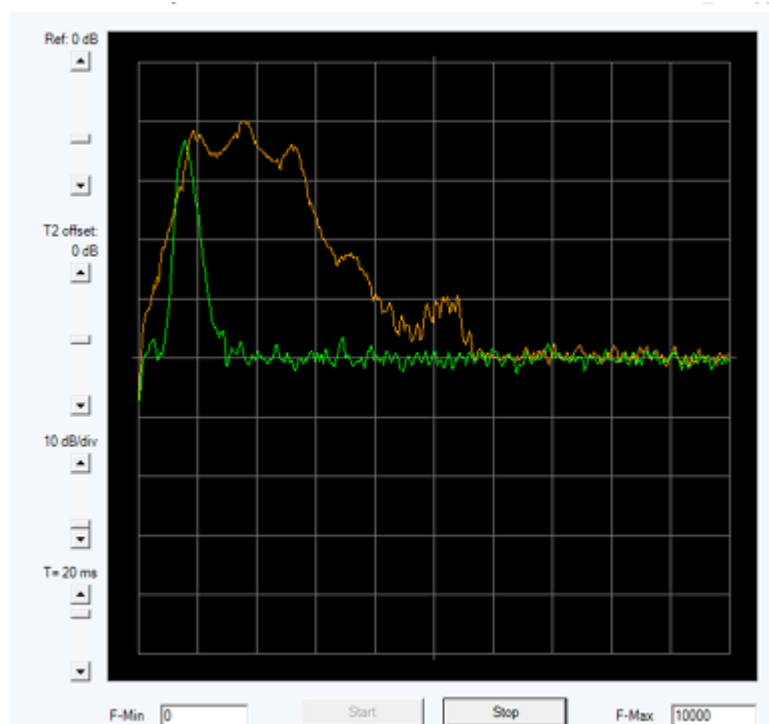
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fs = 4.193 MHz
fp = 4.205 Hz
Cs = 20.1 fF
BP ripple = 0.5 dB (Tchebycheff)
Poles = 4
Target bandwidth = 2.5 kHz

Maximum bandwidth: Bmax = 6.511 kHz

Center frequency: f0 = 4.194565 MHz
Ultimate attenuation: UAtt = 85.7 dB
Filter impedance: Z0 = 827.1 Ohm
CP1 = 38.8 pF
CP2 = 46.1 pF
CS1 = 46.1 pF
  
```

PA2OHHs site features free audio spectrum analyzer software. Getting your microphone level is a bit difficult. At least for me... The other thing you need is a signal generator. What you do is tune over your signal in SSB mode with the spectrum analyzer set on 'hold'. You will see a nice bandwidth appear. Pretty easy procedure.



Orange is SSB (Green is CW fine for comparison)

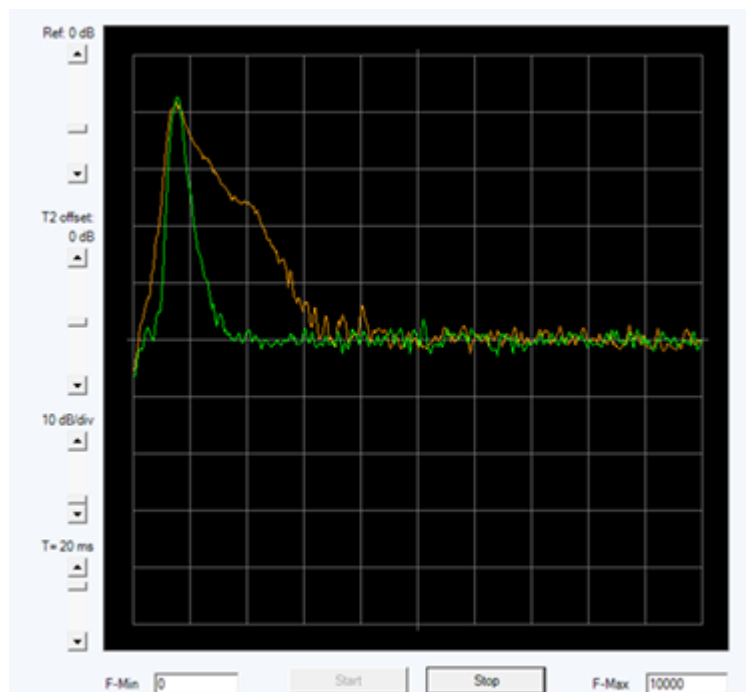
The Orange curve is my SSB bandwidth. It is slightly too narrow. And notice the two dips. The dips are about 5dB and that is unnoticeable. Seems like my impedance termination is too low.

What I **should** be doing is play around with the capacitors and especially the impedance transformer until I have a perfect result.

But SSB reception is fine and I have a YT clip to prove it.

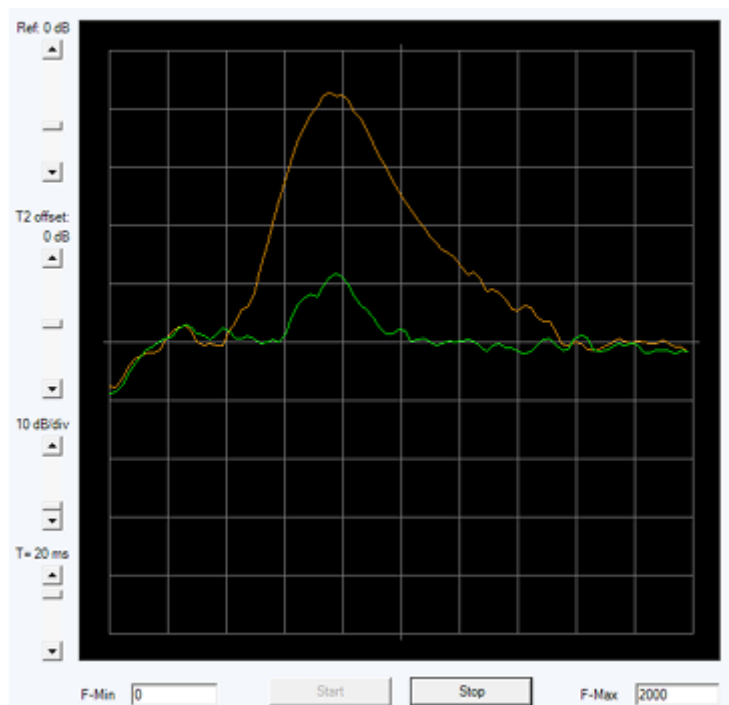
<https://www.youtube.com/shorts/kK5QVQdRVSQ?feature=share>

This is good enough for a radio that just receives. It would be different for a SSB transmitter. In the next chapter you will see that the bandwidth of my crystal filter is perfect in the SSB rig. I did some effort there...



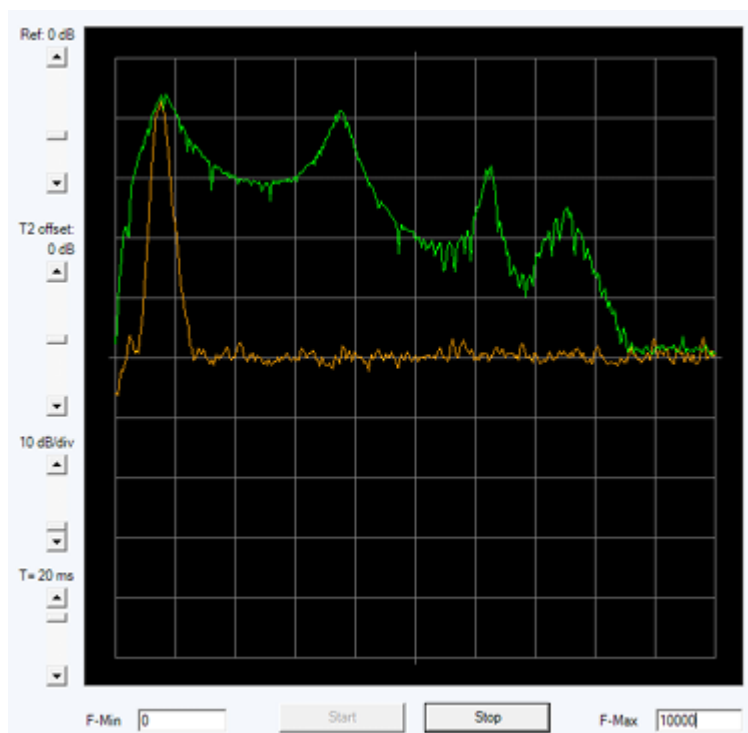
Here we see the bandwidths with one 750Hz audio filter engaged (orange) and three CW filters on (green) The radio is in action on the 40M band CW in the clip below.

<https://www.youtube.com/shorts/uv8lksM2U-c?feature=share>



Orange = CW fine, Green is sideband suppression +30dB.

This is the measurement of the sideband suppression. My general coverage receiver, CW and SSB, get nearly +40dB. But this isn't so bad.

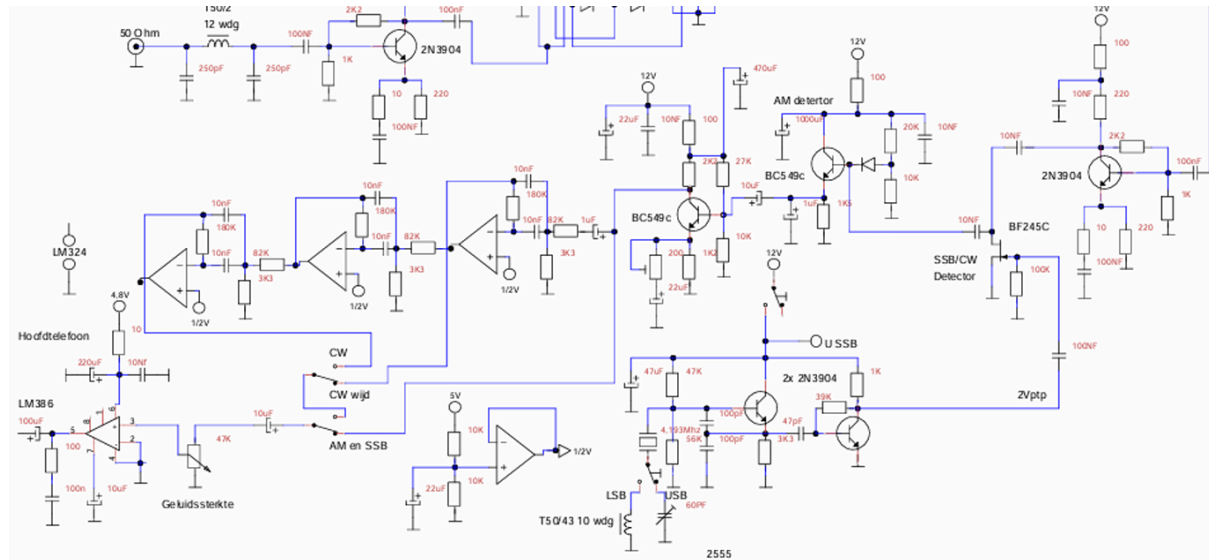


Green is AM (Orange is CW fine for comparison)

The AM bandwidth looks like a bridge on the verge of collapsing. Reality disagrees with me, the music sounds fine.

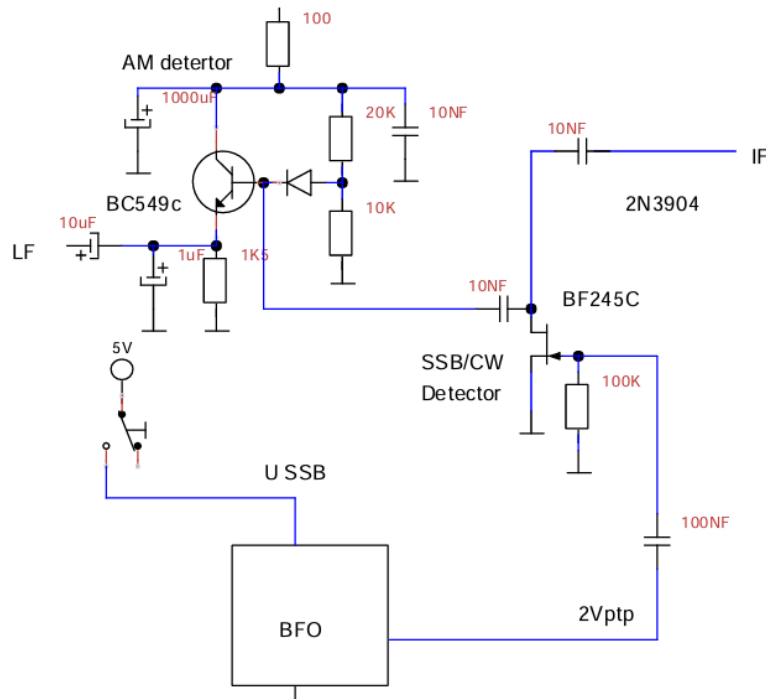
Moving on.

The IF signal leaves the crystal filter and gets amplified one last time by another identical BITX amplifier. We leave the BITX setup and now enter a new set of circuits as our set is AM capable.



The product detector is pretty unusual. When the BFO is off, the BF245c isn't conducting. So the IF signal goes straight into the AM detector and you find yourself listening to Am stations just above the 40M band.

When you turn on the BFO the gate of the BF245c receives the BFO frequency. This time the IF signal finds itself shorted by the BF245c, on and off, in the rhythm of the BFO frequency. This provides the demodulation of CW and SSB signals. The idea came from a book by Burkhard Kainka 'Radio bouwboek'. I am amazed how good this 'simple' detector works! It adds little to no noise to the signal and all signals 'decode' very well. It doesn't seem to matter how big or tiny the signal is.



The FET transistor must be a non-depletion type! At first, I used a J310. That didn't go entirely well. A J310 is a depletion type and is therefore also conducting a bit when there is no BFO signal on the gate. The result was lots of attenuation for AM, and the J310 detector couldn't handle large SSB signals. Luckily the BF245 was easy to buy and very cheap. When you look at a datasheet of a FET I find it hard to figure out if that particular FET is a depletion type or not.

Moving on.

The AM detector is one of my Lego bricks. I forgot where I found it. I seem to remember it was from a National Semiconductor application note.

The BC549 audio pre amplifier is not one of my Lego bricks but was used because of the small space.

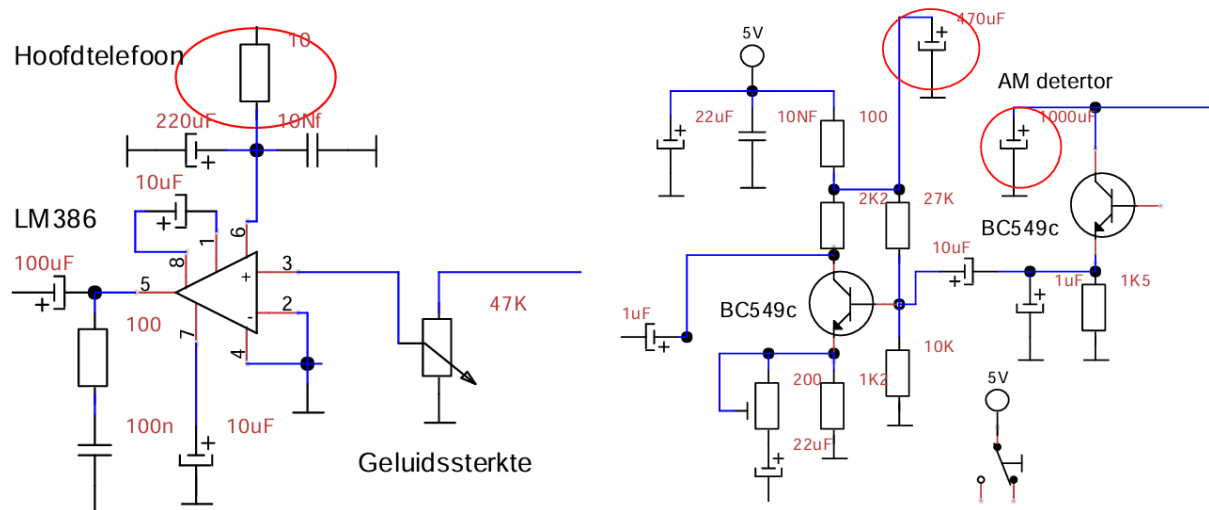
The CW audio filters are made with an online calculator and have been used for about 15 years in all my rigs. Success rate? 100%. The name and whereabouts of the online calculator have been lost in time...

And then finally a LM386 headphone amplifier.

Motorboating woes.

One pitfall I encountered is that the circuit was very susceptible to 'motor boating' When I turned up the volume the audio howled like a wolf in a tin shed. Three components fixed it. I wish all problems in life were that simple.

I soon figured out this unwelcome coupling went via the power supply. Three components were added and can not be omitted. One 10 Ohm resistor and two pretty massive elco's. Once installed the motorboating was completely gone.





The RF circuits.

Oscillator and stabilizer.

We can keep this section very short. The oscillator and stabilizer are the exact same one as the circuit presented in chapter 2 'The gateway challenge' A DDS module can obviously also be used.



These days the shortwave band becomes more and more silent. But the lower HAM bands are still active. This is the radio I should have had as a teen in the 1980s. What I love about this radio is its good performance compared to its simplicity.

The practical way to build.

A homebrew radio is built from back to front. Start with the LF amplifier. Touching the input pin should result in hum. If it doesn't hum, start worrying. Next build the audio preamplifier. Touching the input should result in more hum. Build the audio filters. All voltages should be 6V. Next in line are the sideband oscillators, the sinus should be about 2V_{ptp}. And so on... until you reach the antenna. The voltage readout on the 2N3904 amplifiers is about 7,2V on the collector. 2V on the base and 1,4 on the emitt. Connect 4,193Mhz on your antenna input. Some of the frequency will leak through and it should be deafening. Finally adjust the numbers of turns on the coil of the LSB sideband oscillator to cut out the opposite sideband. And adjust the capacitor trimmer of the USB sideband oscillator to cut off LSB.

Improvements are possible.

You could replace the RF and IF amplifier with the amplifiers we will encounter in the next project. W7ZOI's termination independent amplifiers. Always 50 OHm in and out. That way it is easier to build a perfect crystal filter.

A LF amplifier capable of driving a loudspeaker.

Replace the audio pre amplifier with the one featured in the next project. A double BC549 amplifier (36dB)

The radio can receive the AM band if the oscillator frequency makes it possible.

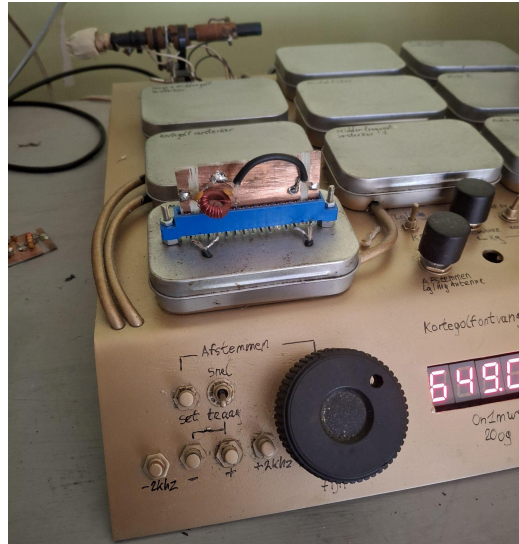
But the biggest improvement will be more adequate filtering of the antenna signal. My version just has a 18MHz low pass filter because my chassis is a little bit small.

You could construct a tuned circuit. Many can be found on the net. There is one problem.

This will mean that you will have to tune both your oscillator and tuned antenna on the same frequency. That's annoying and impractical, ask me how I know.

The best way is to follow the lead of my general coverage receiver. There is an edge card holder where I can plug in any band pass filter I want. They are interchangeable with the edge cards of my CW rig. That's handy.

The values for the band pass filters can be found in the CW rig section.



Before we move on, there's one more improvement that has nothing to do with circuits and everything to do with sanity.

Organization, the other secret of a good technician.

Remember the good technician rule from Chapter 2, **double check everything**. Build block by block, get your magnifying glass out, inspect every solder joint, and check every semiconductor pinout. Take even more care with opamps, the pinouts are easy to confuse and the pins love to short together.

In this chapter we look at another skill that saves you just as much trouble, **organization**.

Below is a picture of my parts closet. Every part I own can be found in under a minute. Relays, coils, switches, connectors, wires, coax, audio cable, copper clad PCB. It's all there.



All resistors, capacitors, diodes, transistors, logic ICs, even electrolytics, are organised in small plastic boxes sorted by value. They cost about 2 € each on AliExpress. My workshop has only been this organized for two years, and I could have saved hundreds of hours in the last decade by not hunting for parts.



Common parts like 2N3904s, op-amps, logic ICs, resistors, and capacitors are dirt cheap. I always buy them double.

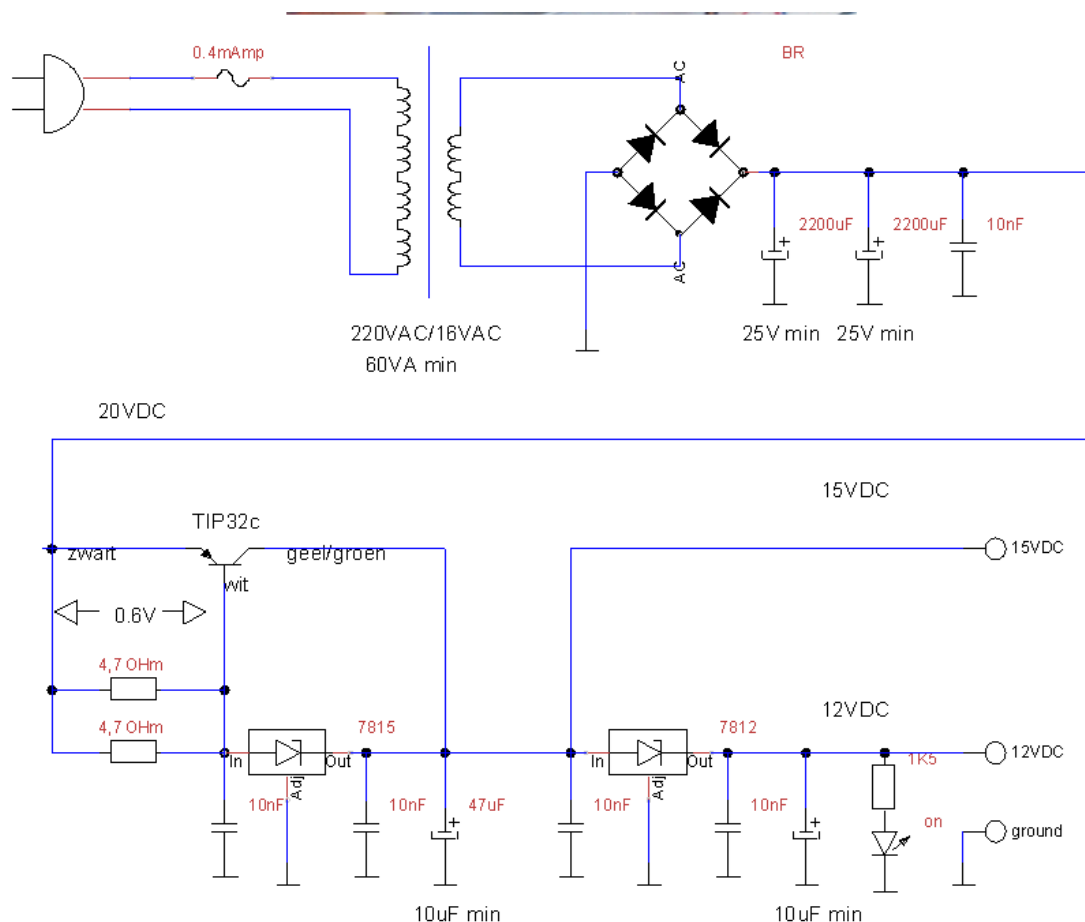
And then there's the junk pile. **Collect junk.** Scavenge every transformer you can find. Toroidal transformers are worth their weight in gold for a homebrewer, you'll see why when we build the power supply. Coils are also worth saving. Old PCBs can be stripped for electrolytics. They're cheap individually, but when you need a handful, the cost adds up fast.

Resistors and capacitors, on the other hand, are so cheap that salvaging them isn't worth the time. Just buy full sets and be done with it.

Paperwork is not to be underestimated. Make accurate notes of all your modifications. I also write down repairs on my schematics.

Powering up.

My station actually has no commercial gear whatsoever. That includes the power supply. I got myself a stand-alone power supply. It is used for everything. CW rig, SSB rig, solid state regen, loop antenna tuner, T/R relay, external receivers... everything. So you only need to build **one** if you make the 'stand alone' power supply.



The schematic above is very simple. the power from the net gets transformed to 16VAC and then rectified with diodes. My diodes were salvaged from an old PCB and the type number is unreadable. They are big. Don't use 1N4007s because their maximum current is 1A and you will need twice that if you ever want to power a QRP linear.

Next are the capacitors. I seem to have overreacted a bit and placed two 2200uF ones. One is probable enough. The rule is 1000uF/A.

Next follows a 7815V voltage regulator. The 15V is for the QRP linears of the CW and SSB rigs.

The 15V is fed to a 7812. The 12V is for everything else besides the linears. A 7812 can deliver 1 A when cooled with a heatsink so that is fine.

1A is on the low side for a QRP linear. So I had to have a way to increase the current of the 7815. The current flowing through the 7815 will cause a voltage over the paralleled 4,7 Ohm resistors (2,35 OHm) The TIP32c will start conducting when this voltage reaches about 0,6 - 0,7V.

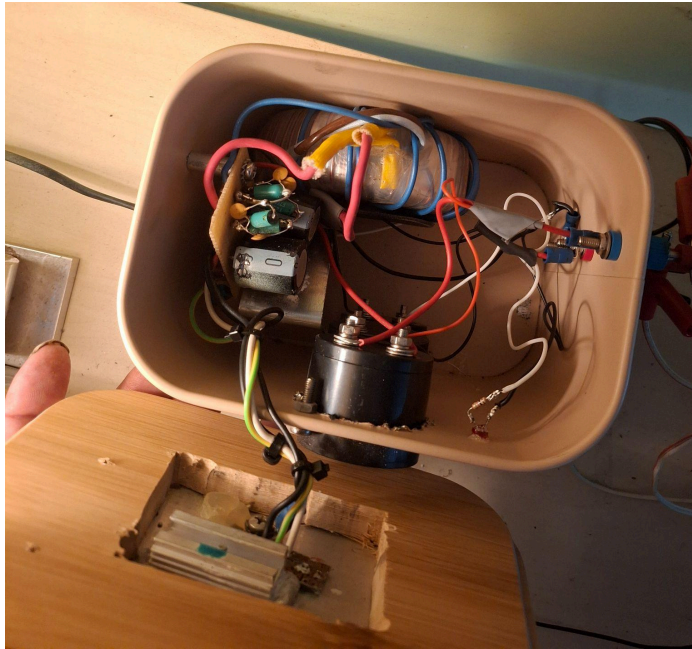
Law of OHm, $I=U/R$, $0,65/2,35 = 0,276A = 276mA$. So the TIP32c will take over as soon as the current reaches 276mA through the 7815. The TIP32C is rated at 3 A, but in this circuit you should think in terms of about 1.5–2 A continuous, limited by heatsinking and transformer size.

You can use any PNP power transistor with at least 3 A rating provided you bolt it to a proper heatsink.



This is how mine looks. Build in a kitchen utensil. The lower readout is 12V, the middle one is 15V and the upper readout is the current (2A) for the 15V output. A homebrew QRP needs a current readout for the operator. The 12 and 15V are just for show and tell. They were very cheap on Aliexpress and seem to be of good quality.

The innards are however a bit of controlled chaos. The box was a bit small. I violated my own mechanical rule 6. The power supply hasn't failed in over 13 years fortunately.



What kind of heat can you expect?

Over the 7812, maximum 1A (will never happen) Input voltage is 15V so the drop is 3V.

$P = U \times I = 3 \times 1 = 3 \text{ Watt}$. As said, this will never happen.

Over the 7815, maximum 0,4A. Input voltage is about 20V so the drop is 5V

$P = U \times I = 5 \times 0,4 = 2 \text{ Watt}$.

Over the TIP 32 C.

$P = U \times I = 5 \times 1 = 5 \text{ Watt}$.

These are all manageable. My 78XX's are bolted to a scrap piece of metal and my TIP to a salvaged heatsink.

The 5-second rule will tell you if you did a good job. If you can hold your finger on the heatsink without burning it for 5 seconds it's ok. If not, get a larger heatsink.

The heatsink of the TIP must be grounded (some weird stuff can happen if not) so you have to mount your transistor isolated! And use heat conducting paste.

The datasheet of 78XX will tell you that they switch off when they get too hot and that they can survive shorts but don't count on it.

Power transformer.

You will need a minimum 3V more on your capacitors then the voltage of your 78XX. So for a 7812, 15V for a 7815, 18V. My supply has 20V. I haven't noted the voltage of the power transformer but it must be about 14 a 15 VAC.

The power requirement will have to be 40 to 60VA.

Mini hack: free extra volts from a salvaged toroid.

Try to find a salvaged toroid power transformer like I have. They are commonly found in light fixtures. They are great! you can wind your own windings on it.



See the blue wire? It is an extra winding I did myself. The transformer will be 12VAC and the blue winding will be about 2 a 3VAC. This winding is connected in series with the original 12VAC winding, et voila. A 15VAC transformer which costs exactly 0 Euro.



Above, one of the transformers of the tube regen. It is also a salvaged light fixture transformer. The black wire that I wound myself, is the 6,3VAC winding for the filaments. All for free!

You can actually also lower the output voltage of a toroid transformer if necessary. I did this in my RF power linear to limit heat in the semiconductors. You connect your homebrew winding in series, but **counter phase**, the overall output voltage is lowered.

The message is, keep your eyes out for free toroid transformers and save a lot of money.

Living with the machine.

You don't just build a station. You live with it. Over time, the same five maintenance problems keep coming back to my station. They're predictable, annoying, and absolutely part of the hobby.

- 1) **Faulty switches.** Good quality switches are probably non-existing. So I always have some in reserve. They will have to be replaced from time to time. Be sure that they are easily reachable.
- 2) **Intermittent potentiometers.** Same problem, you can clean them with contact spray but some will have to be replaced. So, always mount potentiometers at easily reachable places. Some potentiometers live for a decade, some die young. But they all die.
- 3) **Pilot error.** Yes when you park a rig for a couple months you will actually forget what every switch does. That's why every single switch and potentiometer function is labeled on my rigs. I am actually capable of forgetting what a switch is doing on the front panel of a rig I build myself. You might be too.
- 4) **Intermittent solderjoints.** I used to get this a lot. It stopped completely after I acknowledged the fact that my eyes are no longer that of a young man and bought myself a magnifying glass. If you double check your work (and take your time for it) you can never have bad solderjoints.
- 5) **BNC misery.** Many of the connections made in the station are done with **small coax cables**. From SWR meter to linear, from linear to T/R relay, from T/R to transceiver and sometimes a receiver. You are not going to believe this, I don't know how to solder a BNC connection to a coax cable. Yes, the man who homebrewed a SSB rig can't do that. I tried many times and always failed. So I buy ready made ones from my supplier. The quality of these BNC cables is unfortunately poor. This is the **main maintenance problem of my station**. Most faults can be solved by fiddling with some of the BNC connections. I really need to learn to solder a BNC to a coax. It is pretty embarrassing.

Trouble shooting is unfortunately a skill that is hard to explain. And as your station expands it gets more complex. Try to localise where the problem is by eliminating. You hear a weird popping sound? Turn the volume down. If the sound disappears, the problem is before the final LF amplifier. If not, the problem is with your LM386 circuit. You can localise a lot of problems by operating the rig as a start.

Suppose the problem is not your LM386. Disconnect the detector from the last IF amplifier. Does the fault disappear or not? Disconnect the first IF amplifier from the 1st mixer, does the fault disappear or not. And so on. First you need to isolate your problem.

But you won't be doing a lot of deep troubleshooting. All of your problems will be switches, potentiometers, pilot error and in my case, mostly BNC woes once your rig is working.

Most of the troubleshooting will occur **long after** the rig is working. Little glitches that escaped your attention before. Both my general coverage receiver and SSb rig had a similar small glitch. A weird sound when the volume was turned to 0. Turned out that it was interference from my local nemesis, the FM tower in Egem. 10nF capacitors directly

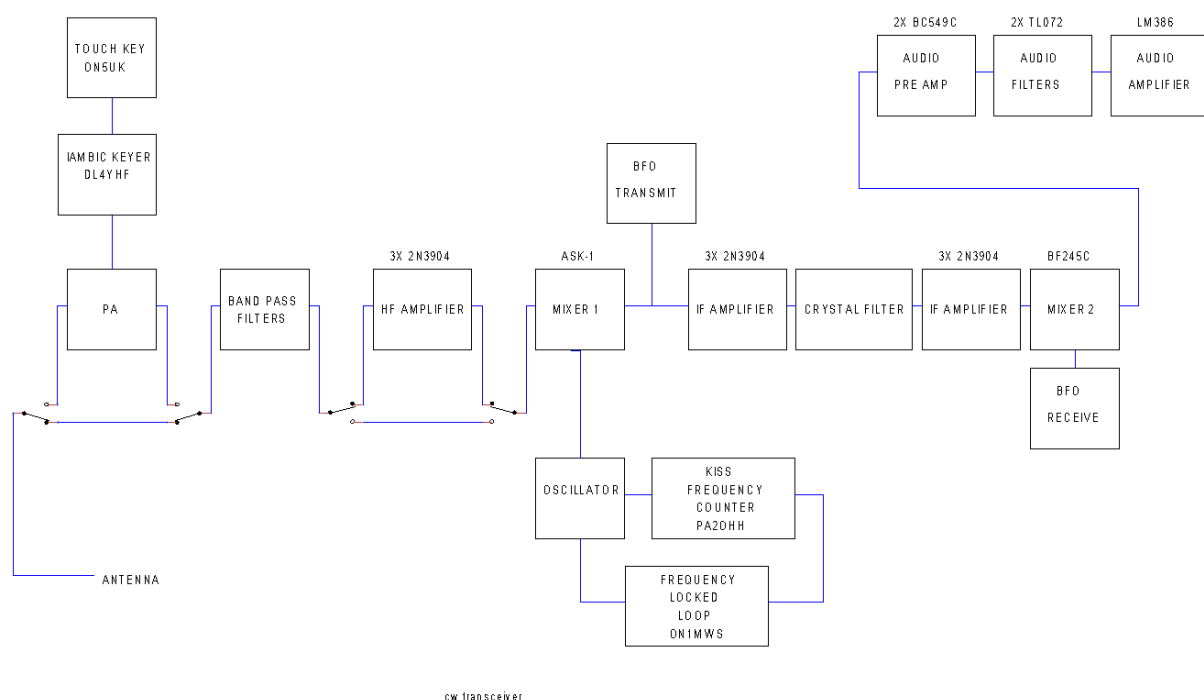
soldered over the input pins of the LF IC's cured that. Shorting the RF interference to ground.

Believe you will find the problem.

This sounds silly, but it's true. Confidence is half the job. If you believe that you will find the fault, you will actually find it. Stay calm, systematic, and patient. Doing a household chore also helps. Your mind will find a way to think of a test to localise your problem while you are away off the work bench.

The configurable CW transceiver.

Now we move on to our next project. The CW transceiver is just like the compact general coverage receiver, basically RF Lego. Below is the block diagram. You immediately recognise the superheterodyne circuit and an identical gain distribution like our previous project.



Let's start with reception.

The antenna signal goes straight to the band pass filters. After filtering the signal goes to the first RF amplifier. Next it gets mixed with the oscillator and the IF goes to the first IF amplifier. Then follows the crystal filter. This transceiver is dedicated to CW reception, so the crystal filter is limited to 600 HZ. 600 HZ is ideal to get rid of a lot of unwanted noise and stations but still wide enough for easy tuning. The crystal filter also gets rid of the unwanted sideband.

Mixer 2 combined with the receive sideband oscillator demodulate the audio. It is configured as a LSB setup. That way the tone goes down if you tune down and up if you tune up. Very natural.

Keep in mind that what you hear is **the difference between your oscillator and the oscillator of the station you listen to**. My preference is about 750 HZ. That is a nice tone to listen to. A higher or lower tone feels wrong, even uncomfortable.

The audio now goes to a 36 dB audio amplifier. So now we got ourselves a 600 HZ wide window to listen to. 600 HZ can be too wide to really separate CW signals. So I got myself four 750HZ audio band pass filters. With 2 switches the bandwidth becomes 400 HZ and with all four 200 HZ. Which is really decent.

Transmitting code.

A lot of circuits lose their power when the rig is switched to transmit. The RF amplifier, the two IF amplifiers, the receiver sideband oscillator and audio pre-amplifier are switched off.

Now the transmit sideband oscillator is powered up. The signal from this sideband oscillator is fed straight into the mixer. The signal gets mixed to the right band and goes through the band pass filter.

The signal is just a sinus wave. That's what CW is, a keyed sinus wave. Our sinus wave arrives at the QRP linear. The keying is just turning the linear on and off.

This is done with a touch key and an iambic keyer. I never use them but use software as we see later on.

A complication but the rig has a clever trick.

Remember that when you listen you actually listen to the difference between your oscillator and the oscillator of the other station? Let's assume the station sends at 7030 KHz. My oscillator will be tuned at 7030,75 KHz. So I am hearing a pleasant 750 HZ tone.

But if I want to answer I have to transmit on 7030 KHz (not 7030,75 KHz) My oscillator frequency is wrong! Earlier solutions tried to shift the main oscillator, which was inefficient and messy.

The rig has **two sideband oscillators**. One for reception and one for transmitting. The transmit sideband oscillator is just tuned 750 HZ higher than the receive sideband oscillator. This way you can choose the actual frequency you send on without changing the main oscillator frequency. The alignment for both sideband oscillators just has to be done once.

By using two sideband oscillators spaced 750 Hz apart, the rig listens at one frequency and transmits at the correct one without any operator gymnastics. No RIT, no re-tuning, no drama, just a clean analog solution that works.

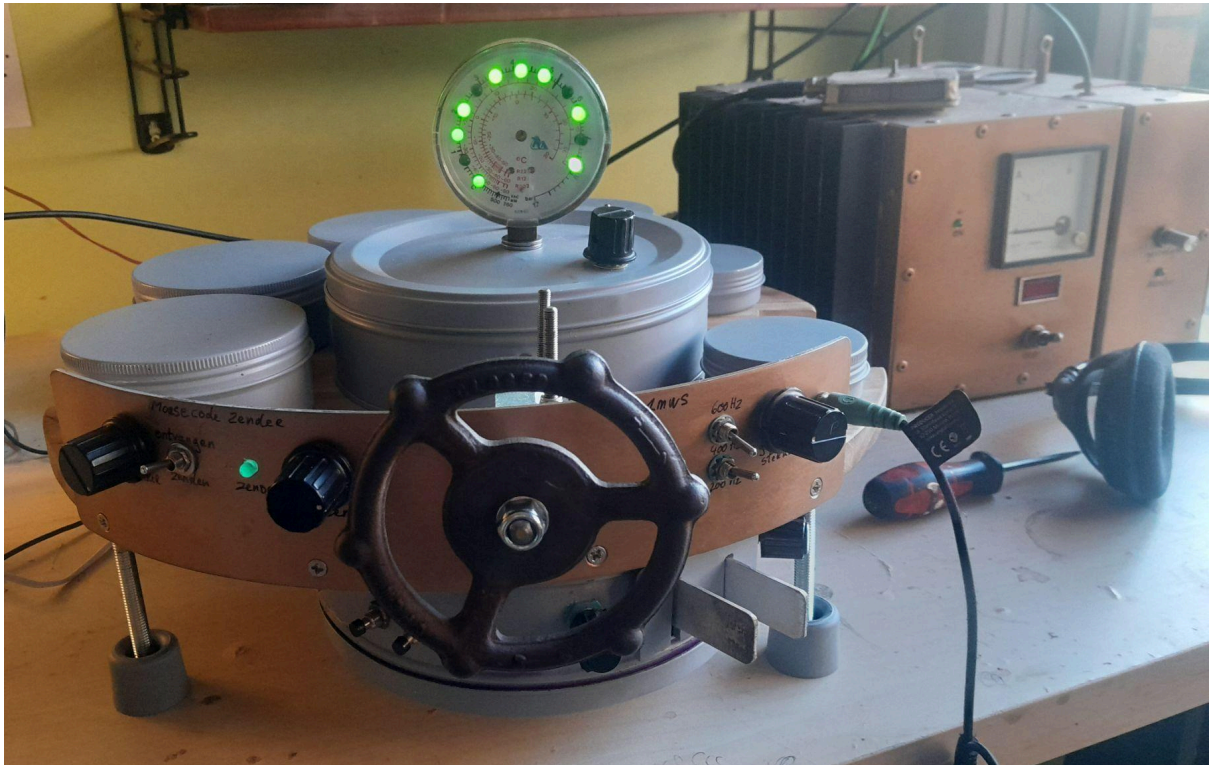
The configurable setup.

What I especially appreciate about this rig is that it is configurable. The band pass filters, diplexer, crystal filter, sideband crystals, oscillator capacitors and linear low pass filters are plug-in PCBs. Edge card connectors are supercheap on Aliexpress. The frequency

determining circuits are just plug-ins. So for I only have prints for three bands 40,30 and 20M but I could in theory reach any HF band.

What is so great about this system? You avoid lots of unnecessary work. You are not building filters for bands you will never use or are dead most of the time and you will not lose hours of annoying wiring.

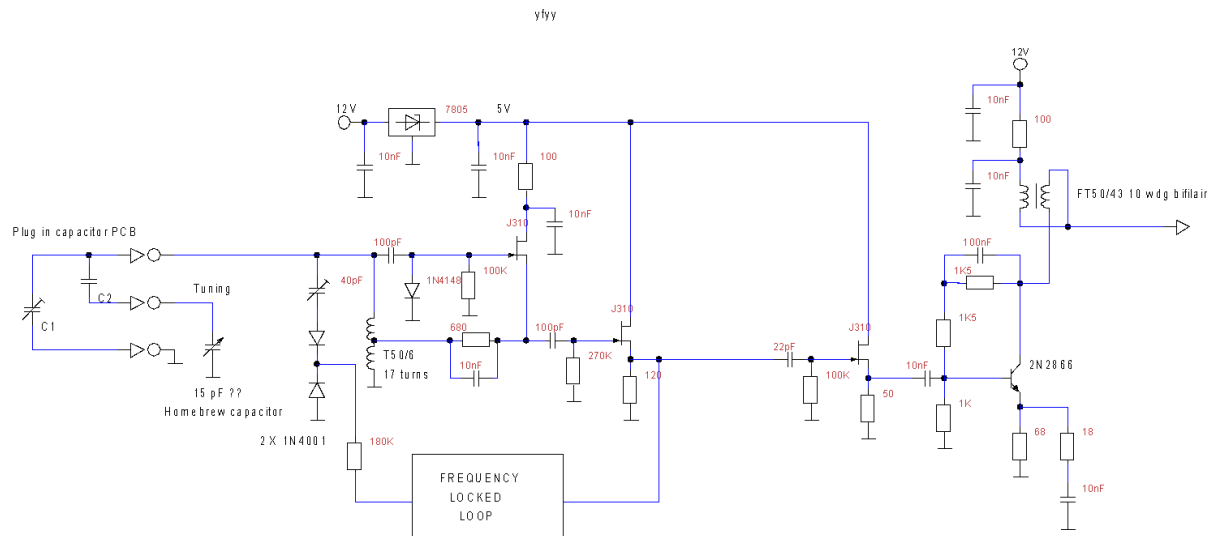
Some of the PCBs are used in other rigs. The linear low pass filter in the SSB rig and the band pass filters in my general coverage receiver, compact receiver s and my regens.



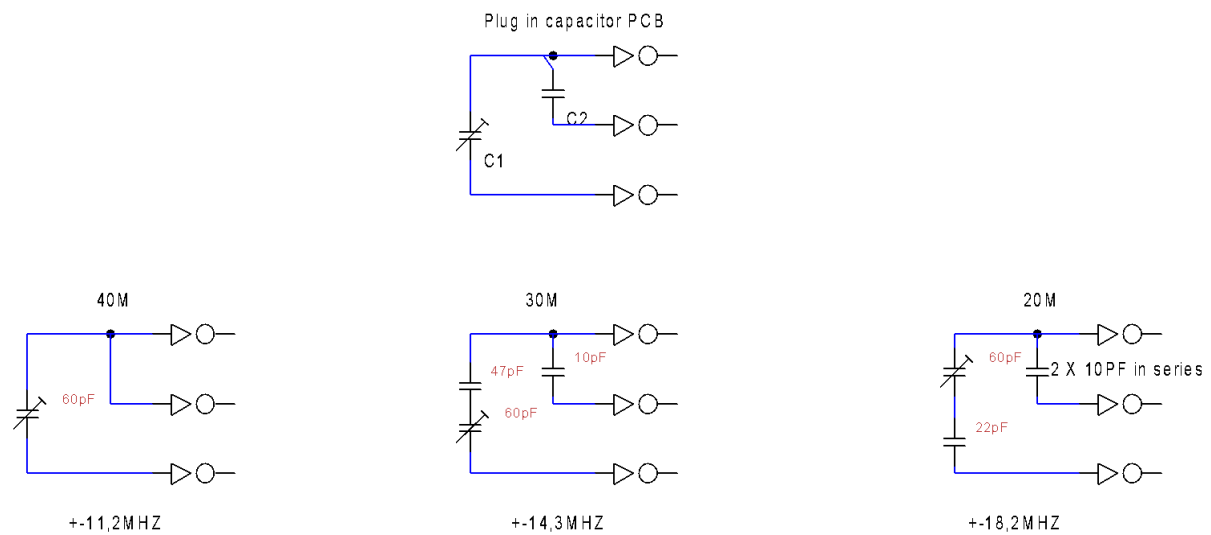
My CW rig is mechanically the most oddball in the whole station. I believe it is fine because it is CW. The completely unusual appearance of the rig makes sense while listening to the 'ancient' dit's and dah's. I do apologise to the future archaeologist who has to try to classify this.

Oscillator.

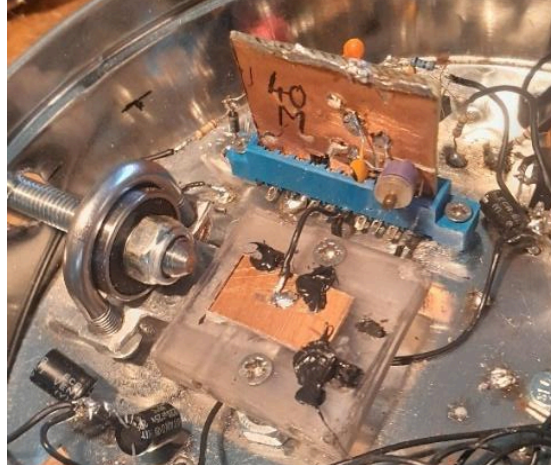
You can definitely use a DDS kit but I obviously used the oscillator from chapter 2. This version uses plug-in capacitor PCB's for every band.



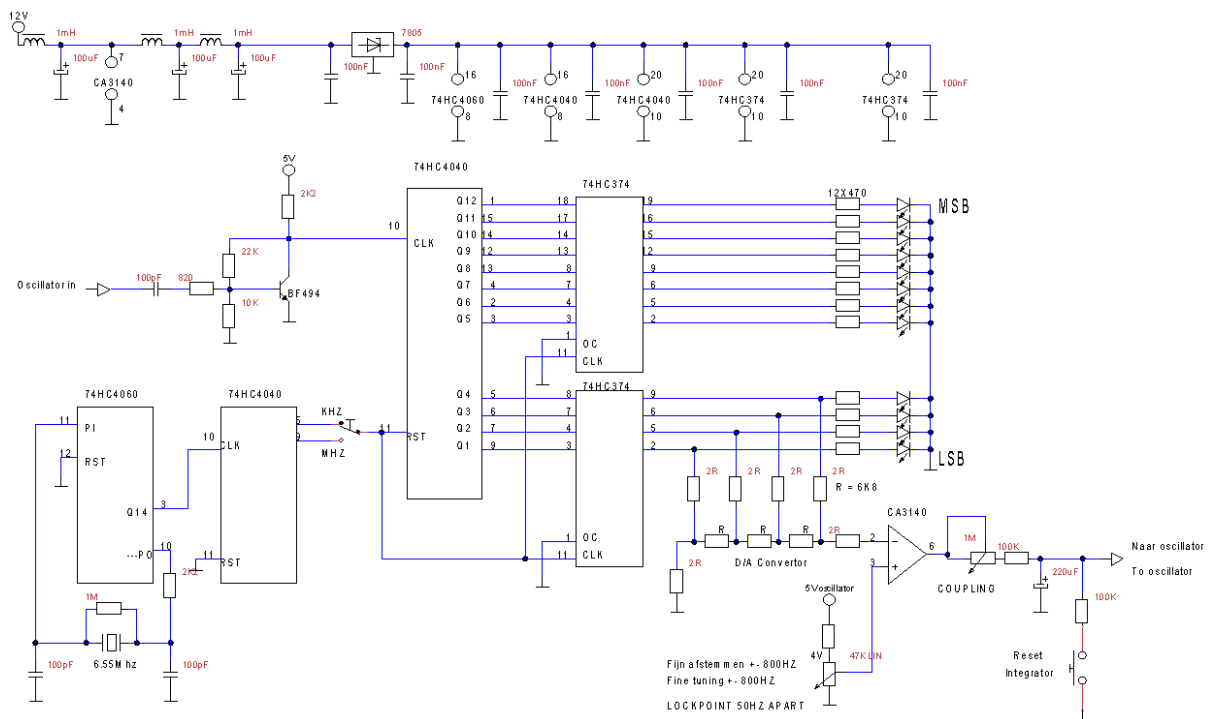
There are **two** J310 buffer amplifiers. The oscillator isn't shielded enough from the mixer with only one J310. The consequence is that it would jump like a nervous grasshopper after a T/R switch with just one J310 buffer.



The capacitor PCBs above. I only made them for 40,30 and 20M.



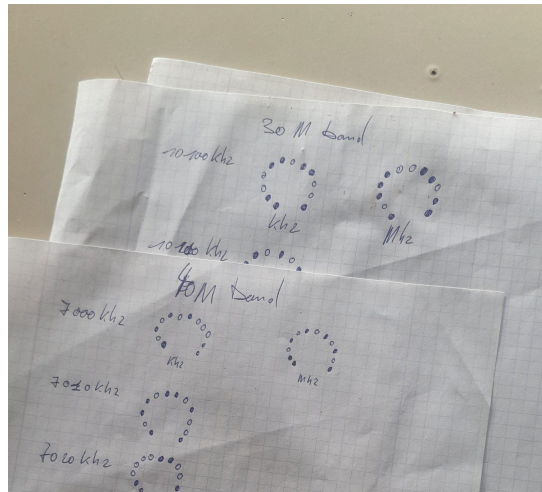
The rig features a homebrew tuning capacitor. It is probably 30pF maximum. This version isn't a really good one. In chapter 3 there is a description to make homebrew tuning capacitors that are just as good as commercial ones. But just a lot cooler.



Frequentiemeter/stabilisator on 1mws

The schematic of the SuSI stabilizer in this rig. The stabilizer is described in detail in chapter 2. For this rig I wanted to avoid a real frequency meter so I made a 12 LED frequency counter. 4 bits are used for the stabilizer.

The full LED frequency experience wouldn't be very practical in a general coverage receiver but this is a rig with plug-in PCB's and every tuning range is limited to 100 KHz.



I got myself notes of which LEDs have to be lidded for certain frequencies. The MHz/KHz switch has to be put on KHz for the actual stabilization.

I got what I wanted, no frequency meter. In return I got myself a lot of 1970s logic ICs to wire.



Okay, I made a mess of it.

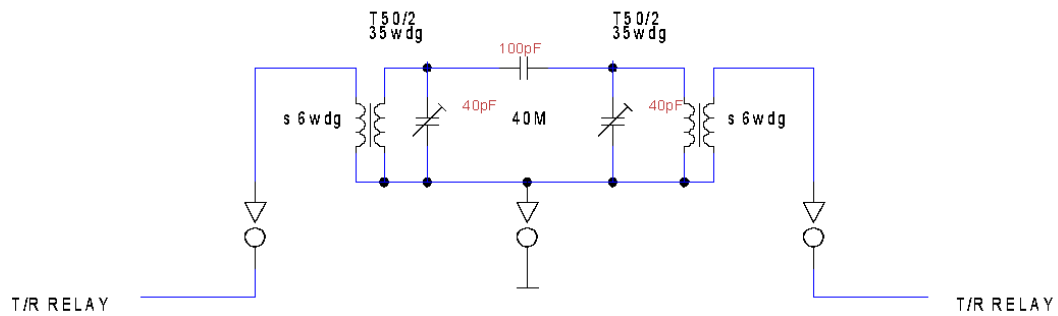
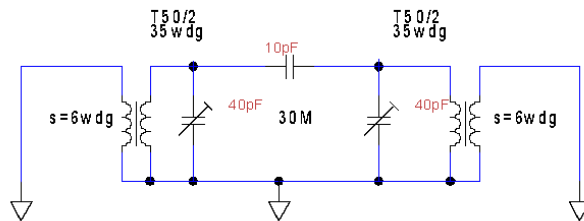
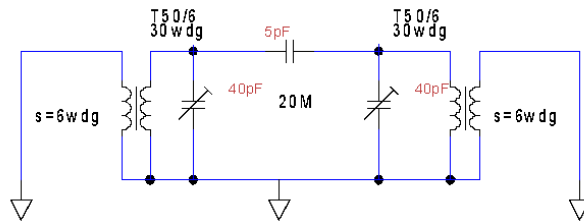
What I **should** have done is use a perfboard with IC sockets and wire everything neatly with the smallest wires possible. Maybe even thin enamelled bell wire.

Instead, the inside of the rig now looks like a 1970s datacenter built by someone who had no perfboard, too much coffee, and an unhealthy amount of stubbornness.

Faults are unlikely, mostly because the electrons are too confused to misbehave, but if this thing ever does develop a fault, it instantly turns into a logic-function-themed escape room.

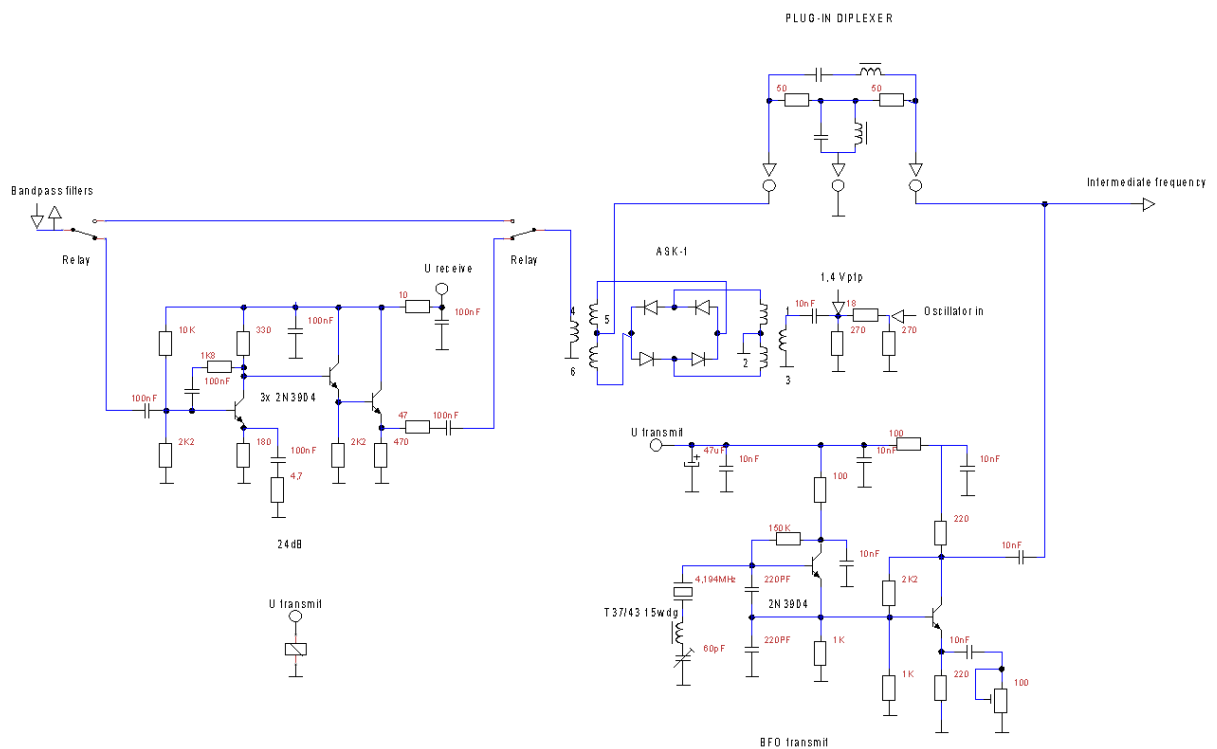
Moving on to the schematic.

Below are the three band pass filters I made so far. They are 50 OHm in and out. The most important component is the couple capacitor between the two tank circuits. It must be as small as possible. Large values ruin the band pass. The capacitor on the 40 M filter is high. It works but take much less. 47 or 33 pF instead of 100 pF.





The plug-in band pass, T/R relay and RF amplifier.



Above the RF amplifier, mixer and transmit sideband oscillator.

The mixer is also a double balanced mixer. Watch M0NTV's YT clip for more info. The double balanced mixer attenuates the oscillator and also the RF and IF ports.

In this rig I did not homebrew the mixer but used a commercial one. A, ASK-1. I had in my part boxes and figured I had the right to use it as I had already homebrewed a lot of mixers.

All amplifiers are W7ZOI's 'termination independent amplifiers' 50 Ohm in and 50 Ohm out. They are set on the **highest amplification which is 24dB**.

Up to 2023 I always used the BITX amplifiers as my standard Lego brick. They are still in use in my Holiday radio and SSB rig.

Up to 2023 I assumed that these amplifiers were either 50 OHm in/ 200 OHm out or vice versa. How a transistor amplifier can have a circumstantial impedance is way beyond my comprehension. It is just one of those things in my axiom box.

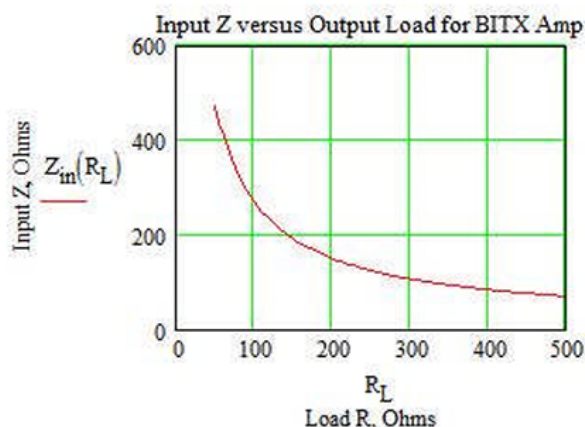
Then I ran into Wes Haywards, W7ZOI, 'termination insensitive amplifiers'

 w7zoi.net
<http://w7zoi.net> > bidirectional_matched_amplifie... · PDF bestand [Dit resultaat vertalen](#)

A Termination Insensitive Amplifier for Bidirectional Transceivers

A bidirectional 50 Ohm amplifier with a gain of 15 dB in either direction. The amplifier is well matched at both ports, independent of the termination at the other port.

Wes specifically examines the BITX amplifiers and purposes to replace them with 50 OHm in and out amplifiers.



My idea of the impedance was wrong. Turns out that if the input impedance is 170 OHM the output is also 170 OHM. The curve clearly shows that my 50/200 idea was wrong.

Wes proposes other amplifiers for the BITX.

Our design for this application is shown in Fig 3.

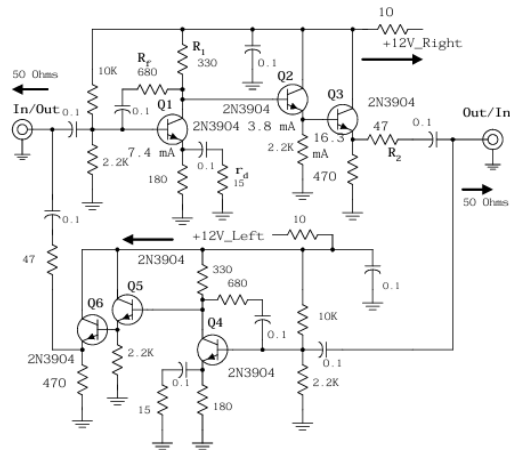


Fig 3. A bidirectional 50 Ohm amplifier with a gain of 15 dB in either direction. The amplifier is well matched at both ports, independent of the termination at the other port.

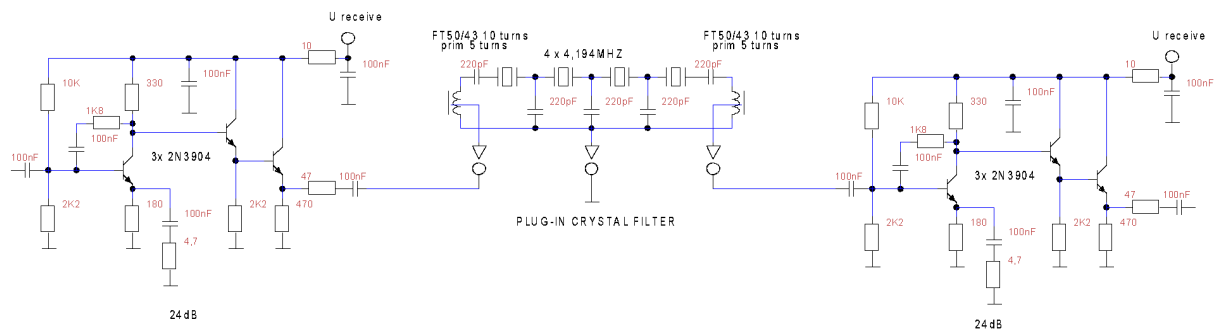
I decided to try them out in the 2023 rebuild of the CW rig. The impedance of these amplifiers **is always 50 OHM**. Which has advantages. Layout becomes less critical because everything can be connected with coax if necessary. The crystal filter becomes easier to design as the impedance is known. and your double balanced mixer is a lot more happy with 50 OHMs on all ports.

Wes does not claim that his amplifiers are superior to the original BITX amplifiers but just easier to use. Easier to use means also more chance of success.

My SSB rig uses the old amplifiers and is just as good as the CW rig. But if I had to start from scratch I would take the W7ZOI amplifiers.

The transmit BFO, Is my usual Lego brick. We look later on how to align it.

The Diplexer is actually never made. It is simply a PCB with a coax for now.



Moving on further.

Above the two IF amplifiers and crystal filter.



Plug-in crystal filter. For the 40, 30 and 20M band it is 4,193Khz. Bandwidth of the filter is about 600Hz

← ↻ <https://www.giangrandi.ch/electronics/xtalfilters/xtalfilters.shtml>

allowed the filter will be Chebytheff one with much stop-band and ultimate attenuation characteristics. The higher the ripple, the better the filter will be. But, of course, the compromise between pass-band and stop-band characteristics is always a compromise.

Quartzes are used in their fundamental mode (even if they are overtone) and in their series resonance (even if they are overtone).

It's also important to select crystals with very similar characteristics; the resonance frequencies should be within a few Hz.

The target bandwidth is the bandwidth the filter should pass: the maximum possible bandwidth depends on all the parameters.

Crystal series resonance frequency:	$f_{s3} =$	4.193	MHz
Crystal parallel resonance frequency:	$f_p =$	4.205	MHz
Crystal series capacitance:	$C_s =$	20.1	fF
Filter bandpass ripple: $RP_{PB} =$		0.5	dB (0..3dB)
Number of poles:	$N =$	☐ 2 ☐ 3 ☒ 4 ☐ 6 ☐ 8	
Target bandwidth:	$BW =$	0.6	kHz @ -3 dB
Calculate			

Calculation result:

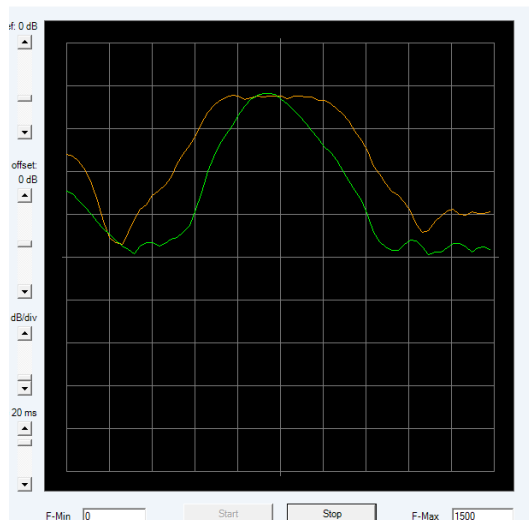
```

fs = 4.193 MHz
fp = 4.205 Hz
Cs = 20.1 fF
BP ripple = 0.5 dB (Tchebycheff)
Poles = 4
Target bandwidth = 0.6 kHz

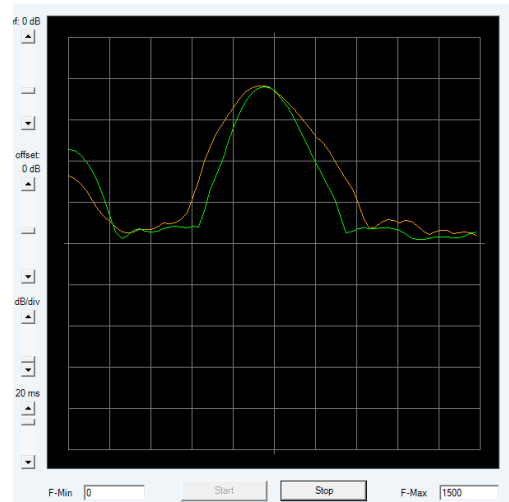
Maximum bandwidth: Bmax = 6.511 kHz

Center frequency: f0 = 4.193361 MHz
Ultimate attenuation: UAtt = 139.1 dB
Filter impedance: Z0 = 157.4 Ohm
CP1 = 203.7 pF
CP2 = 242.5 pF
CS1 = 242.5 pF
  
```

The design of the crystal filters was easier this time as I knew that the input and output impedance is 50 OHM.

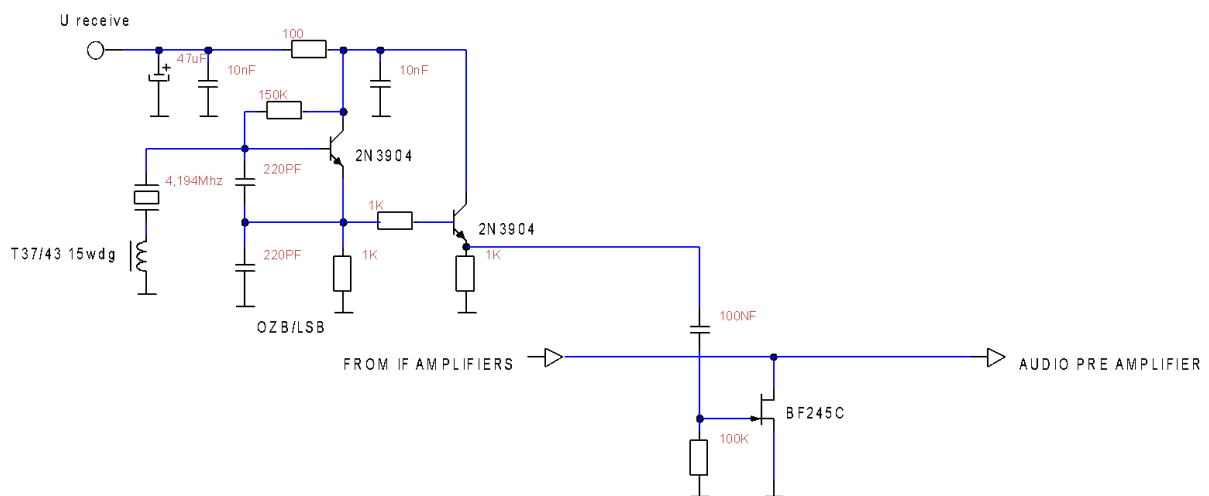


Orange=crystal filter, green=2 audio filters.
audio filters.

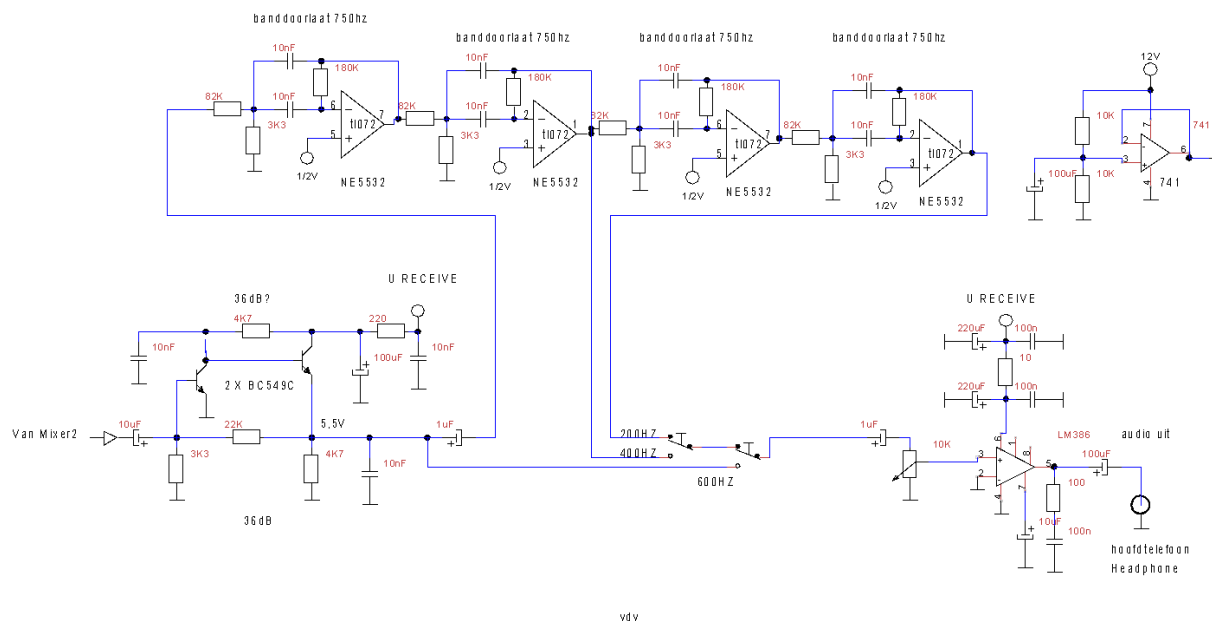


Orange= 2 audio filters, green= 4

Above are the results measured with PA2OHHs spectrum analyzer.



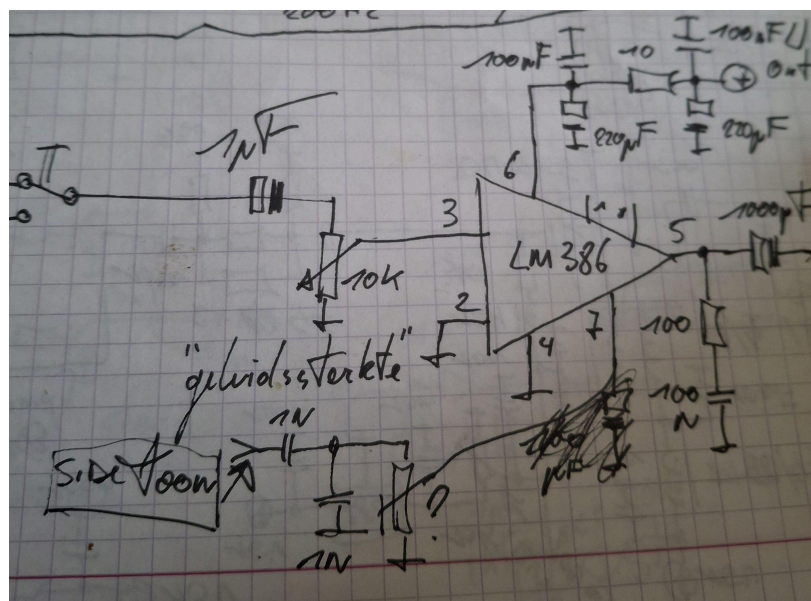
The receive sideband oscillator and product mixer are the same as in the compact general coverage receiver. Lego bricks! Standardization is the quiet super power of the homebrewer. This time there is no AM detector. CW does not need that.



The audio preamplifier is the excellent amplifier from the BITX20 design. I used BC549s because they should be lower noise than 2N3904s. I would recommend this amplifier in the compact receiver if you have space.

Audio filters are my standard circuit for 750 HZ band pass filters. I used an online calculator. The name of the calculator is lost in time. I have used this circuit for over 15 years. Do not use 741s or LM324s. Way too noisy!

And a standard LM386 headphone amplifier. There is one error in the schematic. The side tone signal enters via pin 7 on the LM386. The LM386 keeps working on transmitting and beeps in your ear while sending code.



Reception is done. Now we flip the whole thing upside-down and start transmitting.

Transmitting.

On transmit a lot of stuff gets turned off and our transmit sideband oscillator will be activated. It goes into the mixer. Four products will emerge from the mixer.

- Oscillator
- IF.
- Oscillator + IF.
- Oscillator - IF.

IF and oscillator should be attenuated because the mixer is double balanced. It's an advantage. The band pass filter must only let Oscillator - IF through.

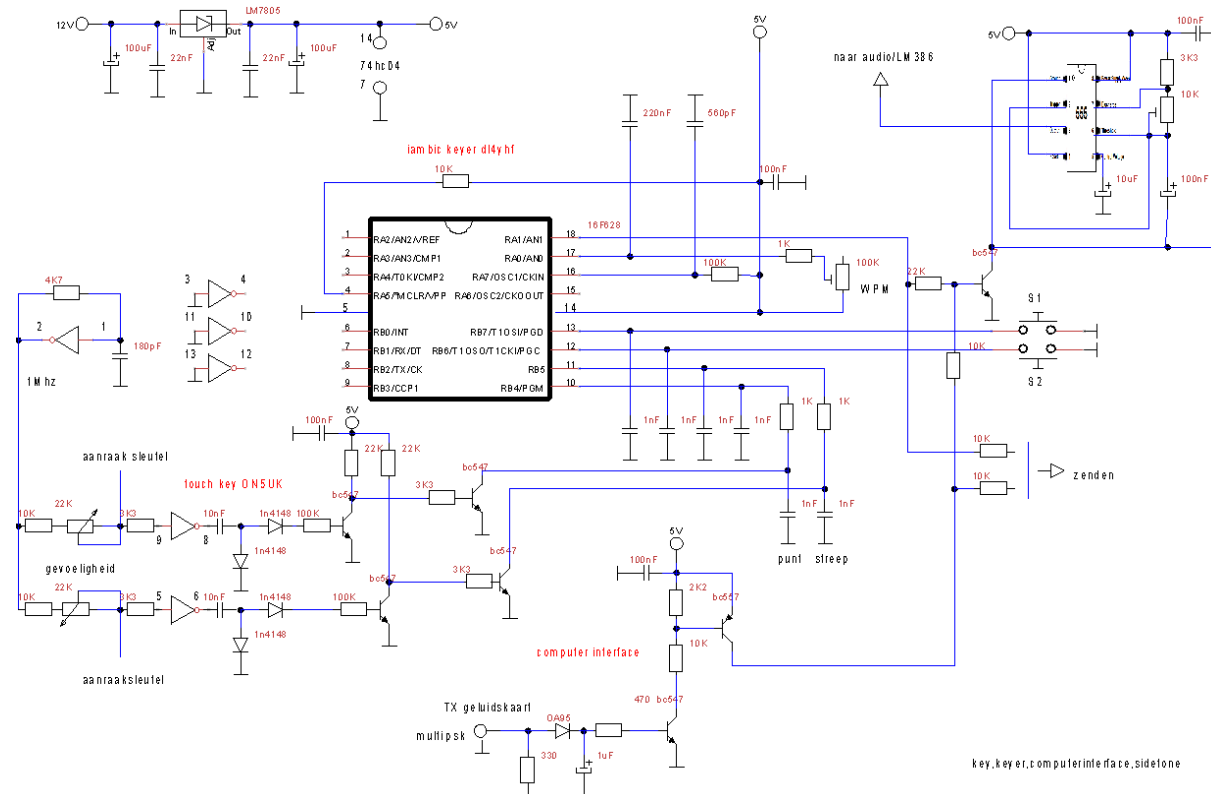
Getting rid of two components makes the choice of the IF frequency easier.

Oscillator + IF is 2 X IF away from IF - IF.

So with an IF frequency of 4,193 MHz the band pass filter has no problem separating IF + IF from IF - IF on the 40, 30 and 20M band.

If you want to transmit on bands higher than 20 M you will have to use a higher IF. 8 or 11 MHz like my SSB rig. Hence the plug-in crystal filter setup.

Out of the band pass comes oscillator - IF and is connected to the linear. It isn't always on but keyed with Morse code.



Have a 1/4 or 1/3 transformer on the drain and provide a voltage to the gate to set the idle current and you're ready to go. Idle current is set at 100mA. More Idle current means a quick end to the FET.

How do you set the idle current?

- Put a resistor in series with the power supply. I use 10 OHM/10 W. Turn on the linear with NO Rf and the trimmer to ground.
- Slowly increase the voltage on the gate.
- At a certain point you will see the voltage over the resistor rise. It will be abrupt!
- Set the trimmer so that the voltage over the 10 Ohm trimmer is 1V. $I = U/R = 1/10 = 0,1 = 100\text{mA}$.
- What happens when you increase the idle current too much? The FET will be destroyed instantaneously. However the 10 Ohm resistor will prevent that! A current of say 1 Amp already drops 10V over it. The resistor smokes but the FET will survive.

The 1mH coil prevents the RF getting into the 7805 voltage regulator. The potentiometer must be very well decoupled from RF. The values do not matter a lot as long as you don't see RF with your oscilloscope on the 7805.

It is the same linear as in my SSB rig but that one has a fancy BN-43-68 output transformer. An ordinary 4/1 transformer wound in a 50FT/43, like in this CW rig works also.

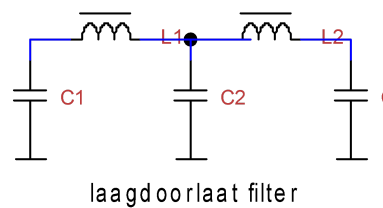
Notice the transmit / receive relay. It is obviously switched by the T/R switch. Notice also the 1K potentiometer. 'RF Gain'. Absolutely necessary to control your creation and to not overdrive a future linear.



Keyer and linear with plug-in low pass filters.

I would advise to make it yourself very easy and use plug-in Low pass filters in edge card holders. Cheap on Aliexpress.

Plug in low pass filters for the QRP linear.



80M = C1,C3= 660pF C2= 1600pF. L1, L2= 20 windingen/turns op T50/2 (rood).

40M = C1,C3= 430pF C2= 860pF. L1, L2= 15 windingen/turns op T50/2 (rood).

20M = C1,C3= 220pF C2= 440pF. L1, L2= 12 windingen/turns op T50/6 (geel).

17M en 15M = C1,C3= 110pF C2= 150pF. L1, L2= 9 windingen/turns op T50/6 (geel).

12M en 10M = C1,C3= 95pF C2= 190pF. L1, L2= 8 windingen/turns op T50/6 (geel).

The point of the low pass filters is to attenuate the harmonics of your linear. Say you send on 40 M (7 MHz) without a filter... the second harmonic is 14 MHz, right into the 20 M band.

How do you check your filter? Plug for example 40 M (7 MHz) Connect a signal generator to the linear and drive up the frequency from 6 Mhz on. The signal on the dummy load should be completely disappeared by the time you reach 14 MHz.

The DU1215S used to be affordable, expensive when I bought it (40 Dollar) and is now obsolete. **My design is a dead end.** We will have to look for alternatives.

In the next chapter we will look deep into the 2026 RF transistor crisis and into alternatives.

Just check out the SSB QRP linear section and QRO Linear section in chapter 6.

For now I would like to suggest just using a cheap IRF510 instead of the DU1215S. Set the idle current for about 100mA.

You will have about

40 m: 6–9 W

20 m: 4–6 W

Above 20 M, a little bit of heat. But there is not much going on above 20 M.

Enough to work all over Europe!

IRFs have one great feature, they cost half a coffee. If you start to learn how to set the idle current of a linear you are bound to make mistakes and blow some FETs up. IRF510s are so cheap that you keep on laughing.

Once you are comfortable with **not blowing** up IRF510s you can graduate to HD16HHF1's if you want. Minimum 8 W, maximum 16 W up to 10 M. They cost 10 to 12 dollars. Idle current 150 to 200mA.

Construction

Exactly like our previous project. Homebrew rigs are built back to front. you start at the LM386 and work your way to the antenna. Check block by block just like the compact receiver. Check the sideband oscillators, band pass filter everything. Yes you won't be finished in one evening. Set yourself easy deadlines and you will be fine.

Checking reception should be easy. Connecting the IF on the antenna should be deafening. And you should be hearing 40, 30 and 20 M stations

Keying the linear on transmit should result in a large sinus on your dummy load. 5 W or more is fine.

The last hurdle.

Before we go on air we need to do two alignments.

The first one is setting the receive sideband oscillator. We will assume the 40 M band. Set your signal generator on 7030 KHz. Now tune over it with the CW rig.

Ideally the tone should go from **zerobeat** → **rising** → **gone** above 650 to 700 Hz, as you tune upward.

If you tune back down and pass zerobeat, the signal generator should become unreadable. This means that the sideband is attenuated as it should.

If this is not the case you will have to lower the frequency of the receive sideband oscillator by increasing the windings on the coil in series with the crystal. The only snag is that the oscillator will stop with too many turns, but normally you should just reach the correct frequency.

Use PA2OHH's spectrum analyzer to check if the bandwidth of the crystal filter is indeed about 600 Hz.

The setting of this sideband oscillator is normally a 10 minute job. No need to panic.

Now we reach a **critical setting** we have to do after our receive sideband oscillator is fixed. We need to set our transmit sideband oscillator so that when we transmit our signal lands exactly where our QSO friend transmits. Because that's where he is listening. It has to be spot on. Fortunately it is not rocket science.

- measure the frequency of the 'receive' sideband oscillator.
- measure the frequency of the 'transmit' sideband oscillator.
- Adjust the trimmer capacitor so the transmit oscillator is **750 Hz higher** than the receive oscillator.

Obviously I found a more complicated and painful 100 % accurate method, what did you expect! But you need a second CW capable receiver.

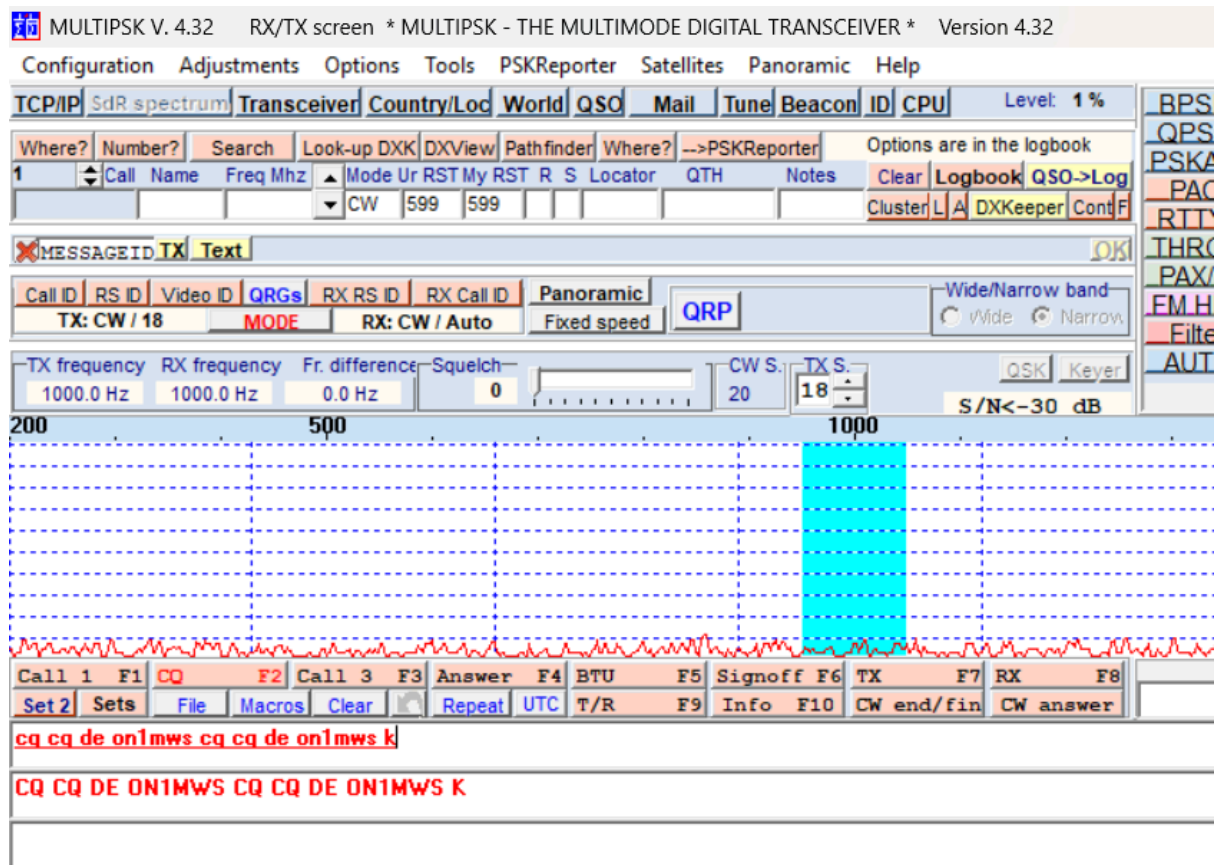
- I put my signal generator on 7030MHz
- Tuned in with the CW rig, all four audio filters engaged
- Tuned in with my general coverage receiver all filters on.
- Both rigs are now spot on frequency
- Switch the CW rig on transmit with a little continuous power.
- adjust the trimmer of the transmit sideband oscillator for maximum signal o my general coverage receiver.

This aligns the transmit oscillator with surgical precision. The kind of alignment that makes your rig behave like a commercial CW transceiver.

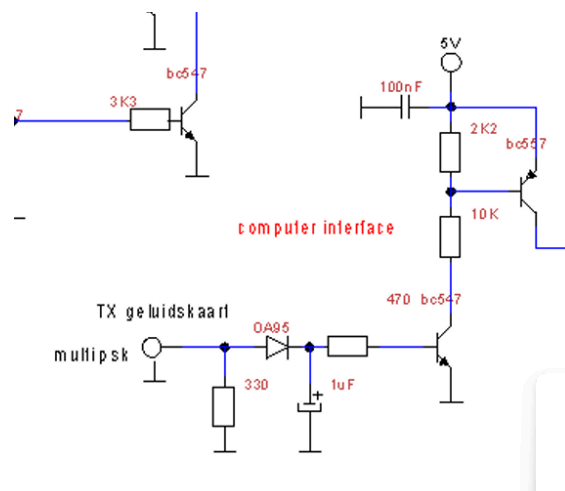
Getting around the lack of code skills.

Well, we're going to cheat our way in.

Sending is simple, download the free version of MultiPSK. Set the mode on CW. Select TX and set the speed on 18 WPM.



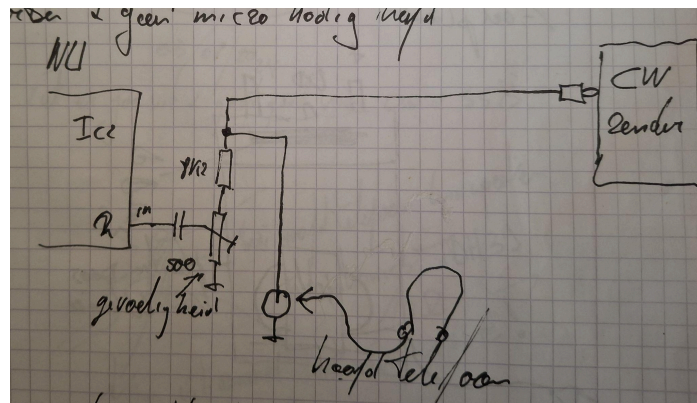
When you type in you will hear morse code in the loudspeakers of your laptop. Connect your laptop with a cable to the 3,5mm jack of the CW rig.



Remember my fancy 'computer interface'? It simply rectifies the laptop audio and keys the linear. You could leave out the touchkey and the iambic keyer if you want to.

Decoding is harder. I tried free software many years ago but it did not work well. Maybe there is good software in 2026 for free?

But I got a Velleman K2659 KIT that decodes CW really well. The KIT used a microphone but I removed it and fed the audio from the CW rig via a resistor trimmer. Works great!

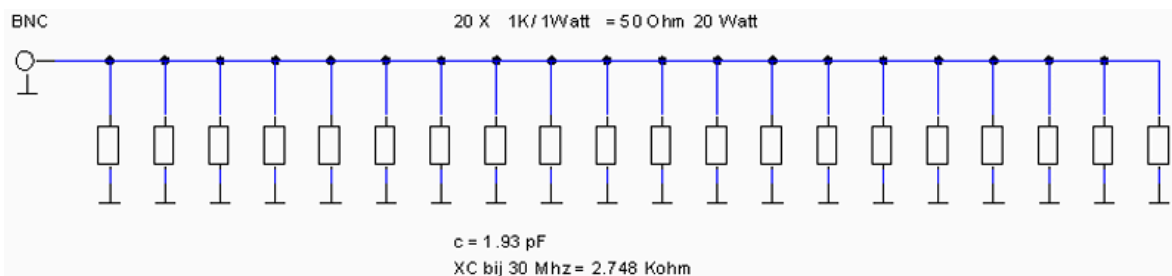


With these work arounds I can do CW QSOs. I did try to learn code years ago but failed despite being very motivated.

Here ends our long CW section... next up is the shortest section. The dummy load.

Dummy load.

We can keep it short on this accessory. The dummy is just 20 paralleled 1K/1W resistors. Resulting in one 50 OHM/20W resistor. A good dummy load has no lead inductance and no capacitance. My resistors are soldered between copper clad PCBs.



Maximum 20Watt.

The two PCBs form a capacitor. There is no way around that. I used an online plate capacitor calculator and the capacitance is only 1,93pF. So I have nothing to worry about.

What I used to do was immerse the dummy load in old frying oil to use it beyond 20W. But that becomes a real mess, even by my standards. The dummy can be used on more power for a reasonable time if you keep an eye on the temperature.

Neighbor friendly antenna.

My very first CW QRP QSOs were done in 2013 with a 10M wire from my garden shed to a small tree. The height of my antenna can be any higher than 2M. I needed something better.

My first choice would be an inverted V. However, my garden lacks any tree that is high enough. So I would have to erect a mast. My garden is large enough but I don't want to annoy my neighbors. The neighbors are more important than my hobby.

An internet search started in 2014 to find a solution. I came across the excellent site of G4ILO '**Stealth** amateur radio' That's it!

<https://www.g4ilo.com/stealth.html>

Still online in 2026. The site gives an overview of what is possible to hide your antenna from your surroundings. And equally important, which antennas to avoid. After careful deliberation I gambled on the tuned loop antenna.

My next R&D breakthrough was the discovery of the PDF 'An Overview of the Underestimated Magnetic Loop HF Antenna' Also still to be found on qsl.net in 2026.

<https://www.qsl.net/vk5bar/Sn>

This PDF gives **every** information you would possibly want before building a loop antenna.

Basically the loop antenna is a tuned circuit. The coil is **one** turn. Your 50 OHm coax is coupled with a second coil which is about 1/5 of the diameter of the tuning coil.

The resistance must be kept to a minimum in your tuning coil and tuning capacitor. Every mOHM counts! VK5BAR recommends welding... This is also the reason why all loops use a butterfly capacitor. So that the current does not need to travel through ball bearings.

The loop must also be located at least one diameter above ground. The PDF promises an antenna equally good as a full sized dipole. Only drawback, it has to be tuned **exactly** for transmitting.

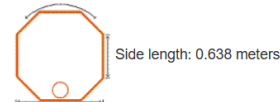
You just fill in the number until you have the antenna you need. The calculator will let you know if your diameter is wrong for the frequency you want. After a lot of playing with the calculator I found a way to build a 40, 30 and 20M loop.

Diameter 1,6M = circumference 5,1M

Antenna efficiency: 34% (-4.7 dB below 100%)
Antenna bandwidth: 7.09 kHz
Tuning Capacitance: 108 pF

Capacitor voltage: 4,553 volts RMS
Resonant circulating current: 21.7 A
Radiation resistance: 0.036 ohms
Loss Resistance: 0.070 ohms
Inductance: 4.77 microhenrys
Inductive Reactance: 210 ohms
Quality Factor (Q): 988
Distributed capacity: 14 pF

Antenna "circumference": 5.1 meters



Antenna diameter: 1.5 meters

Comments:

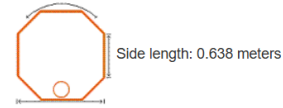
The specified conductor length of 5.1 meters is not ideal.

40M

Antenna efficiency: 65% (-1.9 dB below 100%)
Antenna bandwidth: 16.1 kHz
Tuning Capacitance: 52 pF

Capacitor voltage: 4,361 volts RMS
Resonant circulating current: 14.4 A
Radiation resistance: 0.157 ohms
Loss Resistance: 0.084 ohms
Inductance: 4.77 microhenrys
Inductive Reactance: 303 ohms
Quality Factor (Q): 628
Distributed capacity: 14 pF

Antenna "circumference": 5.1 meters



Antenna diameter: 1.5 meters

Comments:

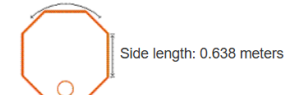
The specified conductor length of 5.1 meters is OK.

30M

Antenna efficiency: 85% (-0.7 dB below 100%)
Antenna bandwidth: 45.3 kHz
Tuning Capacitance: 27 pF

Capacitor voltage: 3,603 volts RMS
Resonant circulating current: 8.59 A
Radiation resistance: 0.579 ohms
Loss Resistance: 0.099 ohms
Inductance: 4.77 microhenrys
Inductive Reactance: 420 ohms
Quality Factor (Q): 309
Distributed capacity: 14 pF

Antenna "circumference": 5.1 meters



Antenna diameter: 1.5 meters

Comments:

The specified conductor length of 5.1 meters is OK.

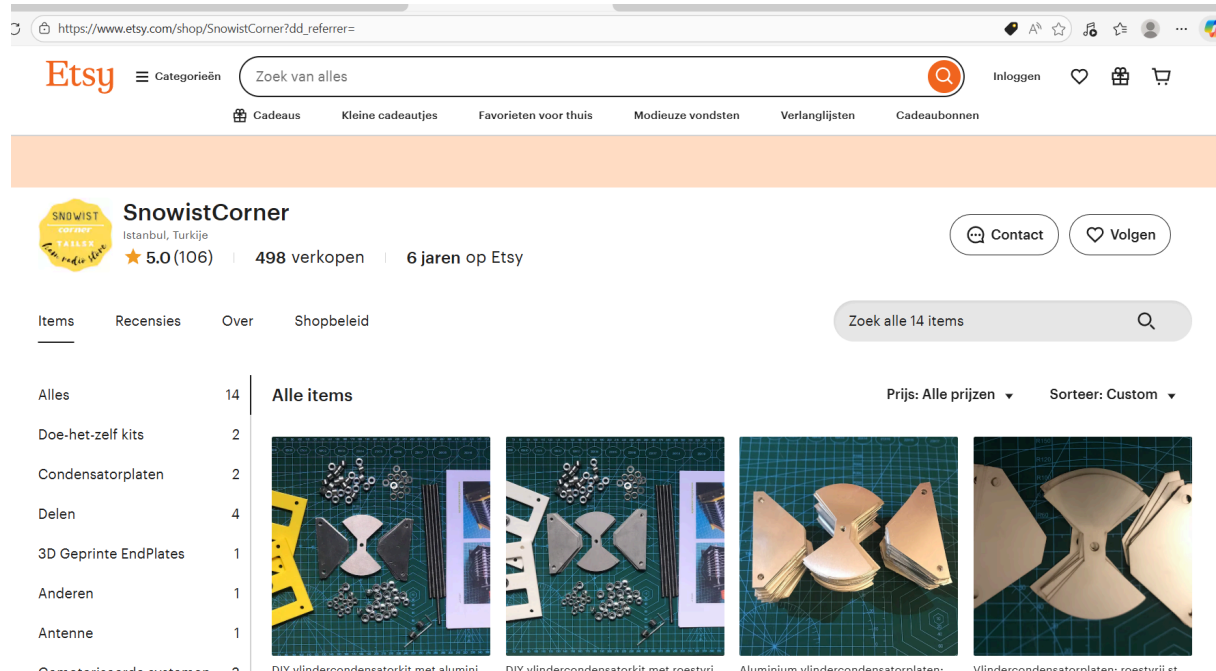
20M

I ignored the warning for 40M because the minimum circumference is 5,12M...

The loop was made from **soft copper** sanitary pipe. Diameter 16 mm. I shaped it with professional machinery... This is a bottleneck for the homebrewer. But I've seen homebrew examples with coax cable.

The capacitor I needed had to be between 110pF and 27pF. And it has to be a high voltage one. QRO the voltage can be 4553V! QRP is still 1280V.

The capacitor was made with plans of ON4CEQ. At the time I worked in a light advertising company and my colleague made the plates on a professional milling machine during lunch breaks (actually during our working hours) . For this book I searched for an alternative.



There is a Turkish guy on Etsy who sells KIT high voltage capacitors. 50 Euro which is not much for what you get. Good reviews.

Loop antenne 1. (2015)



The capacitor is operated remotely by a DC motor. It is a 12V DC motor with a 3000/1 gear reduction. Notice that I did not weld the loop onto the capacitor but bolted it as **tight as I could** with M8 bolts. Remember every mOHM loses power.

MFA 950D30001 Transmissiemotor 12 V/DC 3000:1



Artikelnummer: 222376

Fabrikantnummer: 950D30001

EAN: 5014111960066

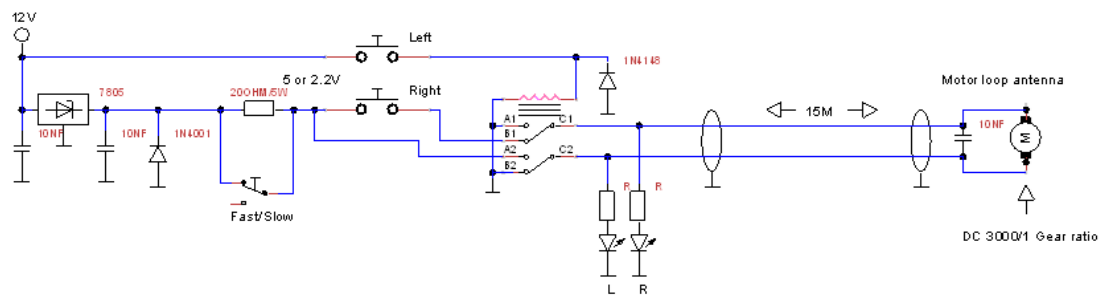
MFA 950D30001 Transmissiemotor 12 V/DC 3000:1 is een motor die wordt gebruikt in modellen en modellenbouw, waarbij een krachtige aandrijving noodzakelijk is.

[Volledige beschrijving](#)

★★★★★
2 reviews

Below is the motor control in the shack.

Motersturing nr 2 (2020)

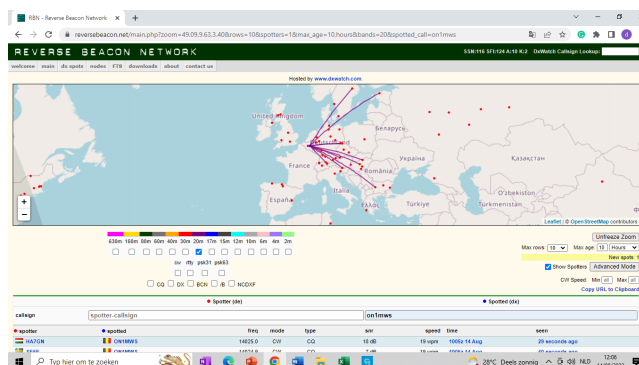


12V was still too fast and I used 5V. Even this is kinda fast so I can switch in a resistor to lower the speed even further. Tuning is now perfect.

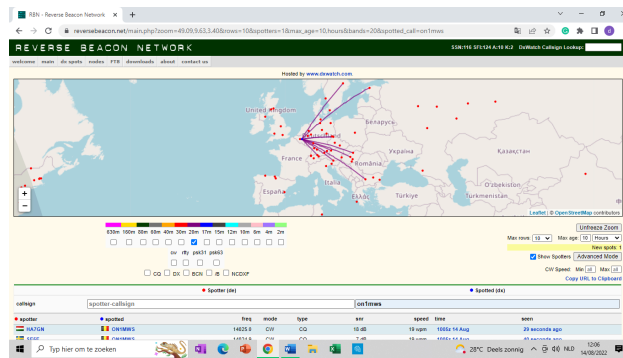
The couple loop itself is connected with 10 M of RG58 coax. The couple loop is made from ordinary 2,5mm² installation wire and has a circumference of 1/5 of the main loop. Diameter = 318 mm. The coax connection must be soldered perfectly for Tx work!

How good does it work?

It covers Europa easily. Results of a 5 minute CW QRP CQ run on RBN.



20M



40M

The furthest SSB QRO (60W) QSO was with Austria, about 2000 KM. The lowest power CW QRP QSO was with Italy with 1 Watt. 1 Watt!

Sometimes I hear US HAMs. Unfortunately they don't hear me. Remember I am the kind of HAM that melts more solder than transmitting. Maybe it could reach further with more effort and time behind the rig?

I realise that this antenna is difficult to build mechanically. You could consider it. Homebrew is for once, cheaper. The G4ILO site lists commercial loop antennas if you want to buy one.

The antenna turned out to be fairly reliable over 9 years. I did have to re-bolt the loop onto the capacitor once. The connection of the **50 OHM coax on the couple loop** had to be redone also a couple of times. Turns out that this connection also has to be perfect.

The only annoying thing is that the antenna has to be retuned every time (for TX) when you move along the band. But that's a price I am willing to pay to keep my neighbors happy.

SWR meter.

You will need a SWR readout to check if your 50 OHM TX antenna is matched to your transmitter. This SWR meter uses a symmetric RF bridge that combines voltage and current, rectifies both components, and displays **the forward and reflected energy** on two analog meters. If your reflected energy is zero or near zero you are actually transmitting. If your reflected energy is equal or larger than the forward energy, you are not transmitting but heating up your linear.

My design is a copy of David Stockton, G4ZNQ SWR meter.



triera.net

<http://users.triera.net> › zupanbra › Radioamater › ... › PDF bestand [Dit resultaat vertalen](#)

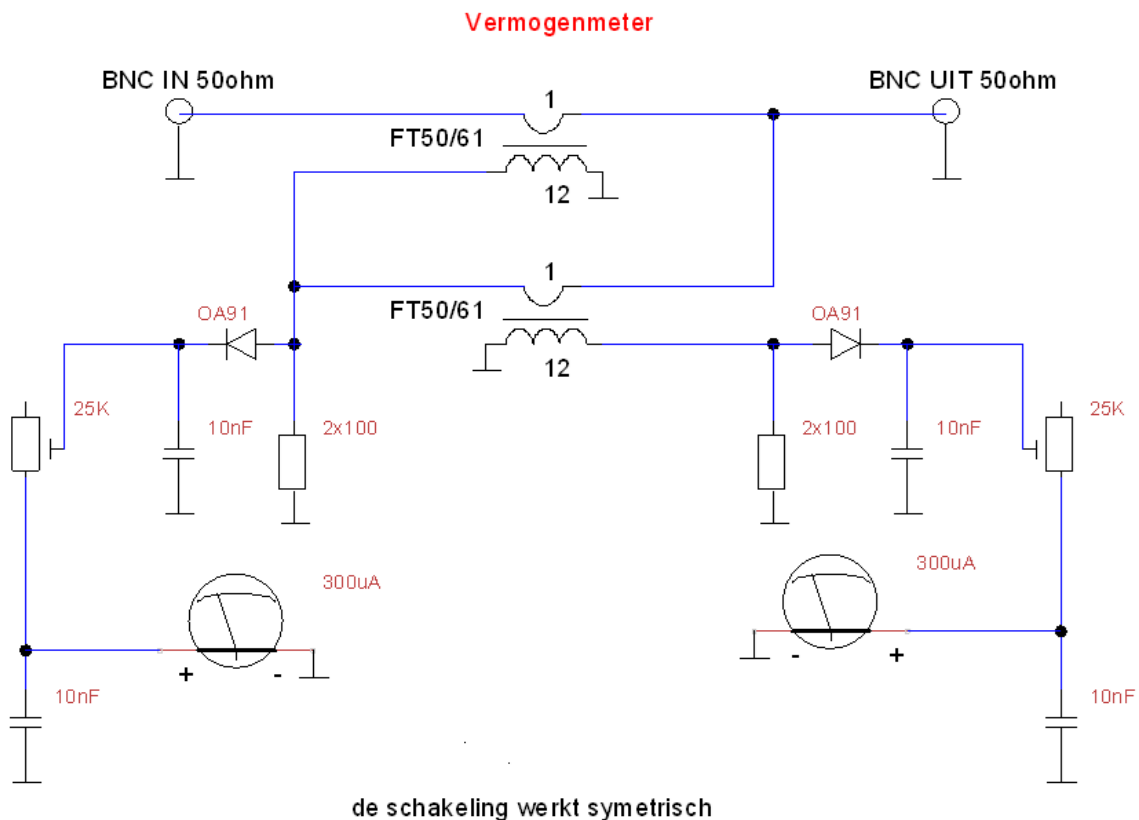
A Bi-DIRECTIONAL INLINE WATTMETER DAVID STOCKTON G4AZNO ...

The photographs and diagrams refer to the Kanga Kit version of the Power Meter. This kit includes all that is shown in the "head" of the meter including the case, the special cores for T1/2 and all ...

The article is still online. To quote David, "The operation of this circuit is extremely difficult to understand, yet (it only uses two components. Fortunately it is easy to build and easy to use"

There was a local HAM club in my region some ten years ago and I brought my new homebrew SWR meter to show. I admitted that I did not understand how it worked. The older HAM said 'lets take a look at the schematic' We soon both got completely stuck.

However, David is right. It is easy to build and works well. Mine worked perfect from the start. How it worked lived in my axiom box; 'It works because smarter people than me designed it'



I still don't get it.

We did not have AI ten years ago. So now I uploaded the schematic to Copilot... Brace yourself.

"This SWR meter is a **bidirectional RF bridge** that separates forward and reflected power by combining sampled **line voltage** and **line current** with the correct phase relationship.

1. Current sampling via the FT50-61 transformers

Each FT50-61 core has a **1-turn primary** in series with the transmission line. This produces a secondary voltage proportional to the **RF current** through the line:

$$V_s \propto I_{RF}$$

Because the two transformers are wired with opposite polarity, one secondary produces a voltage that is **in phase** with the line current (forward direction), and the other produces a voltage **180° out of phase** (reflected direction).

2. Voltage sampling via the resistor bridge

The 100 Ω resistors form a **voltage divider** that samples the RF line voltage:

$$V_{\text{sample}} \propto V_{RF}$$

This voltage is combined with the transformer-derived current sample. The bridge is dimensioned so that for a **50 Ω load**, the voltage and current samples cancel on the reflected side:

$$V_{RF} - (I_{RF} \cdot 50\Omega) = 0. \text{ This is the key:}$$

When the load is 50 Ω , the reflected detector sees zero net RF.

3. Directional separation by phase addition/subtraction

Forward and reflected waves differ in the **phase relationship** between voltage and current:

- Forward wave: V and I are **in phase**
- Reflected wave: V and I are **180° out of phase**

The bridge uses this to isolate the two components:

- **Forward detector** sees $V + I \cdot Z_0$
- **Reflected detector** sees $V - I \cdot Z_0$

Where $Z_0 = 50\Omega$. This is the same principle used in commercial directional couplers, just implemented with resistors and toroids instead of stripline.

4. Detection and filtering

Each detector uses an OA91 germanium diode to rectify the RF.

Germanium is chosen because of its low forward voltage ($\sim 0.2\text{ V}$), which improves sensitivity at low power levels. The 10 nF capacitors act as **low-pass filters**, converting the rectified RF into a stable DC voltage proportional to the RF amplitude.

5. Metering

The DC outputs drive two 300 μA analog meters:

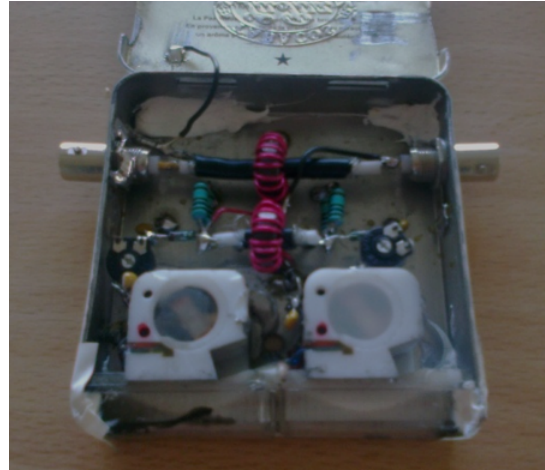
- Forward meter shows the magnitude of the forward travelling wave
- Reflected meter shows the magnitude of the reflected wave

SWR is then: $SWR = 1 + P_{\text{refl}}/P_{\text{fwd}} = 1 - P_{\text{refl}}/P_{\text{fwd}}$

The user typically reads SWR from a scale or calculates it mentally"

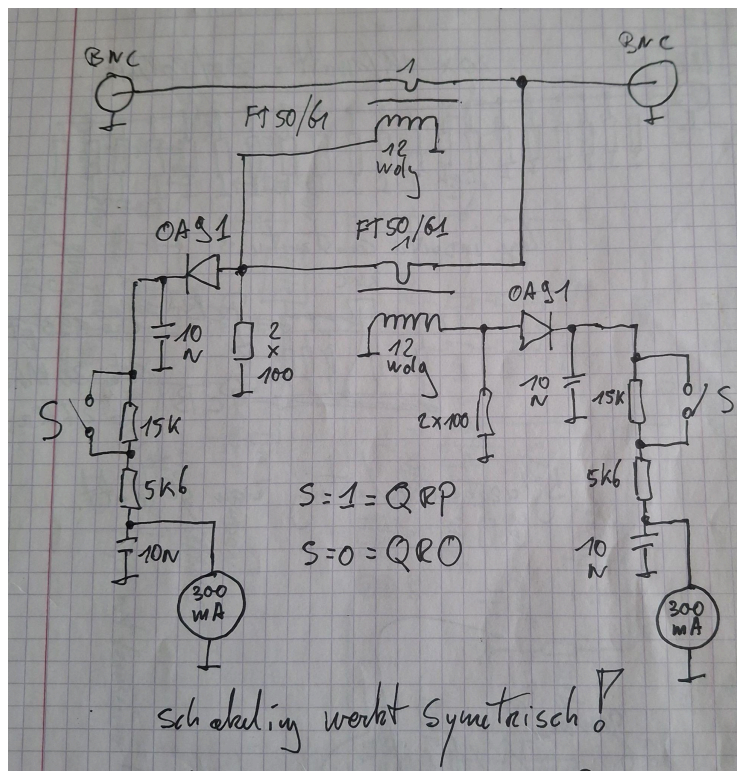
I'm gonna be honest here, part of the SWR meter will stay in my axiom box. What I especially don't get is how it can work both ways. It feels like magic.

But it works well. I built my version in a cigar box.



Using it in the station.

I put my transceiver on continuous power. QRP! and tune my loop antenna until I see no reflected power and turn the continuous power off. Now I am ready for QRP. If I want to transmit QRO I turn on the linear. To handle the increased power I changed the design.



My modified SWR meter can now be used for both QRP and QRO. Switch S open = QRO. Closed its QRP.

With the SWR meter finished and the station now properly monitored, we can turn to the next building block. On paper it is the simplest receiver in this chapter. In practice, it is the one that will test your patience the most: the homebrew one-band regenerative receiver.

The supposedly easy radio is secretly one of the hardest

Homebrew one band regenerative receiver.

Many books and articles will portray a regen as a friendly beginners radio. This book presents it as more difficult. This might be a bit controversial. I will argue that the superheterodyne from the start of the chapter is not more difficult than a regen. In some respects maybe easier. Why?

A superheterodyne is a series of blocks that do one specific thing. You can swap mixer types, change the gain of the blocks, tweak filters, it will still work. It is a bit like cooking Flemish stew. Yes, there is a recipe but you can swap brown beer, spicing... it won't always be a culinary breakthrough but it will always be Flemish stew. Regens have **one** transistor that does several things at once. Amplifying, oscillating, detecting. A regen is a balancing act. It's like baking a soufflé. The recipe is the recipe. If you deviate from the recipe you don't have 'slightly worse soufflé', no you have **no** soufflé.

Superhets look difficult on paper, but behave well.

Regens look simple on paper, but fight back.

Masters like Olivier Ernst F5LVG can make their own regen recipe but we, mere mortals, better stick to a trusted one.

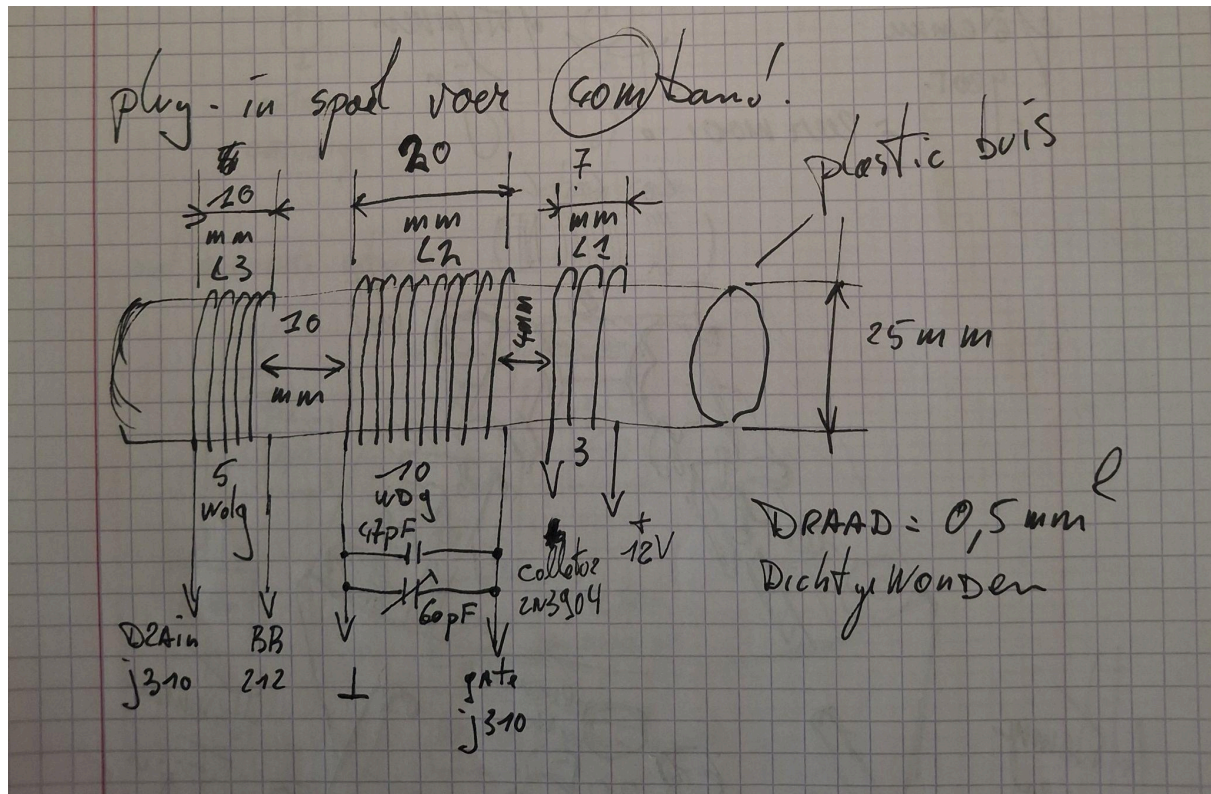
I chose N1TEVs 'high performance regenerative receiver'.

Charles Kitchin, N1TEV, regeneration PDF is easy to find on the internet where the receivers are explained in detail.

There are two regens featured on the PDF and I chose the second one as it promised a better performance. But I wanted a receiver that is as stable as possible. Otherwise it is hard to listen to a HAM band when you constantly have to re-tune.

Hence, a narrow band receiver/oscillator is the way to go.

I ended up with only 100 KHZ of tuning bandspread, but that's enough for a Ham band. The original NTEV receiver is easily recognised in the schematic. This receiver might look simple but is a really tricky build.



- K0IYE tips are to use a high precision voltage supply for the oscillator. For this a LM336-5 is used.
- Only the oscillator should be fed by this voltage regulator.
- Use the lowest possible voltage for the oscillator.
- Build any heat source (HF amplifier, voltage regulator and audio circuits) in a separate enclosure.

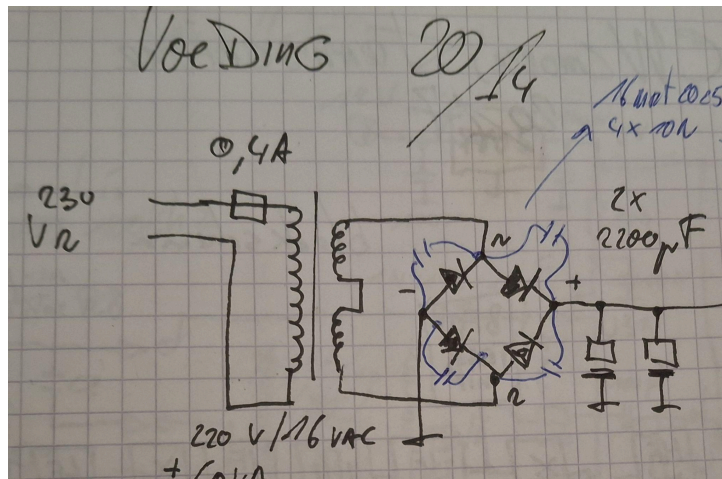
F5LVG has a website with an article about oscillator stability and you could locate chapter 10 from "Crystal set to sideband" of K0IYE for more info about oscillator stability .

The radio worked fine with a battery. And I had because the regen radio was overwhelmed with 50 HZ hum from my power supply. The hum problem was solved by using another tip from F5LVG.

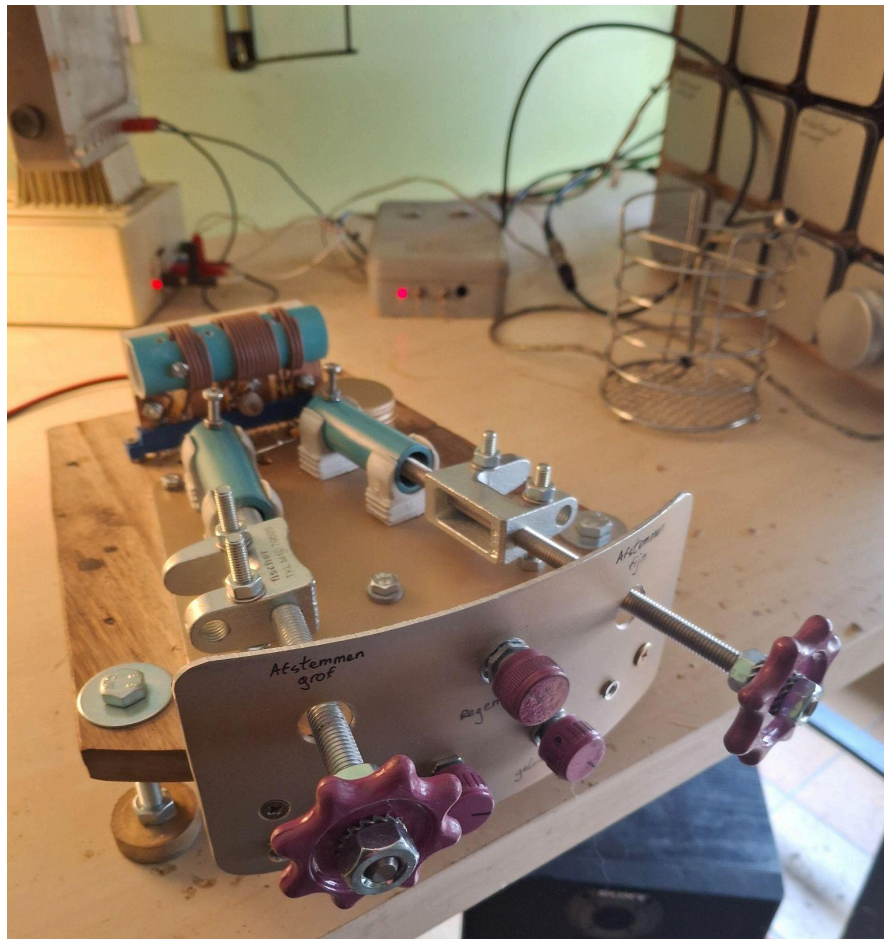
"The receiver works like a small transmitter. The oscillation emitted by the antenna is picked up by the mains wires. It reaches the power supply unit where the rectification bridge modulates in 50 Hz the oscillation that returns to the receiver via the power cables".

The F5LVG solution is shunting the rectifier diodes with 10NF capacitors. I was sceptical, but did do this modification to my old power supply.

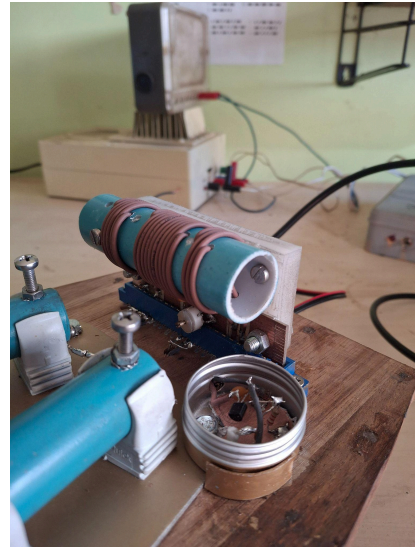
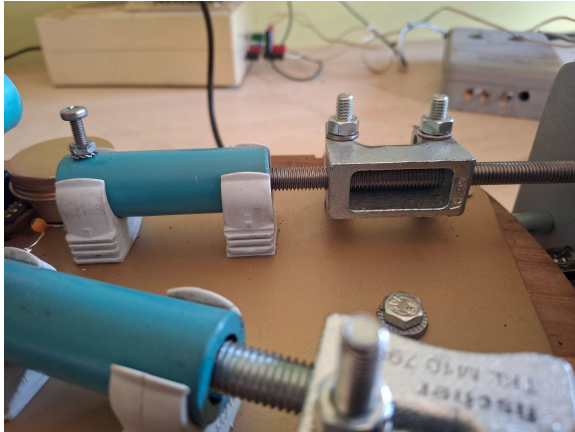
10NF capacitors parallel over the four rectifier diodes cured the hum completely. This was a pleasant surprise! The separate power supply is located about 30 Cm from the regen. I have not noticed any radiation if it is placed closer.



The way I see it is that the radiation still reaches the power supply and still leaps through to the receiver but no longer gets modulated by the rectifier diodes. The high frequency radiation now has an uninterrupted path through the 10 nF capacitors.



The homebrew capacitors are basically a threaded rod that are being driven in or out a metal tube. One is M10 in a tube that is about 12mm. This is the coarse tuning and is probably about 35 pF. The other one is a M8 rod in a 17 mm tube. Probably around 10pF. The rods are driven through a M10 and M8 steel beam clamp. These provide gear reduction. About 1/40.



Any other capacitor will also work and the easiest is probably to use a 1N4001 as a tuning varactor. The ground of the homebrew capacitors doubles as a ground plate for the whole radio.

The coil is placed more than **one diameter above the ground plate to avoid coupling**. Read this in N1TEVs article.

After the set worked with a classic tuning capacitor for the regeneration I swapped it for a BB212 varicap.

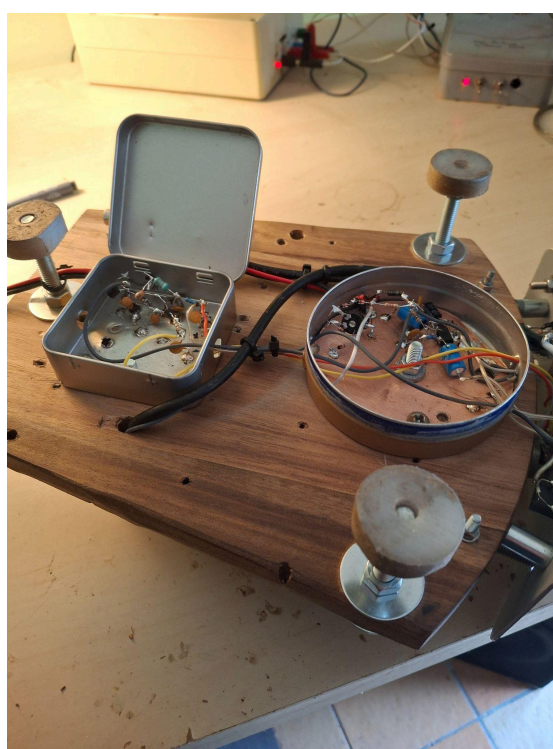
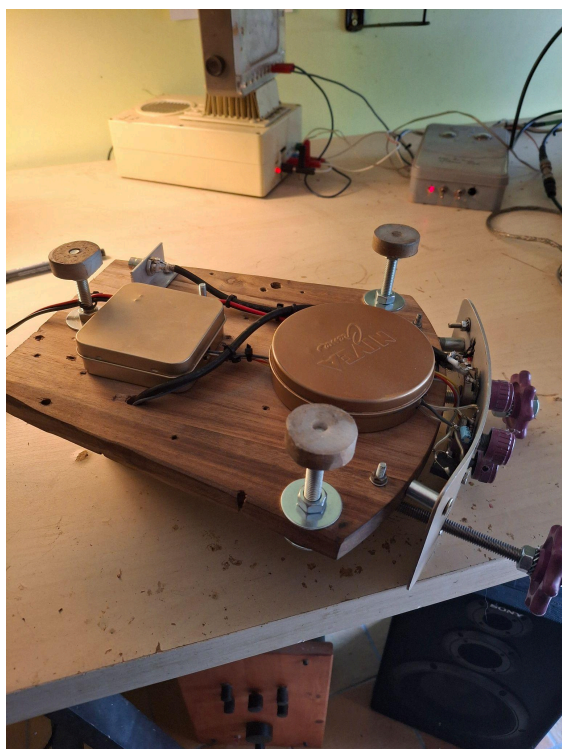
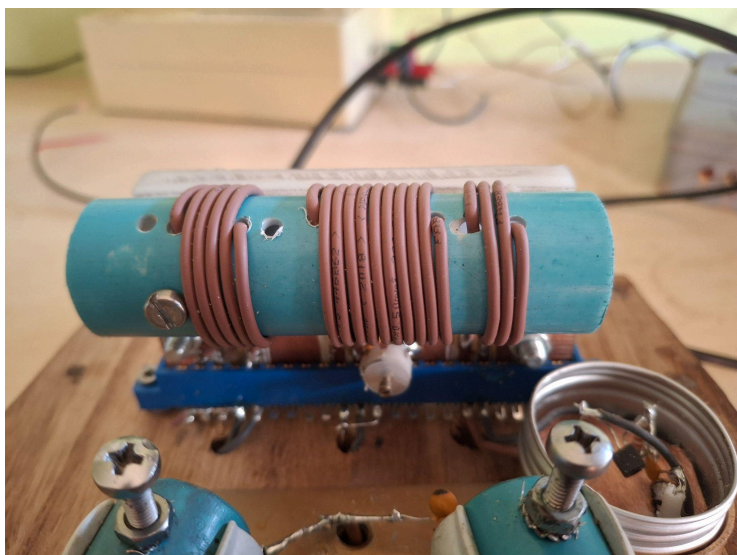
It would be much **easier** to use a normal tuning capacitor for the regeneration control. I however used my last BB212 because a potentiometer is easier to mount on a front panel. But it was tricky to make it work.

More capacitance is oscillation and less capacitance is less or no oscillation. The oscillation must be easy to regulate in and out.

The oscillation can be measured on the hot side of the regen capacitor or on the drain of the J310. For this you need to set your oscillator probe on **X10**. The probe will always trigger a large oscillation if it is set on X1!

I measured that the frequency on the drain is **0,55 Vptp** when regeneration is set on maximum. My +40 years Hameg scoop can not be trusted but the frequency amplitude is obviously small.

For receiving CW and SSB you only need a tiny bit of oscillation. For AM obviously no oscillation. Finding the right combination of regen capacitor and tickler coil dimensions for a smooth 'in and out' regulation takes some effort.

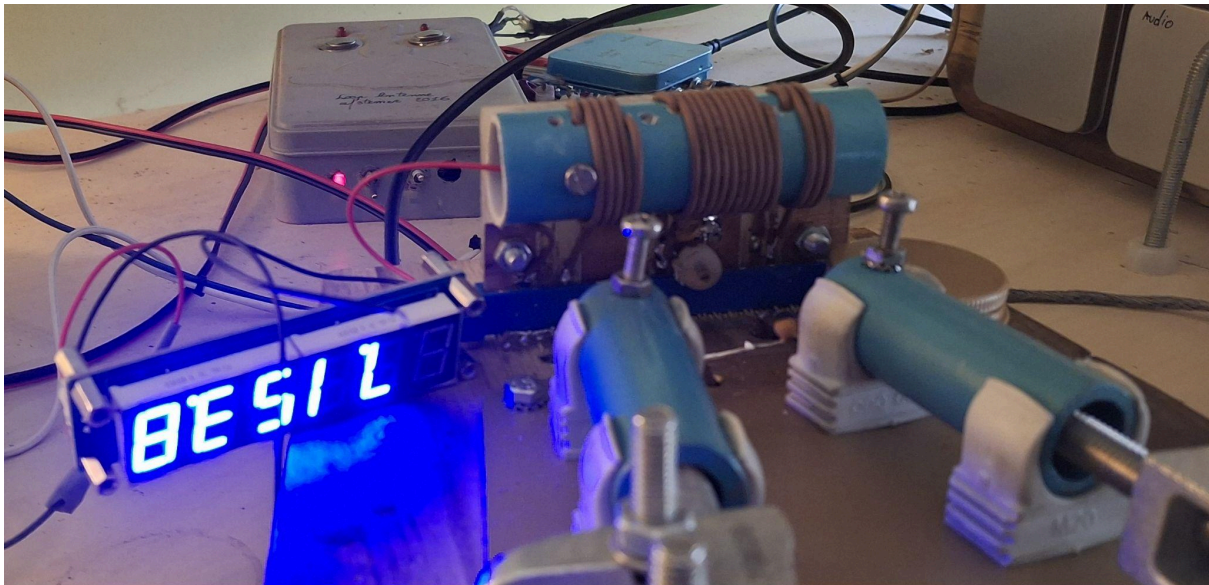


The set works really well for such a simple schematic. Sensitivity is amazing, however, selectivity is not up to modern standards. If I would include audio filters for CW and SSB between the oscillator and LM386 the performance would be quite ok. Equal to a good DC receiver. I expect that it would have a better S/N ratio than a DC receiver. However, I won't bother and keep it as it is and experience the full "1920s experience"

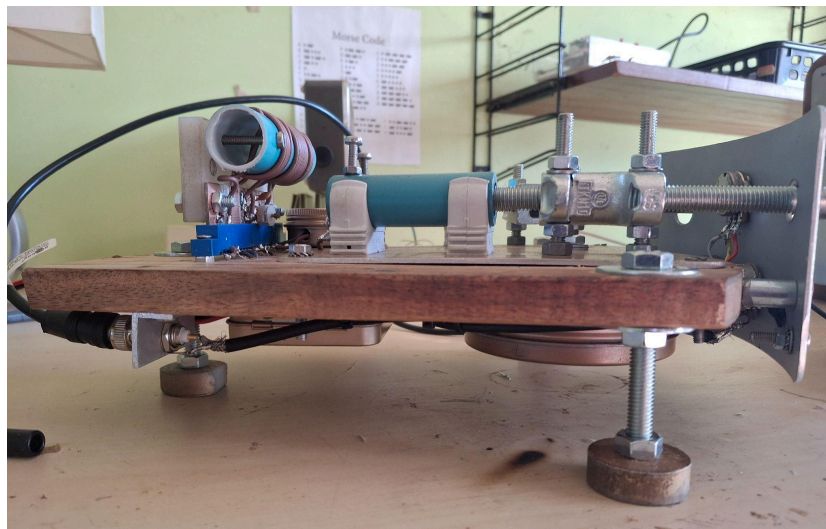
It is also a 'happy' regen! no sudden bursts or squeals. All credit goes to Charles Kitchen, I merely copied his design.

Wanna see it alive? <https://www.youtube.com/shorts/cZD0fz3nBI4?feature=share>
This YT clip was made before the rudimentary tone control was installed.

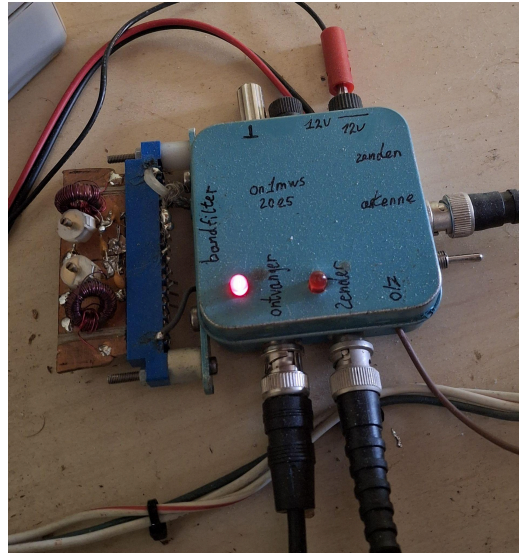
It took me some time to find out how to connect my frequency counter to the regen set. It is not really needed while operating but very **easy to align** the set to the right frequency. Additional coils did not work.



Slipping the short lead (red wire) from my cheap Aliexpress frequency counter in the left side of the plug-in coil did the trick. This is where L3, the tickler coil, is located. A long wire lead did not work either.



The radio is so stable that I figured that it would stay long enough on frequency to use it for a QSO. For this I built a T/R relay. One contact switches the antenna to the regen in receive and to the transceiver in transmit. This is obvious. An edge card connector is also a feature in my T/R relay. The band pass filters of my CW transceiver can fit. This gives my humble regen some more tranquility.



The second relay contact switches the regen set completely off in transmit mode. The question is naturally how far off frequency the regen is after you go back to receive mode? Well, if the antenna attenuator is on full signal, the frequency is slightly higher than before but not far. If the antenna attenuator is slightly attenuating, the regen is completely on frequency after switching back to receive. Spot on to my amazement.

My first 'regeneration' QSO was in March 2025 and I worked M0KRI for about 25 minutes without re-tuning much. It was amazing. M0KRI had some trouble coming to grips with the fact that I was listening with a homebrew two-transistor radio. A twenty five minute QSO with a two-transistor homebrew regen is like taking a 2CV on the motorway and keeping up with traffic.

Why is the regen still fun? Because its charm isn't in what it does well, but in its limitations.

Anyone with an oldtimer understands this instantly. My Gen-Z colleagues mechanics ride 1970s and 1980s mopeds, not for speed, not for reliability, but to feel something real. It's contagious. I bought a 1987 50cc Peugeot Vogue myself, despite knowing nothing about two-stroke engines. A new hobby. A new R&D challenge.

You've built the ecosystem.

Everything works. Nothing smokes. You are now a capable homebrewer. Chapter 6 won't scare you. The bosses are doable. They just don't want you to think that.

Turn the page.

Chapter 6

The final bosses of analog scratch building.

Wanna join a very exclusive club?

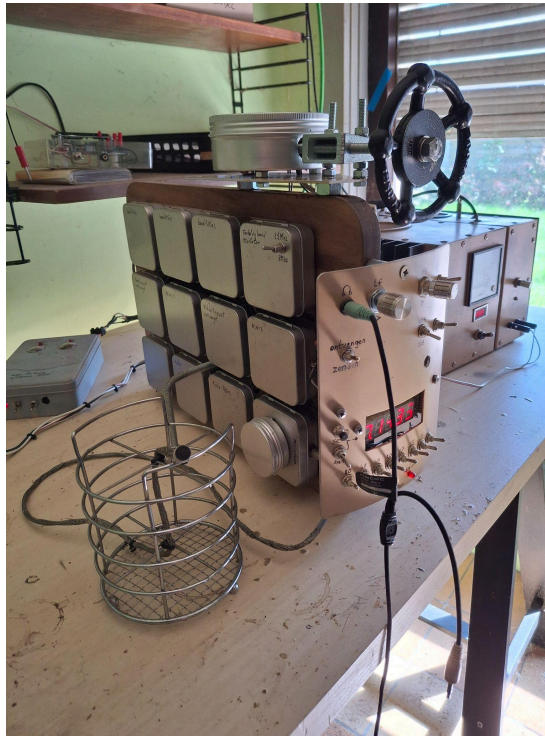
on1mws

Most kit builders, “I can solder, read a schematic but I’m no EE professor”, think an analog SSB transceiver is out of reach. I’ve only got a high-school degree, nothing more, and I still managed to build one that works. So don’t let the word SSB scare you off. The transceiver presented below uses the same building blocks as we have seen in **chapter 5**. Just arranged differently, but just as easy. The tricky bit is the microphone amplifier and how to check your voice modulation on a dummy load. There is nothing complicated about it, but homebrew SSB articles rarely teach that. This chapter will hopefully be different.

Then we will look at **linears** and learn that they can engulf you in smoke while robbing your wallet at the same time.

And once you survive the serious SSB part, you deserve the full on1mws chaos of the **Tube regen**. Now that’s the real analog boss. There is no sugarcoating that beast.

The friendly boss, the SSB transceiver.

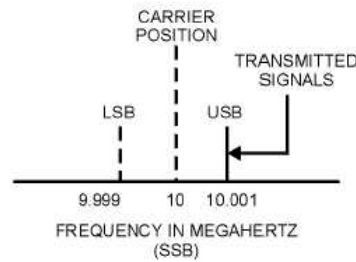
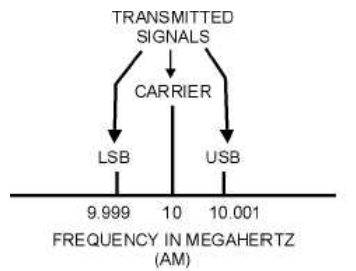


This book will not go into the basics, as usual. This book is about **how**? Where to find the basics? Chapter 15 in Crystal set to sideband. Our design will be much simpler than Frank's K0IYE double super circuits. Another great source is the 5 part article series called 'The principles and building of SSB gear' by Doug Demaw. It can be found online via the Solderblog Daily news site. It is intermediate level and contains many schematics. I found part one with just the principles very useful. Get yourself a drink, this is going to be mostly dry.

An AM signal contains the carrier, and two sidebands. One on each side of the carrier. Don't worry if you don't understand this. I don't either. We are going to just put this in our 'axiom box' It is true because smarter people proved it.

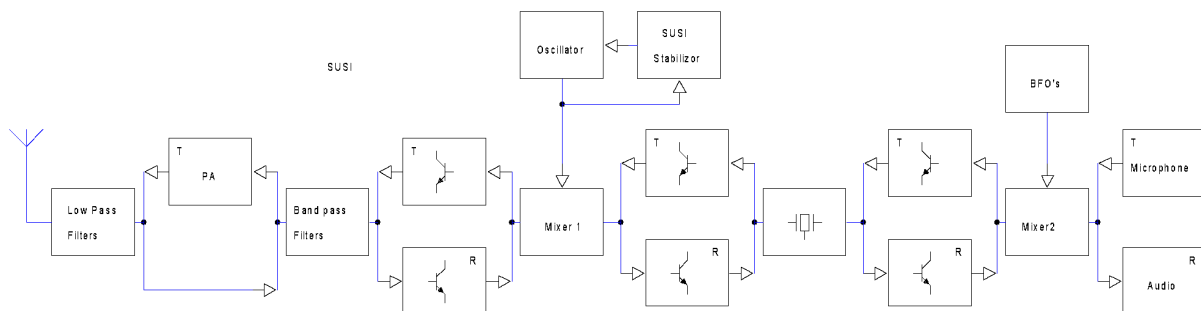
The carrier does not contain information, so SSB gets rid of that. The sidebands contain identical information, so SSB gets rid of one of the sidebands.

The goal is that by removing the carrier, one sideband you can transmit a signal equal to an AM signal but with 6 times less power. That is the reason why SSB exists. **Saving power.**



What we want to do is modulate the frequency of the sideband oscillator. We have ourselves an AM signal. Remove the carrier next in the second mixer, so that only the two sidebands arrive at the crystal filter. And next filter out one of the sidebands with the crystal filter. Then we shift our single sideband to the HAM band we want with the first mixer.

It will become clearer after we run down the block diagram.



The transceiver is based on the bitx20A. **All credits go to Ashhar (Ashar) Farhan, VU2ESE.**

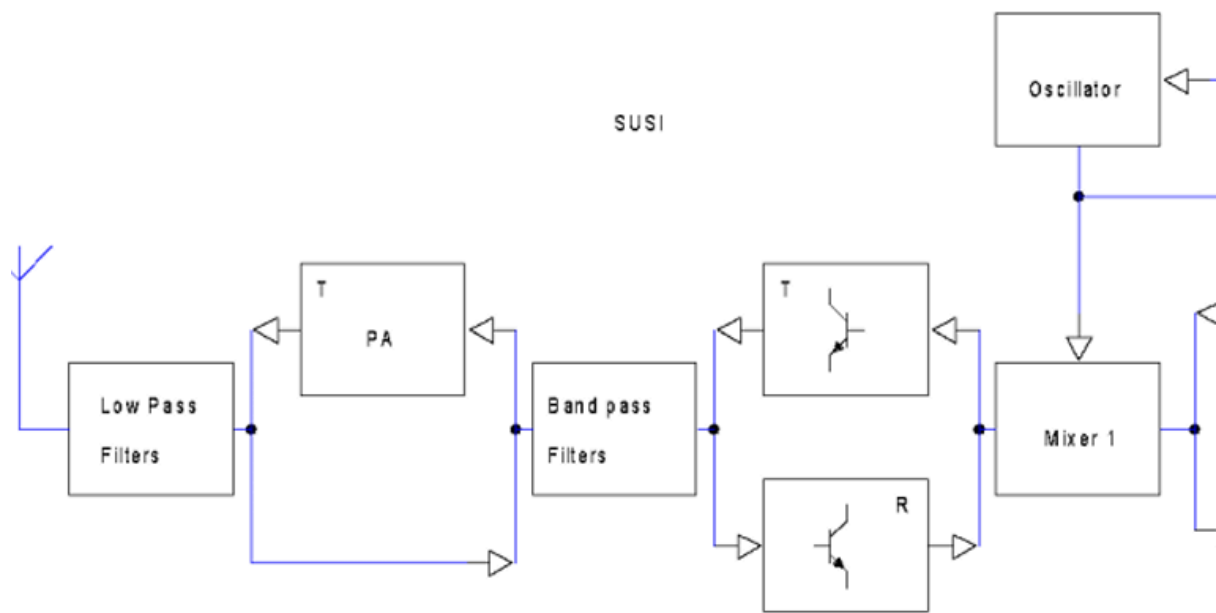
First we look at receiving signals.

The transceiver has exactly the same distribution as the 'Holiday radio' and CW transceiver. It is also a single super. For a deeper dive into superheterodynes see for more in chapter 5 or search online for superheterodyne receivers theory.

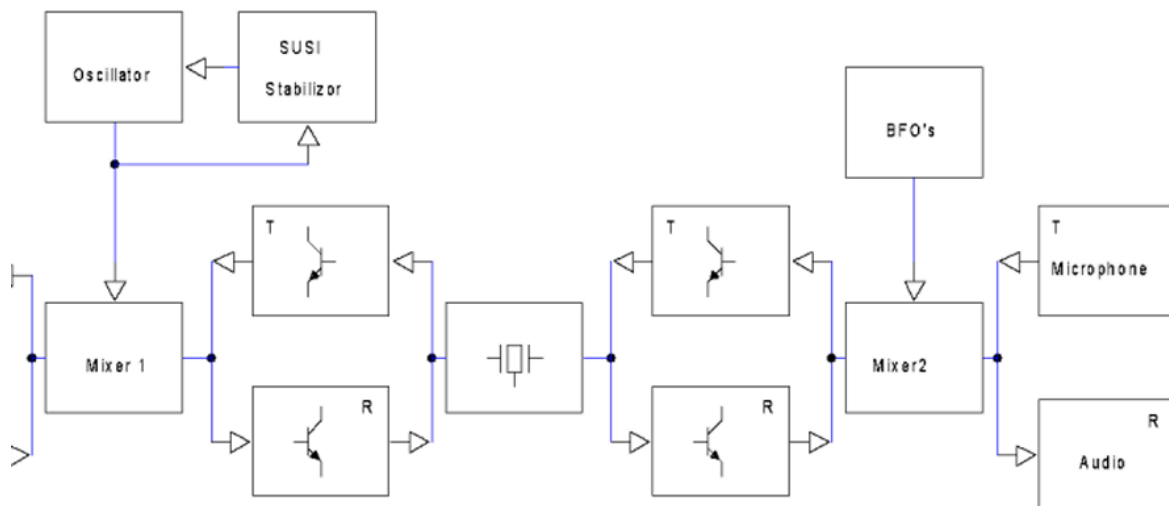
In receiving mode, all blocks marked R get powered.

In transmit mode, all blocks marked T get powered.

Simple.



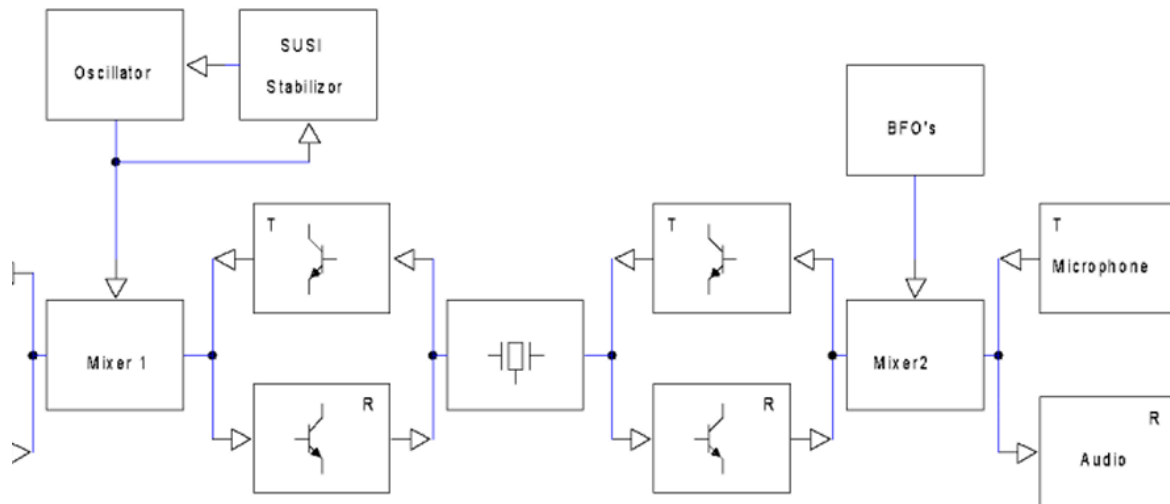
The antenna signal goes from the antenna straight into the bandpass filters, yes the block diagram is wrong (the schematic will be ok) The only amplifiers working on receive are the one marked R. The amplifier marked T (transmit) does not get any power. A clever trick indeed. The signal leaves the HF amplifier and gets fed into the **balanced** mixer. Exactly the same one from our CW transceiver.



The signal then goes to our first IF amplifier. Next through a 2,5 KHz crystal filter where the IF gets filtered out. IF is 11 MHz. Then follow another IF amplifier. See just like the holiday radio and CW rig. Now there is a different Mixer 2 is a single ended mixer. Here our IF gets mixed with the sideband oscillator and audio leaves the mixer. Finally follows the audio amplifier.

So how do you transmit?

First of all, there will be a complete alignment section presented later on, so don't worry. The audio amplifier loses his power and now the microphone amplifier is turned on.



Our microphone signal get mixed 'modulated' on the sideband oscillator. Because it is a single balanced mixer the sideband frequency gets attenuated. We need to get rid of the 'carrier' right. The signal out of mixer 2 has both sidebands.

How does the single balanced mixer work? Watch the YT clip from M0NTV. Nick does a great job explaining balanced mixers.

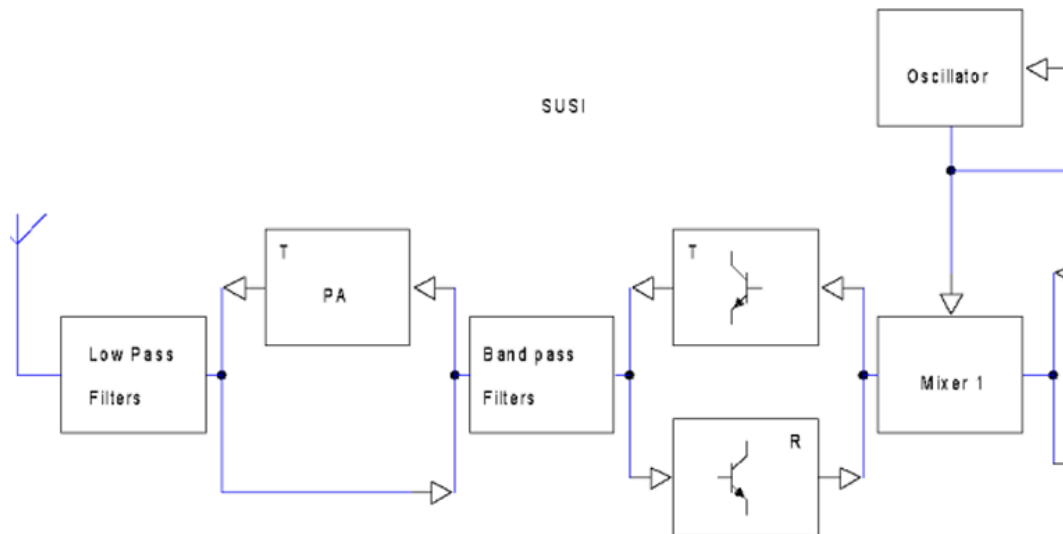
📺 20 - Double Balanced Diode Ring Mixer

What do we put in our Axiom box? A **single balanced mixer attenuates the oscillator signal**. So the 11 MHz oscillator signal would become the carrier but the mixer suppressed it. Therefore only the two sidebands come out of mixer 2. A DSB signal, double sideband signal.

Next our signal flows through the crystal filter. Here our signal loses one of the sidebands (we already lost the carrier in the mixer) and a **SSB signal** of 11 MHz comes out of the filter. Now we need to shift to an actual HAM band. First another IF amplifier and the signal goes to the mixer to be shifted to the HAM band.

The mixer is double balanced so that the band filter gets it easier. **The double balanced mixer attenuates the oscillator and also the RF and IF ports**. So our band pass filter will not see 11MHz (IF) and 18,1 MHz (oscillator). Is a double balanced mixer really necessary? Later on we will look at IF frequencies and see that it simplifies the choice if the oscillator and IF frequencies are attenuated.

Out of the mixer now comes only two signals. We only want Oscillator minus IF. For instance $18.1 - 11 = 7,1 \text{ MHz} = 40\text{M band}$.



The signal gets amplified again before feeding it into the band pass filter. It is an important task! It must attenuate the oscillator + IF signal. $18,1 + 11 = 28,1$ MHz and let through 7,1 MHz.

Once that is fixed the signal goes to a 5 Watt linear and on air.

In short, the single balanced mixer gets rid of the carrier, the crystal filter gets rid of one sideband and we have SSB.

Before we go into the details we are going to give the stage to my true passion. Mechanics.

Mechanical construction for SSB, or how to prevent a monster from being born.

“Sideband must be shielded, sorry” A direct quote from ‘Crystal Set to Sideband’ from K0IYE. **RF feedback** is one of your main worries for your homebrew SSB rig. I took Frank’s advice to heart and shielded rigorously from the start. Every circuit block in a separate tin can. Over the years I got many complaints but never a ‘You have RF feedback problem’ So my advice is **follow Frank’s advice**. How do you shield every circuit? Tin cans on a ground plate.

Some readers will think at this point ‘Mister so-called ON1MWS thinks his rigs are the next amazing thing since the Antikythera Mechanism, when in reality they look like he tripped over his feet in the shack, with his scrap bin in his hands, landed face first on the chassis, and then declared the mess ‘mechanical folk art’

Fair enough! Just get cans or buy them from amazon/Aliexpress and mount them in a perfectly normal square or rectangular box. Or build boxes out of copper clad PCBs. Whatever, shield every circuit.

What is the bare minimum for shielding?

As I shielded rigorously I can’t quite say for sure. But enclosing the complete SSB transceiver in a metal box is obviously necessary. Shielding the oscillator and sideband oscillators inside your enclosure isn’t so much trouble, so why not.

What shielding is essential?

All connections from your microphone to the microphone amplifier. Everything must be shielded! RF will leak in while you transmit and you will get roasted on air. Below a picture of how rigorous I built it.



There is no microphone input on the front panel. The 3.5mm microphone jack is located in the microphone tin can. The absolute best way possible. If you use a 'normal' enclosure and you mount a microphone input on the front panel, don't forget the connector **immediately to the metal chassis** (remember our pin1 problem from chapter 3?).



The elktret microphone also has the shortest connection possible as you can see. Cable is a LICY but a shielded audio cable will be fine. The cable **must** be shielded.

Avoiding a heroic battle.

Frank KOIYE describes a heroic battle against RF feedback in CSTSB. I did not have any problem because I took his battle as a serious warning. I shielded every single separate circuit block and am very glad I did.

- Must shield, microphone input, complete transceiver, PA stage.
- Optional shield, oscillator, sideband oscillator,
- Luxury shielding, IF amplifiers, mixers.

The problem with the optional and luxury shielding is that it can be hard to fit afterwards if you are suddenly exposed to all sorts of weird glitches. Retrofitting usually results in anger management problems.

Doing it my way and **taking no chances** is best. Any RF feedback will lead to 'mystery' glitches that you won't be able to solve. Your SSB project will end in the attic eating dust. The tin cans I used were bought from Amazon and are not pure aluminium but an alloy. The shielding of these cans is not optimal as we have seen in chapter 3. But my rig is proof that they shield enough.

Layout.

Pretty simple for our design.

You can route any audio signal as far as convenient but use shielded audio cable.

Any 50 Ohm signal can also be routed with 50 Ohm cable. There are not so many 50 Ohm connections. Basically only the connections from the input filter to the antenna and PA stage. And from oscillator to the mixer. I will point them out as we go through the schematic.

All other connections must be as short as possible. So lay out your circuit blocks along the signal path.

Encouragement.

The three difficulties for scratch building a SSB rig are, getting your modulation right, getting the bandwidth of the crystal filter right, and avoiding RF feedback. If you start off with good (maybe over the top) shielding and sensible layout, **you already won 1/3 of your battle.**

Practical construction.

My advice would be, follow the lead of the CW rig we have seen in chapter 5. Build a **configurable** SSB rig. Get some super cheap edge card connectors on Aliexpress and build copper clad PCB for your bandpass filter, crystal filter and even the crystals of the sideband oscillators. The low pass filters for the QRP linear can also be plug-ins. This will save you a massive amount of **teeth grinding work** (and money)

At least I have the plug-in low pass filters for the PA. Which are interchangeable with my CW rig (chapter 5)

This way you can start off with just one band. Build one plug-in 11 MHz crystal filter (good for all bands except 15M) and one plug-in 40 M band pass filter. If you are considering the 15 M band, also plug-in 11 MHz crystals for the sideband oscillators. Later on you can make plug-in's for 20M or whatever band you want.



If I had to do it over, that's the way I would build it: a **configurable** SSB rig. A rig that saves me a lot of boring wiring. In fact, I only ever use 40 m, and only switched to 20 m once, just to prove to myself that it actually works.

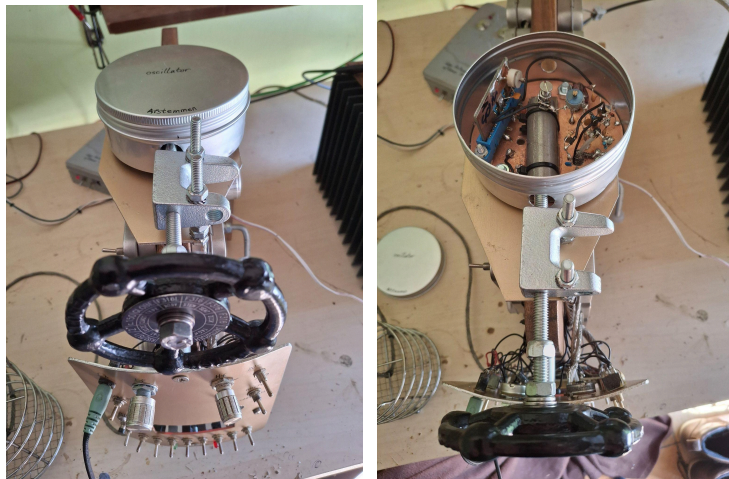
Now we are ready for the intricate details, let's start off with the oscillator.

Can I use a DDS module? Certainly, this chapter will try to give a reader a reasonably simple but well performing SSB circuit, an alignment procedure and a path for RF PA circuits. The chapter is not meant to turn you into an analog monk.

The oscillator I use is the oscillator presented in chapter 2 'the gateway challenge'. Just check out chapter 2.

17M	60p	220p	470p	7MHz	11 Mhz
15M	40p	47p	47p	13Mhz	8 Mhz

The oscillator features a homebrew tuning capacitor.



There is a description in chapter 3 on how to build these.

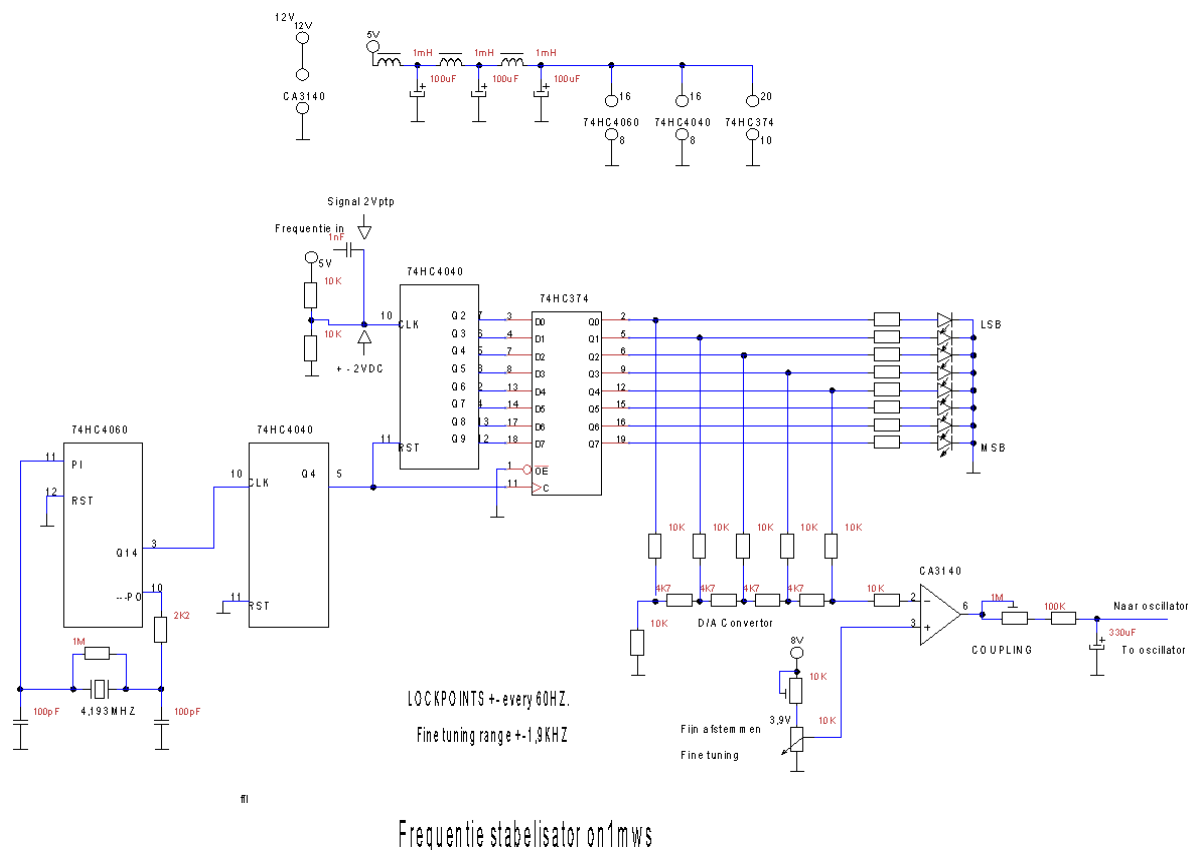
The hot side of the capacitor is a steel tube with an inner diameter of 12mm. The ground is a M8 threaded rod. As the rod gets turned in or out the tube, the capacitance changes. The capacitance is about 10pF. The rod is driven through a steel beam bracket. This bracket has two M8 holes on both sides. The bracket provides a 54:1 gear ratio.



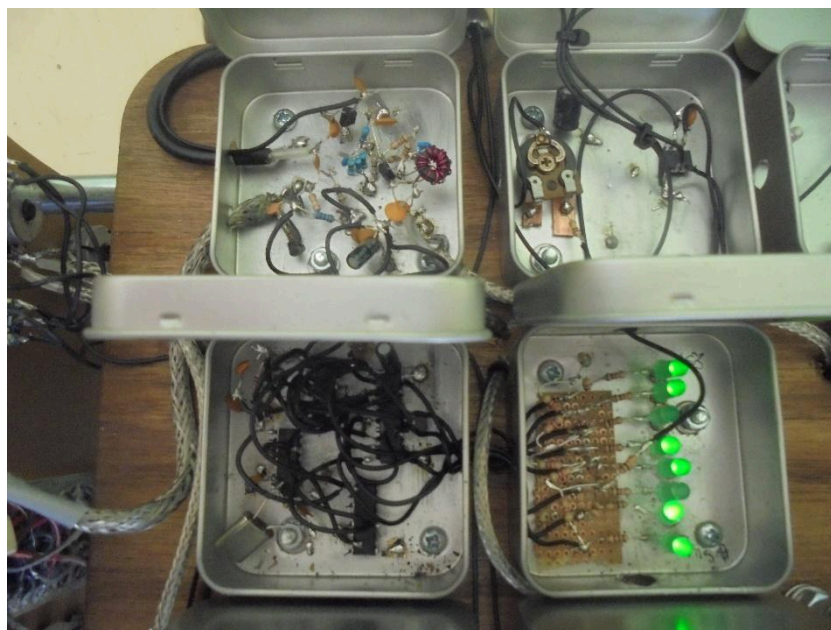
The homebrew capacitor works very well. It is just as good as a commercial one but a lot cooler.

But there are so many arrangements that work as we have seen in chapter 2. And have seen how to tinker with the oscillator.

The wide range oscillator from the gateway challenge will work fine here. My advice would be that if you have a 1950s 450 pF air capacitor, build the wide range oscillator. If not, work with the capacitor plug-ins and fine tune with a 1N4001 diode. 200 KHz tuning is plenty for a HAM band



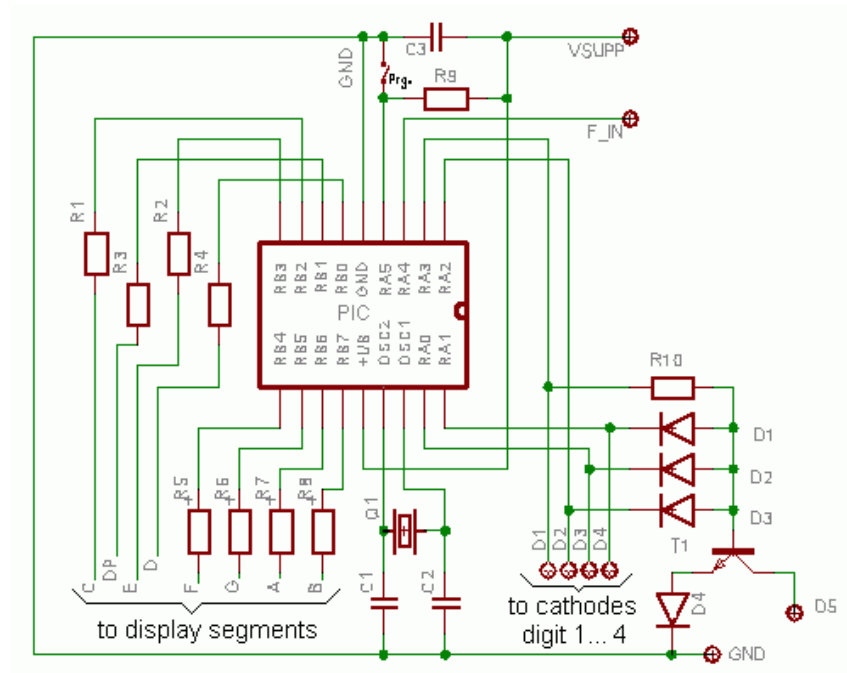
The frequency stabilizer is the SuSi, see for more info chapter 2 or the dedicated page on my QSL page. This version is slightly different and uses 5 bits.



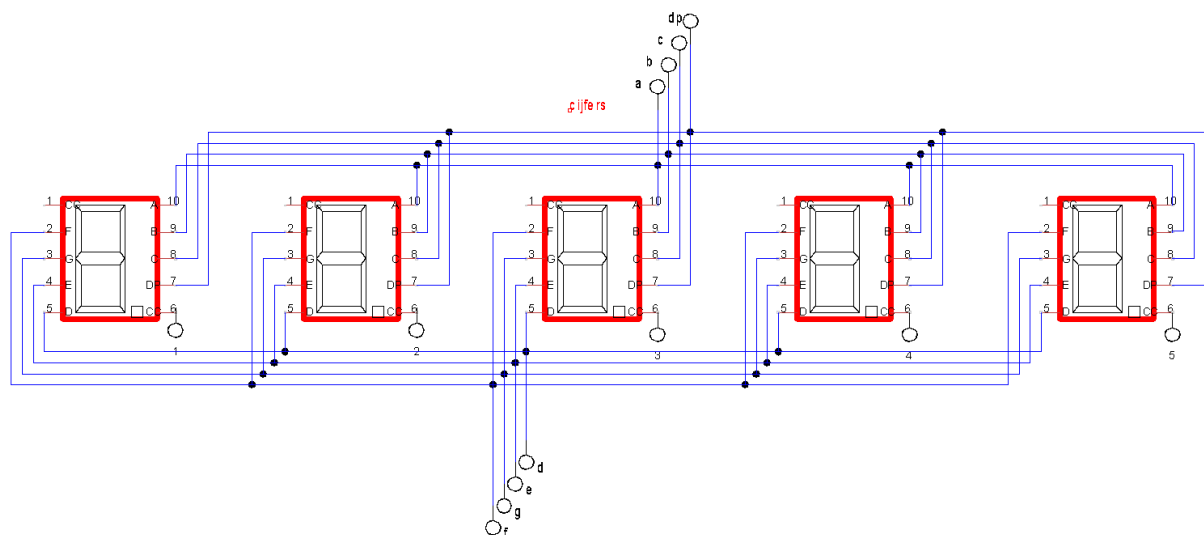
That's it, either use an analog oscillator or a DDS module. Whatever you use **it must be shielded** and connected with 50 Ohm coax to the mixer. Don't forget about RF feedback.

You probably noticed the frequency display on the front panel? About that...

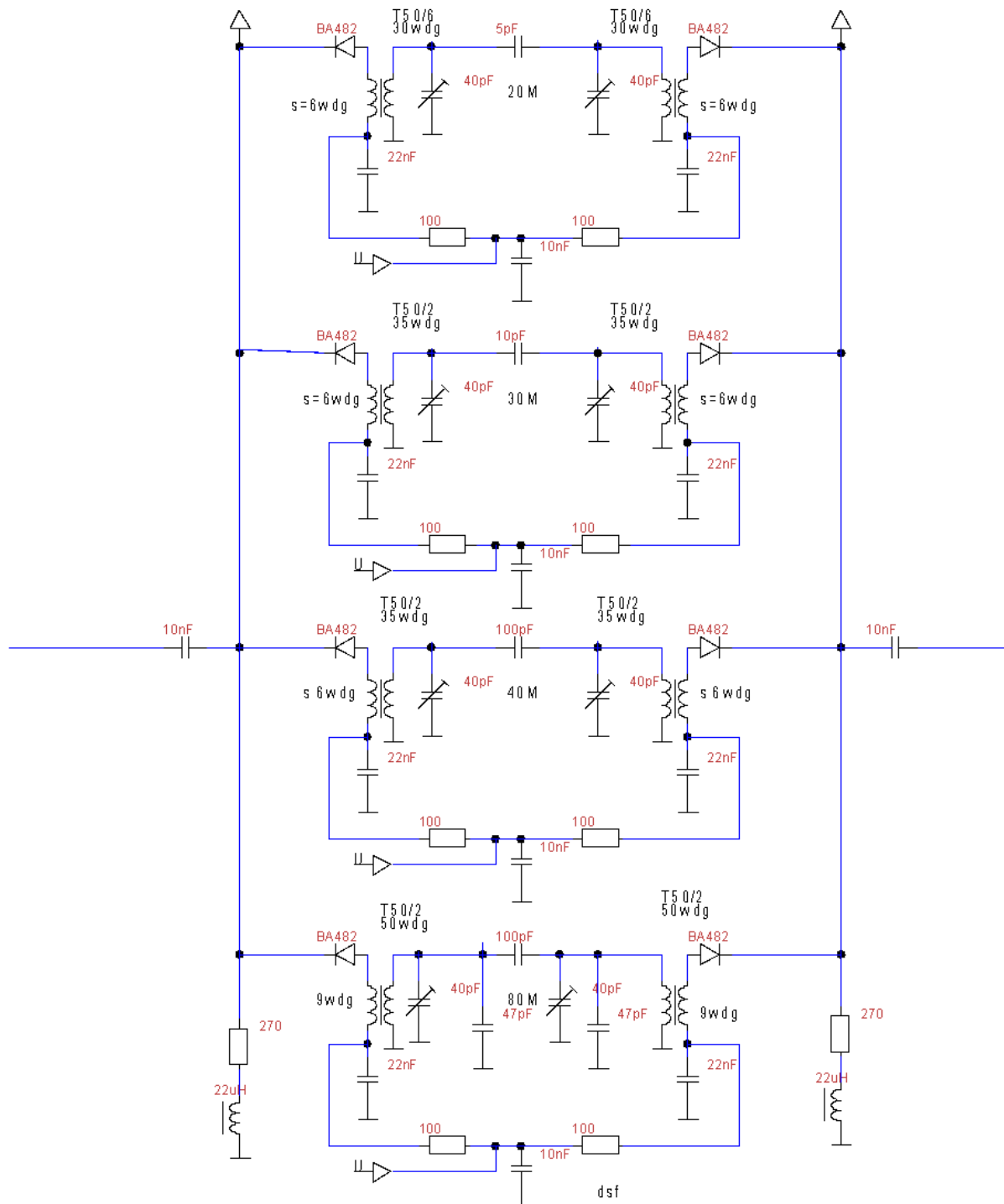
It is a design from dl4yh. All info on his webpage, including the software.



Component values for variant 2 (as shown above): R1...R8 = 1k, R9=R10=10k, D1..D4=1N4148, T1=BC547 or similar, C1=C2 about 22pF (select them to tune the crystal to exactly 20 MHz), C3=100nF, Q1=20 MHz, PIC: 16F628 programmed with firmware "counter2.hex".



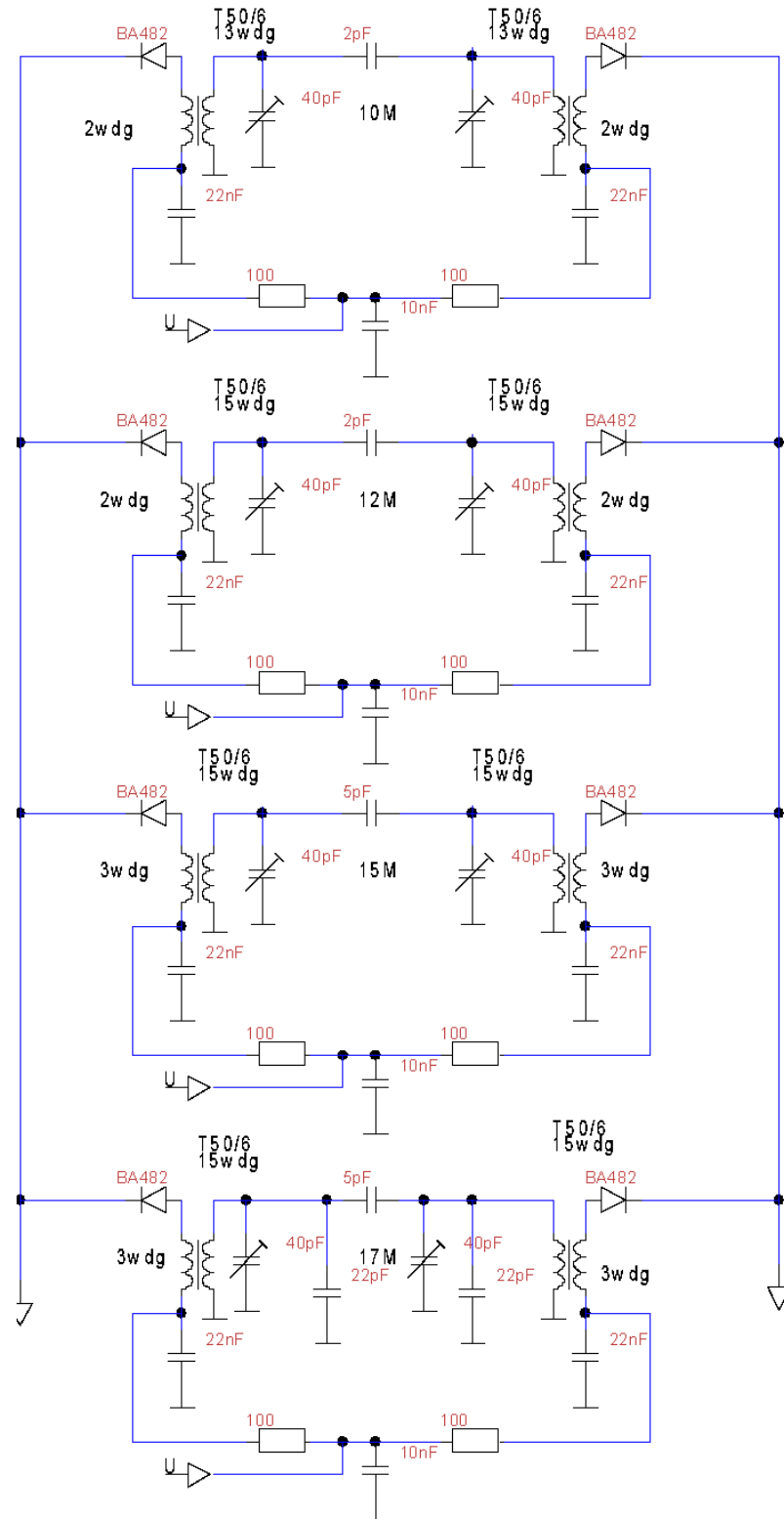
And now for the actual SSB circuits.



My transceiver has all band pass filters built in. They are switched with PIN diodes. Much easier than with an actual switch on your front panel. This would require a massive amount of 50 Ohm coax cable. You will not love this job! And it will take a massive amount of space. If you really want all the filters, switch them with PIN diodes. Then the band-switch can just switch two diodes on with just +12V power. This is how the arrangement works, two of the diodes switch on and the RF frequency gets a free ride through. You can not substitute PIN diodes with 1N4148 diodes. Ordinary diodes don't 'close' enough. PIN diodes are very well explained in 'Secrets of RF circuit design' by Joseph J Carr.

Honestly, don't copy it. Get some cheap edgcard connectors and make your band pass plug-ins. Saves you a lot of trouble and work.

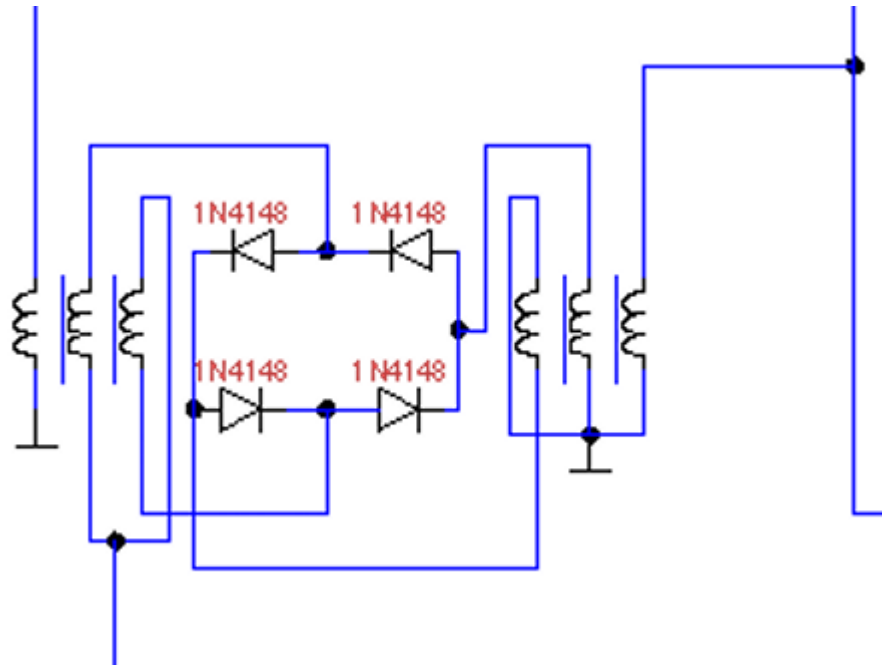
If you try to switch all bands with 50 OHm coax and a front panel rotary switch, you will discover **new forms of suffering**.



dsf

HF amplifier, mixer 1, and first IF amplifier.

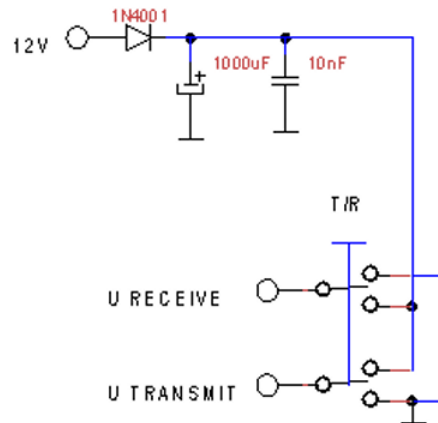
The double balanced mixer is also identical. 1N4148s works well but now I use real scotch diodes BAT47s. Do they perform better? They should do it. Do I notice any difference, no. The input of the oscillator frequency is done via a 50 Ohm attenuator. So that is no discussion about the input impedance. The oscillator must turn the diodes on and off. Ideally the oscillator signal is about 1.4 V_{ptp}.



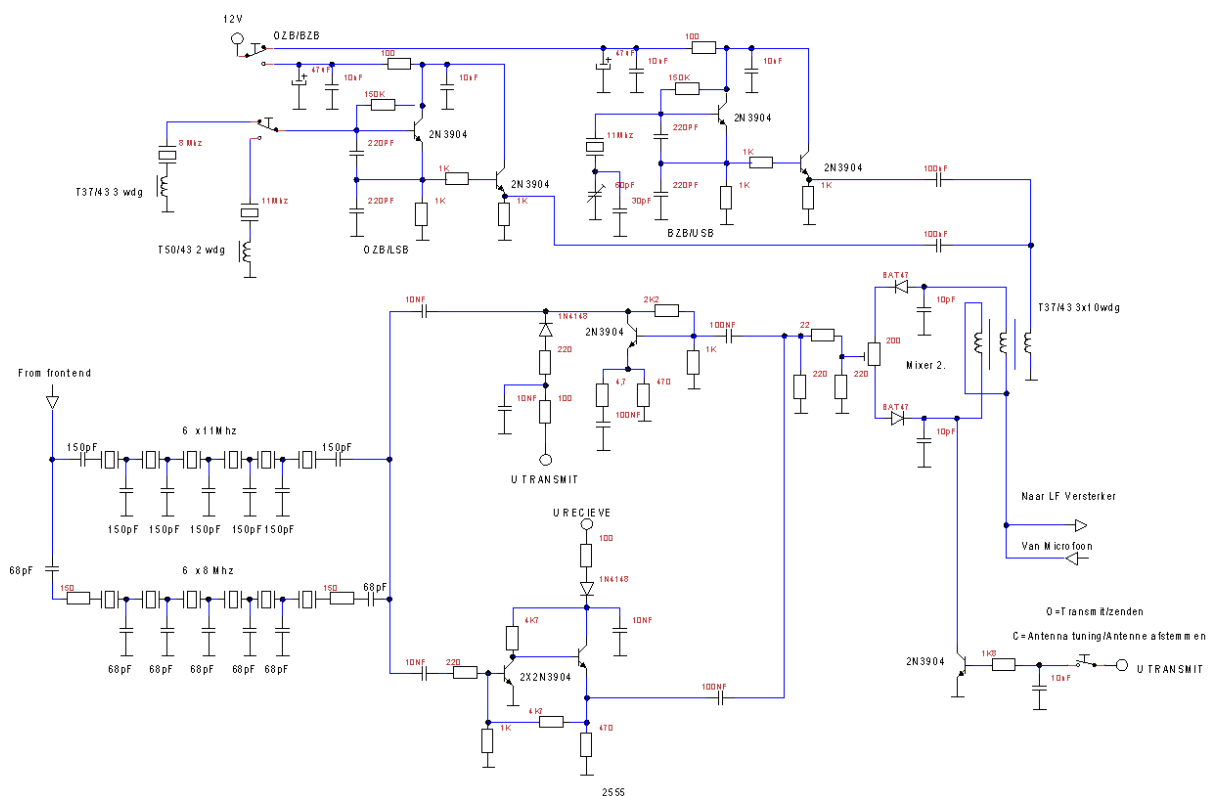
take good care that you build the mixer right. It will be important for canceling the carrier.

The amplifiers are not 50 Ohm, 50 Ohm out. So all connections must be short wired. The connections between the bandpass filters and HF amplifier are also short wired in my rig.

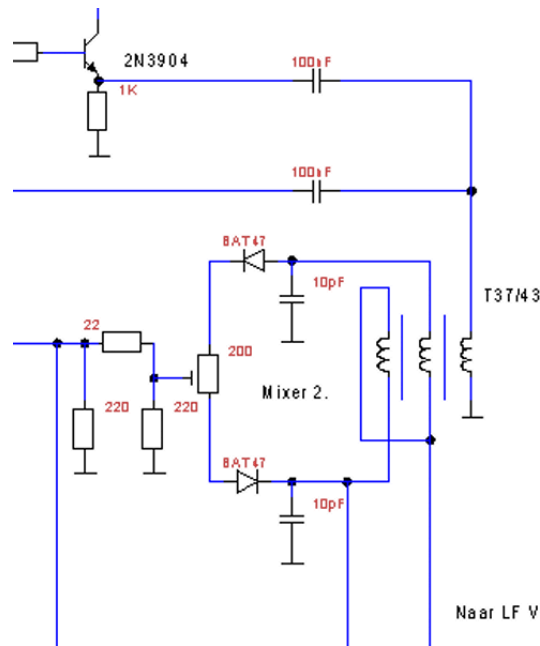




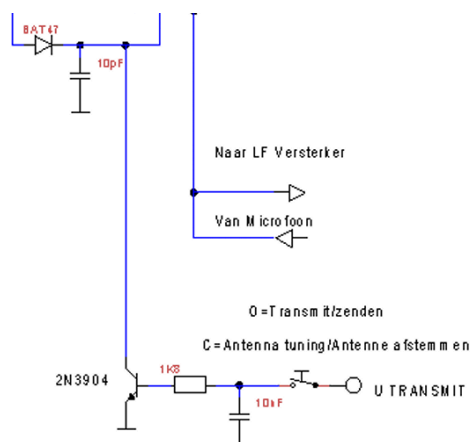
Notice the T/R switch. Wired it like this and does not use the arrangement of the original BITX schematic. Every time I switched there was a momentary short. My oscillator really did not like that! Remember the cool on/off LED from version 3 in chapter 4? This was worse. The diode prevents damage if you accidentally connect your power supply the wrong way. Don't leave it out.



Now we arrive at the crystal filter and second IF amplifiers. The amplifiers are also identical to a BITX20A. But I used my own 'Lego' block for the sideband oscillators. They are just selected by a power switch, neat. Mixer 2 is an identical copy of the mixer in a BITX20A.



The utmost care must be done while you build the second mixer that you get it right. Again you do this to attenuate the carrier. Consider that the diodes are 'switches' turned on and off by the oscillator signal. The signal is about 1V_{ptp}.



This feature does not appear in the BITX. What does it do? when you close the switch the transistor will conduct. The mixer will be unbalanced and the sideband frequency will get through. The base resistor of the transistor will determine how much. This will be amplified to the antenna.

So the switch has two settings: 'microphone' and 'continuously'. On continuously you can tune your antenna to a good SWR before transmitting. It must be fed with U transmit. What can happen if this switch is connected to the main 12V? It can accidentally be closed while receiving. Result: no reception. Been there, done that. And it ruined my weekend.

The importance of the intermediate frequency in a SSB rig.

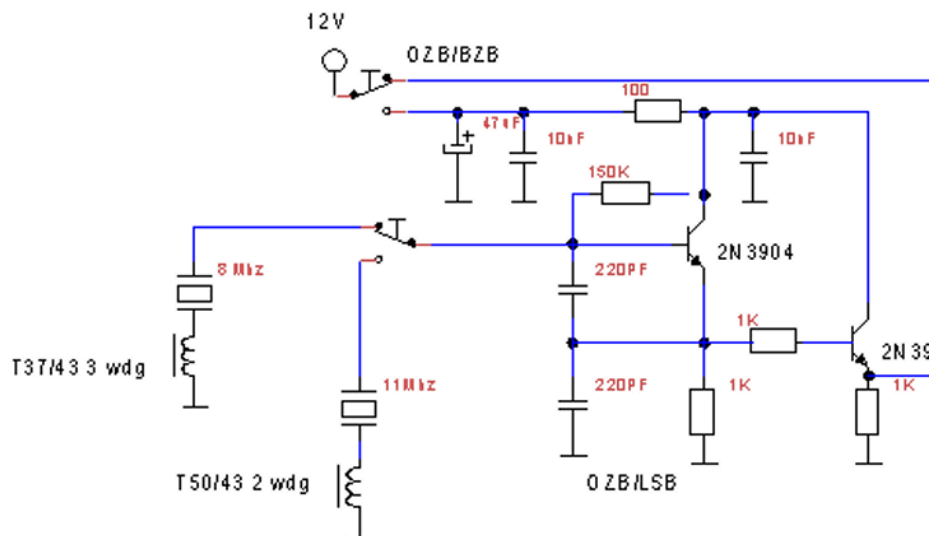
So what is that second crystal filter doing? We have glanced over a very important function of the band pass filter. Yes they filter out the frequencies you wanna hear, but they do more... Say we transmit on 40M. The frequency is about 7,1 MHz. The mixer will also produce oscillator frequency plus IF, that is 28,1 Mhz. Yes it is a double balanced mixer but still there will be leakage of IF and oscillator frequency to the bandpass filter.

Our 40M band pass filter gets confronted with: 7,1 MHz, 11 MHz, 18,1 MHz, and 28,1 MHz. The band pass filter must reject everything the mixer throws at it. 11 (IF) and 18.1 (oscillator) are already greatly attenuated because mixer 1 is double balanced.

The nearest unwanted frequency is 11 MHz. No problem for our 7,1 MHz band pass.

The IF must be chosen so that the nearest **unwanted** frequency is as far away from the band pass as possible. Far enough that the band pass filter will attenuate it.

11 MHz works for all bands except 15 M. Please don't ask me to do the calculations. An IF of 8 MHz works for 15M. That's why there is an 8 MHz crystal filter. The design luckily allows for the two crystal filters to be placed without switches. And that is also why there is an 8 MHz sideband oscillator.

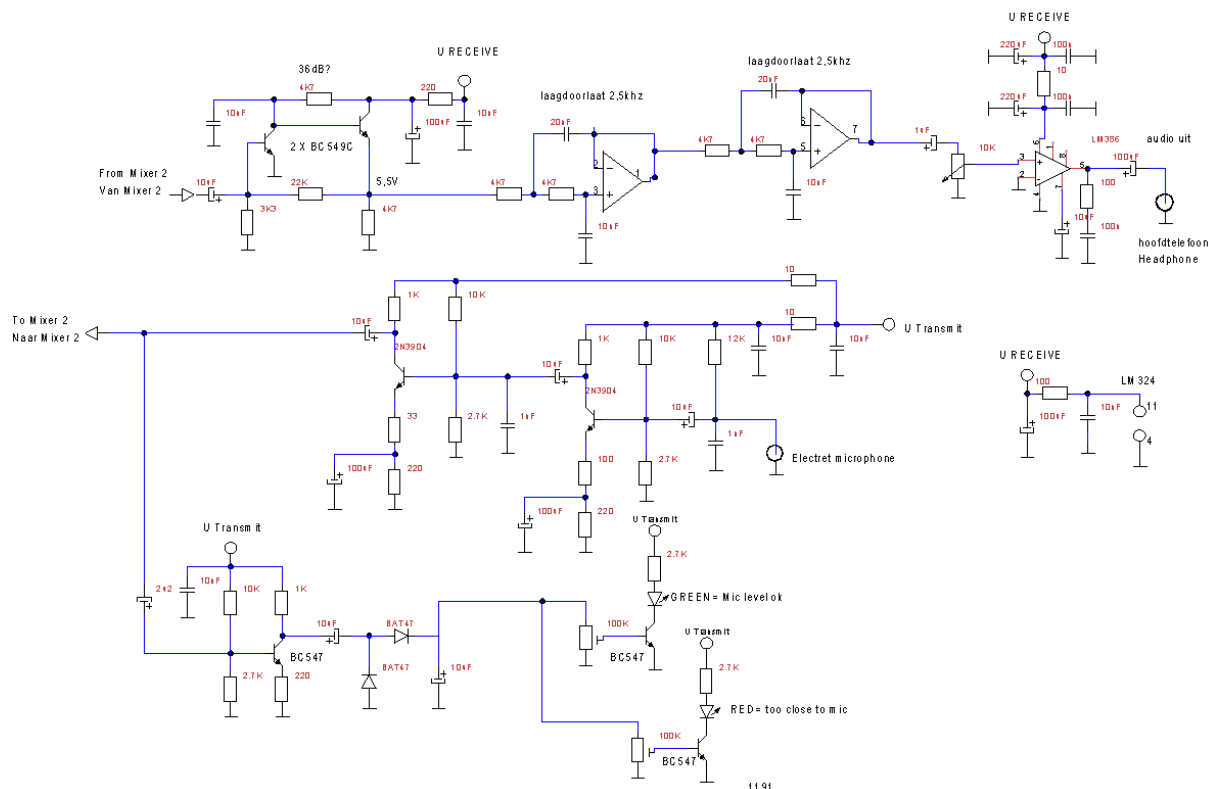


As you can see I use a switch to select between the 8 and 11 MHz crystal. The switch is located on the sideband oscillator tin can. The switch has a severe influence on the frequency. 1KHz as I remember. If you don't use the 8 MHz oscillator and leave the switch out your coil (that lowers the frequency) will probably need more turns.

I recommend leaving out the coil, and do the first start up without. That way you are sure that your oscillator works well. Remember that with too much windings on your coil the oscillator won't start up at all.

Add the coil afterwards. How to align the sideband oscillators will be explained in a **detailed separate section**.

audio filters en versterker



Moving on to audio. From now on you don't really need to layout everything close by. You can use wires or preferably shielded audio cable.

First stop the dual BC549 amplifier. The original BITX uses 2N3904s but I swapped them for low noise BC549s. Is that better? Who knows? The amplifier gives 38 dB amplification which is a lot of the overall amplification. The first audio preamplifier was made from a LM324 opamp. That was a mistake. An LM324 gives you a lot of noise. They add garbage. Replacing it with the double BC549 amplifier changed the reception from 'Meh' to 'super'. If you want to use opamps, TL081s and TL071s should be fine.

The opamp is DC coupled with the BC549 amplifier. It is not a 'stand alone' stage. It only works when there is a voltage on the 4K7 resistor. This is provided by the emitter of the second BC549. Remember this when you test it.

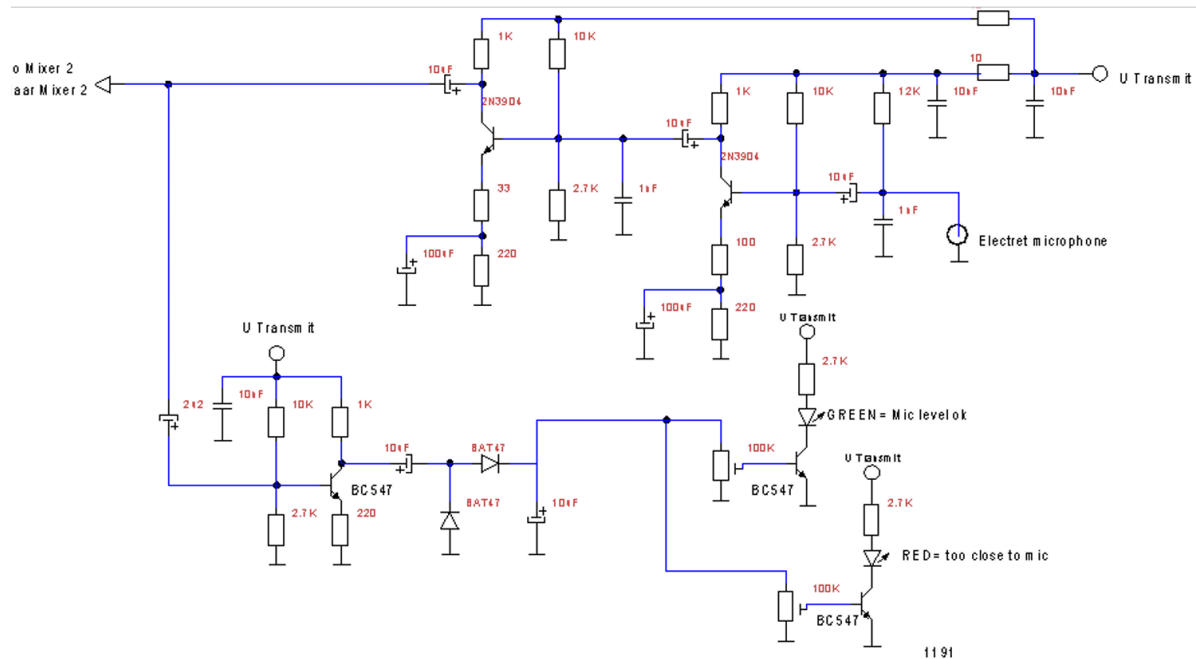
Followed by a two stage 2,5 KHz audio low pass filter opamps. One of my Lego blocks. The values were calculated with an online calculator. You can leave them out because the crystal filter will be shaped for 2,5 KHz anyway.

Last comes a LM386 LF amplifier for your headset. LM386s can be very temperamental. That's why there is a 10 Ohm resistor in series with the power supply. Calm it down! The volume pot is 10K log. Don't take higher values out of your junkbox. The LM386 will be unhappy and drive you crazy.

Another glitch was a weird popping sound when the volume pot was turned down to zero. Not crucial but an annoying glitch. Took me years to figure that one out. It was interference from my local nemesis, the FM tower in Egem. A capacitor of 10nF soldered directly over pin 3 of the LM386 cured that. It shorts all RF signals but lets LF through.



Moving on the microphone amplifier. This is the microphone amplifier. Treat it with respect. It can turn a perfect SSB rig into a farmyard of squeals. The original BITX has one transistor. I needed two to reach an acceptable level.



The mic I use is a salvaged elektret microphone. To make it work it needs a pull-up resistor. That's the 12K resistor. Both amplifiers are copies from the BITX schematic. First build one, if the amplification is too little, build a second one. **Use a trimmer of 150 Ohm** in the place where you see the 100 Ohm **emitter resistor** of the first transistor. The schematic is wrong! You need to be able to set the gain. **Your aim is that if you speak in your normal voice at about 2 a 3 CM the signal in your crystal filter is just not clipping.** If you use a larger amplification and therefore you have to hold your mic further away you amplify too much of your 'room' and get complaints. The 1nF capacitor paralleled over the mic has an important function. It must short whatever RF gets in, to ground.

A feature that the BITX does not have. An amplifier that amplifies the microphone signal. This is rectified and goes to the two BC547 LED switchers. They switch two LEDs. One green 'ok' and the red one 'clipping'

How to adjust and align everything is explained in a separate section.



The microphone was salvaged from a 1980s cassette player...

Practical construction continued.

I would recommend doing exactly as with the holiday radio and CW rig and build it from back to front. So you can first test your LM386. Add the BC549 stage, The low pass filters, think I used TL072s. Test them together. Thinking the input of the BC549 stage should result in some serious hum.

Remember our good technicians practice from chapter2! **A good technician double checks his work as a minimum.** Solder the circuit block one by one, and get your magnifying glasses out after every circuit block. Check every single solder joint and check the pinout of the transistors and opamps again. Be sure that the output of an opamp is not shorted to plus or ground. **Double checking will save lots of problems.**

The voltages on the 2N3904's should be around,

- 7,2V on the collector.
- 2V on the base.
- 1,4 on the emitter

All voltages can be checked after first turn on.

The voltage on the 4K7 emitter resistor of the last BC549 is about 5,6V. Therefore the voltages on the opamp will also be 5,6V.

Take great care in making the toroid transformers for mixer 1 and mixer 2. I try to use different colours to make it easier. Usually I first connect all the ground wires to ground and connect the oscillator input. From them mistakes are less likely. All the mixer transformers must be correct. There will be no carrier suppression when you mess the winding up.

 #166: How to wind a trifilar toroid transformer for a diode ring mixer I did find this YT clip on the W2AEW channel. Most KIT builders will have experience with winding toroids.

 20 - Double Balanced Diode Ring Mixer MONTV. My diodes are not matched. I am too lazy for that.



Mixer 1, mine are not as beautifully built but beauty does not matter. The 4 diodes are out in the breeze.



Same for mixer 2.

Then build the amplifier from mixers to mixer 1 and the amplifier to your band pass filter.

You can check mixer 2 by putting your oscilloscope probe on the 50 Ohm attenuator. While you turn the 220 Ohm trimmer the carrier should appear at both ends and disappear close to the middle. If not, the windings are wrong. Same for mixer 1. The large oscillator should hardly be seen before and after the mixer. If not, again your windings are wrong.

If all works well and you connect 11 MHz (IF) to the antenna input of your working rig on receive, you should be deafened.

Your SSB rig now produces a clean SSB signal, but only milliwatts. Time to make it heard. Enter the QRP linear.

There are two stages.

But you also see a switchable copy of the 2N3866 stage with a 2N3904? Why, turned out that I did not have enough power above 17 M. For those frequencies I needed extra amplification. I have to be careful because this extra stage causes the linear violent oscillator on lower bands like 40 and 20M. I have a sneaky suspicion that my 2N3866 is not a real one but a fake. Just leave the 2N3904 out if you are not going above 20M.

Notice the transmit / receive relay. It is obviously switched by the T/R switch.

Notice also the 1K potentiometer. '**RF Gain**'. Absolutely necessary as we will see in the alignment section.

A QRP linear can also use a **DC** Ampere meter to monitor how things are going. The are cheap on Aliexpress.



The actual linear is built around a DU1215S. With no examples on the datasheet or the internet I 'invented' the circuit. Which is easy with FETs.

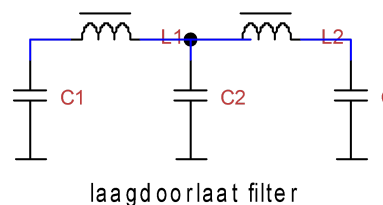
Idle current is set at 100mA.



My DU1215S in an old pencil case. Heathsink is behind it.

I would advise to make it yourself very easy and use plug-in Low pass filters in edge card holders. Cheap on Aliexpress.

Plug in low pass filters for the QRP linear.



80M = C1,C3= 660pF C2= 1600pF. L1, L2= 20 windingen/turns op T50/2 (rood).

40M = C1,C3= 430pF C2= 860pF. L1, L2= 15 windingen/turns op T50/2 (rood).

20M = C1,C3= 220pF C2= 440pF. L1, L2= 12 windingen/turns op T50/6 (geel).

17M en 15M = C1,C3= 110pF C2= 150pF. L1, L2= 9 windingen/turns op T50/6 (geel).

12M en 10M = C1,C3= 95pF C2= 190pF. L1, L2= 8 windingen/turns op T50/6 (geel).

The DU1215S used to be affordable, expensive when I bought it (40 Dollar) and **is now obsolete**. My design is a dead end. We will have to look for alternatives.

Alternative suited for novices and to have lots of fun.

My very first linear for my CW rig back in 2014, was made with a dirt cheap single IRF 510 FET. On 40M it nearly turned out 9 W. And about 5 W on 20M. Ok, IRF510 doesn't do well above the 20M band but where is the fun? 20M and below.

To put the IRF510 into perspective. This FET was never meant to be an RF power FET. It was meant to switch currents. Some fellow one day found out that you can build a modest HF linear around it. They are dirt cheap.

In 2014 I probably bought 20 of them and blew half of them up before I had a working single ended linear. Who cares, I paid 30 cents for one IRF510. **If you're not blowing them up, you're not learning.**

Why don't they work well beyond 20M. The gate capacitance. The IRF510 was designed as a switching MOSFET, not an RF device. Its gate behaves like a big, slow, heavy capacitor that your driver must charge and discharge every RF cycle.

Manufacturer values (typical):

Input capacitance $C_{iss} \approx 135 \text{ pF}$

Reverse transfer capacitance $C_{rss} \approx 35 \text{ pF}$

Output capacitance $C_{oss} \approx 45 \text{ pF}$

These numbers vary with V_{ds} , but they're in the right ballpark. What this means in RF terms

At 7 MHz (40 m), 135 pF is annoying but manageable.

At 14 MHz (20 m), it's borderline.

At 21–28 MHz (15–10 m), By 10 m the IRF510 is basically a polite heater.

Why? Because the gate capacitance forms a low-pass filter with your driver impedance.

The reactance of 135 pF is: $X_C = 2 \cdot \pi \cdot f \cdot C$

At 7 MHz $\rightarrow \sim 170 \Omega$

At 14 MHz $\rightarrow \sim 85 \Omega$

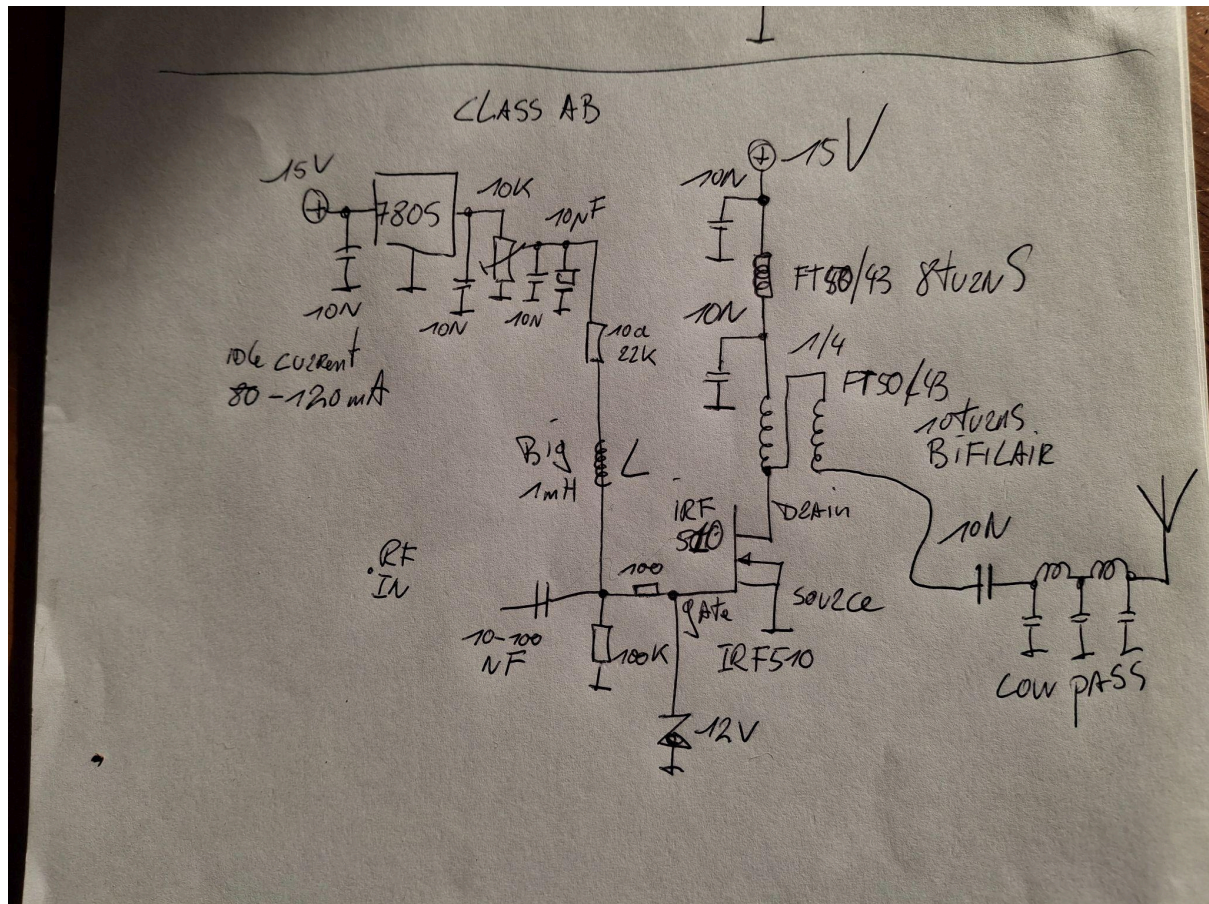
At 21 MHz $\rightarrow \sim 57 \Omega$

At 28 MHz $\rightarrow \sim 43 \Omega$

By 10 m, you're trying to swing RF voltage into something that looks like a 43 Ohm. That's why the IRF510 turns into a warm, slightly embarrassed resistor.

However it does work well up to 20M. And I can't emphasize enough how cheap they are. If you never build a QRP linear, this is where you start.

The original 2014 schematic is lost in time so I used copilot to construct a single ended IRF510 linear suitable for SSB.



This is what Copilot came up with. Looks reasonable to me.

A trimmer sets the idle current, The idle current should be set between 80 and 120 mA.

A small resistor on the gate prevents oscillations.

On the drain a 1 to 4 impedance transformer. The drain sees 12 Ohm, the antenna 50 Ohm.

Power expectations.

40 m: 6–9 W

20 m: 4–6 W

15 m: maybe 1 W

10 m: warm air

Notice the 12V zener, apparently to prevent spikes. I am not sure if my 2014 IRF510 linear had that? Can't hurt.

The output transformer can be built on a common FT50/43 Amidon core.

Very important is that the RF does not reach your 10K trimmer. Use decoupling Cs (10NF, 10uF) and possibly a large coil in the Bias feedline. Values don't matter much. Just check

with your oscilloscope on the trimmer that there is no RF to be seen. Any RF there will make the linear unstable.

How do you set the idle current?

- Put a resistor in series with the power supply. I use 10 OHM/10 W. Turn on the linear with NO Rf and the trimmer to ground.
- Slowly increase the voltage on the gate.
- At a certain point you will see the voltage over the resistor rise. It will be abrupt!
- Set the trimmer so that the voltage over the 10 Ohm trimmer is 1V. $I = U/R$ $1/10$ 0,1= 100mA.
- What happens when you increase the idle current too much? The IRF510 will be destroyed instantaneously. However the 10 Ohm resistor will prevent that! A current of say 1 Amp already drops 10V over it. The resistor smokes but the IRF will survive.
- Nevertheless you will blunder and blow some IRF510s up. **But that is leaning!** They only cost half a coffee so you will keep laughing.

The power supply for this QRP linear will have to be between 12 to 15V and must be capable of delivering 2 Ampere. It will never draw 2 Amps but you need a safety margin.

Remember that the heathsink body of an IRF510 is connected to the Drain. So it has to be insulated on your grounded heatsink. There are special sets for that.



An alternative is ripping the insulating plastic that cheap switching supplies use and use it yourself. In my power supply the transistor is squeezed by a piece of scrap metal, yes scrap, against the heatsink. With the plastic in between to insulate. I also used heath conducting paste. It looks horrible but the commercial sets are annoying things to install.

Now you can graduate to a RD06HHF1 or a RD16HHF1.

Once you have experience in not blowing IRF510s up you are ready for the next real HF device. We will go **more in detail** about the RF semiconductor crisis in 2026 in the next Boss.

For now it's enough to say that the first affordable RF FET in 2026 is the RD06HHF1 (6W) or RD16HHF1 (16W). They are readily available and the price is about 10 to 12 dollars. Relative cheap but you don't want to blow ten of them up. That's why I advise you to play with the IRF510 first.

I again asked Coplit to design a SSB QRP linear.

You can use the same schematic as above! That's convenient. Idle current must be set at 150 to 250mA for the RD16HHF1 and the expected output power is minimum 8 W Maximum 16W. Unlike the IRF510 The RD will keep performing up to 10M.

Resist the urge to answer a CQ.

So here we are. The linear works, you suspect that both of your mixers work as they should. Every amplifier has the right voltages, You are hearing HAMS on receive. When you speak in the microphone a SSB signal in transmit mode, a SSB signal is visible on your dummy load. You might think 'Ok, that's sorted' and answer a CQ.

Your only hope then is that the fellow does not catch your callsign. The roast will be the same but if he catches your call sign, it will be more personal.

The alignment ritual, what the magazines almost never tell.

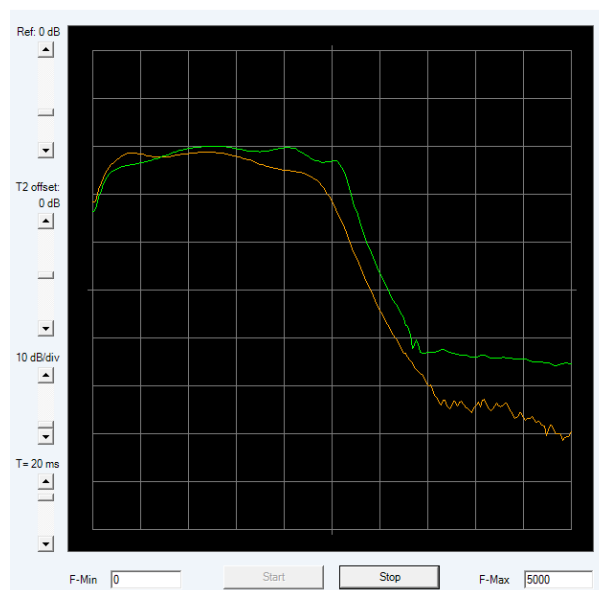
We have basically a working SSB transceiver but now comes the part few articles actually explain. We have to fiddle with a lot of adjustments. I am going to assume that we have configured our SSB for 40M.

- 1) Our oscillator frequency must be attenuated to relieve our band pass filter. How do we check? Put your probe on the input of the first mixer. The signal should be huge. 1,4 V_{ptp}. Now put the probe at the end of your crystal filter near the second IF amplifier. This signal should virtually disappear. If you have wind the two coils of your balanced mixer in the right way, you're done. No adjustments to be done.
- 2) The frequency of the sideband oscillators must also be attenuated. Otherwise they appear as carriers. We don't want that! Hook up your oscilloscope at the end of your crystal filter, close to the first IF amplifier. Turn the 100 Ohm trimmer left and right. If your mixer is properly working (you did not mess up the windings) this should cause the carrier to appear both when you turn left and right. The difference should be dramatic. Just put the trimmer where the carrier is at his lowest point. Probably in the middle. The attenuation of the carrier should be ideally close to 40dB.
- 3) Put the transceiver on receive and hook up a signal generator on the antenna input or use a short wire as antenna to listen to the signal generator and set it to about 7,150 Mhz. Adjust the two capacitor trimmers of the 40M band pass filter to maximum and cleanest output. Achievement? Our band pass filter is in the right ball park. You should be able to pick up stations on 40M with a real antenna.
- 4) Now it is time to check the bandwidth of the crystal filter. Hook up PA2OHH's audio spectrum analyzer to the audio output. The software is free on his website. **Don't forget to bypass the 2,5Khz audio filters** if you have built them! We want to measure the bandwidth of the crystal filter **NOT** the bandwidth of the audio filter. It will take some fiddling with the microphone settings of your laptop to get a good readout on the spectrum analyzer.

- 5) Set your signal generator on 7,150 Mhz and tune over the signal with the transceiver. Set the spectrum analyzer on 'hold' and the maximum F on 5000 Hz. There will be a shape forming that is the bandwidth of your filter. Look at the width of the band pass. It should be 2,5 KHz. If too narrow, decrease the capacitors, if too wide, increase the capacitors.

- 6) Now we are going to set the frequency of the sideband oscillators. You are still listening to your signal on 7,150Mhz. If you have installed the USB sideband oscillator, start with that one as it is the easiest. Tune your SSB over your signal over and over again. Set the USB sideband oscillator frequency with the capacitor trimmer, so that you can hear the upper sideband (if you tune up the pitch goes down) hear zero beat and just a **little bit** of the lower sideband. Yes, don't kill off all of the unwanted sideband!

- 7) It is more work for the lower sideband oscillator as there is no convenient trimmer. Now the pitch goes down as you tune down. You do the same procedure but to change the frequency you will have to lower or increase the windings on the coil in series with the crystal. The sideband oscillator will unfortunately stop if there are too many windings on the coil. Normally you should just reach the ideal setting.



Green is LSB, orange is USB.

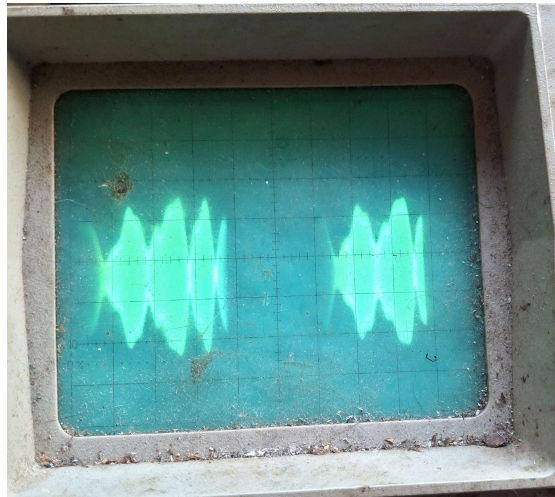
Fiddle with the sideband oscillators and bandwidth of the crystal filter until you have the above result. A nice 2,5 KHz bandwidth and the opposite sideband nearly cut-off. **Don't cut off the opposite sideband completely**, you will have a bad 'sound'

It must be just like the picture above. Why? The crystal filter sideband oscillator combo is not just used for listening it is also used to transmit. The crystal filter will limit your signal to 2,5 KHz.

Remember that your listener will have a waterfall display. If your signal is wider he will love to share '**your problem**'. Are these adjustments hard to do? I don't think so. Just do them when you have time in one go. You have passed the most difficult hurdle when you are past this stage. The setting will work for every band you add. It is a one time investment.

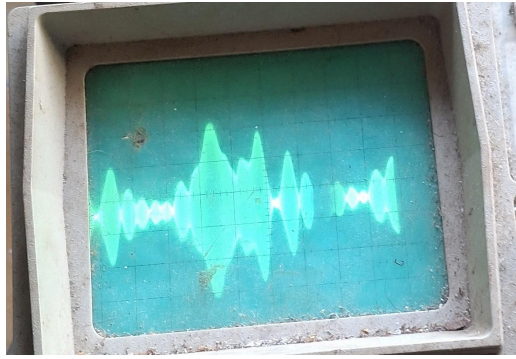
Where are we at now? Now you can easily hook up an antenna and **start listening to HAMS**. But before we transmit we need to get the microphone modulation right. Set the transceiver on transmit and switch to 'continuous'

- 8) We are going to set our voice modulation now. Switch to microphone. Start speaking in the microphone. Your SSB signal should appear on your scope connected on the end of the crystal filter. When you speak loudly, the signal will start clipping. It's easy to see. Set the microphone trimmer pot so that when you speak into your microphone at say **2 CM** the signal is about 0,150 mV in the crystal filter. My probe was set on 1X.

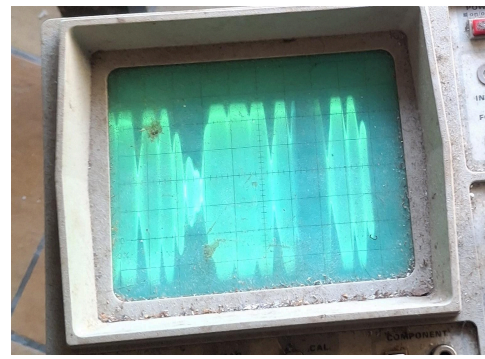


The time base of the oscilloscope was set on 2 mSEC.

- 9) We are nearly there! Speak into the microphone, and watch the signal on your dummy load. Now adjust the two capacitor trimmers of the band pass filter (that are already in the right ballpark) so that the SSB signal on your dummy load looks clean. Switch to continuous, does the sinus look perfect? You will have to do it for every band you add later on.
- 10) Ok, we now have a perfect SSB signal on our dummy load. But we still can **overdrive** our QRP linear stage. So speak again in the microphone and slowly raise the power with the 'RF gain' potentiometer. At a certain point (should be 3/4 of the setting) you will see your SSB signal clip. Adjust your microphone gain trimmer so that the clipping occurs at least at the end of your RF Gain potentiometer.



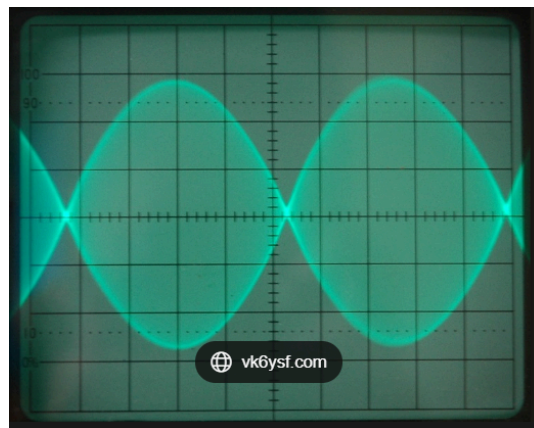
OK



Clearly clipped.

11) Mark the spot with a pen. From now on you will never overdrive your QRP linear again. And adjust the trimmer of the red LED at the exact point where the clipping on your dummy load starts. From now on you will also be warned when you speak too loud.

12) The QRP linear must be working 'linear' so doing the 'two tone test' is a good idea. The test is an intermodulation test. Pfff, I just noted in my Axiom box 'intermodulation=bad'. I did my test years after the rig was working. I downloaded a two tone generator software. Plugged my laptop to the microphone input (pull-up 12K removed!) and injected, according to my notebook 783 and 1365 HZ. The result was ok and looked like this. My notebook does not mention the name of the software.



This is not my result but mine was identical. If you do not have this result, you have a problem. An inadequate idle current of your linear is the most likely culprit.

13) Your aim is to have about 5 to 6, maybe 7 watt of clean SSB signal (40M) on your dummy load when you speak in your normal voice, at 2 a 3 CM into the microphone. When you raise your voice the red LED lights up. With your RF gain pot at about 3/4 of the way. Adjust mic gain trimmer, and red LED trimmer until you have that.

The lack of knowledge of these adjustments cost me four years of complaints. You get them for free.

If it all looks hopeless for you at this point. Let it sink in. Study the block schematic again. The alignment is just 'work'. A SSB chain is just a couple of predictable blocks.

Checklist, no magic required!

Did you shield the microphone cable and the whole transceiver?

Does your microphone amplifier clipping LED light up when it should?

Is your oscillator and sideband oscillator properly attenuated?

Is your crystal filter around 2.5 kHz?

Do you have a clear HF gain clipping point indication on your potentiometer?

Is your two-tone test clean.

Does the SSB signal look clean on the dummy load when you speak into the microphone?

Does the sinus on your dummy look perfect when you switch to continuous?

Does the SSB signal look ok on the dummy load?

If all the answers are yes, congratulations, you've joined a very exclusive club. There are at most 800 working scratch-built SSB rigs on the planet. There are twice as many chess grandmasters. Total SSB rigs ever built: maybe 1200. I have never heard a homebrewed SSB rig on air in 18 years.

You beat the Boss.

You survived the friendly boss. Now comes the one that just waits.

The boss that waits for your mistake

Linears are powerful, expensive and unforgiving.

7 Watt CW covers all of Europa 7 Watt SSB isn't going to cut it. The logical follow up is a Linear. I suspect that from 30 to 40 Watt upwards you're in business. There is a [link](#) on my QSL page with a 70 W linear built around a MRF150 power FET. It works great, only drops a little before the 10M band. It was built before Corona.

The FET is still available but costs, last time I checked in 2026, a whopping **150** Dollar without shipping. I suppose they started to be made from gold. They used to cost 45 Dollars in 2020, which was already a lot for one FET transistor.

Maybe I will write up my linear better but will have to look for alternatives.

The power supply and linear are a true Boss challenge. One wrong move, one slip with a measurement lead and you're engulfed in smoke. While you catch your breath you can think

about how your blunder set you back 150 Dollar. You leave the territory of innocent tinkering when you are building a powerful linear. This Boss is a sniper.

You will blow FETs up. At least I did it. Two of them. That was 90 Euro (minus shipping) That's a lot of money but not '300 Dollar minus shipping' kind of money.

The problem in the 2020s is finding HF power FETs and transistors that are **affordable to blow up**. This is not a deadpan ON1MWS joke for all clarity. I can exactly describe how you set the idle current of my MRF510 linear without blowing it up. But if you make one tiny slipup you are set back an amount between 150 and 200 Dollar.

Why have they become so expensive? Icom and Yaesu don't use discrete components for over 20 years but use custom RF modules and later LDMOS devices (whatever that is) The remaining discrete RF power semiconductors are therefore old, or limited production, rare, limited demand. You guessed it, it's expensive. When I laid eyes on the 2026 price of a MRF510 I first thought they were mined, instead of manufactured.

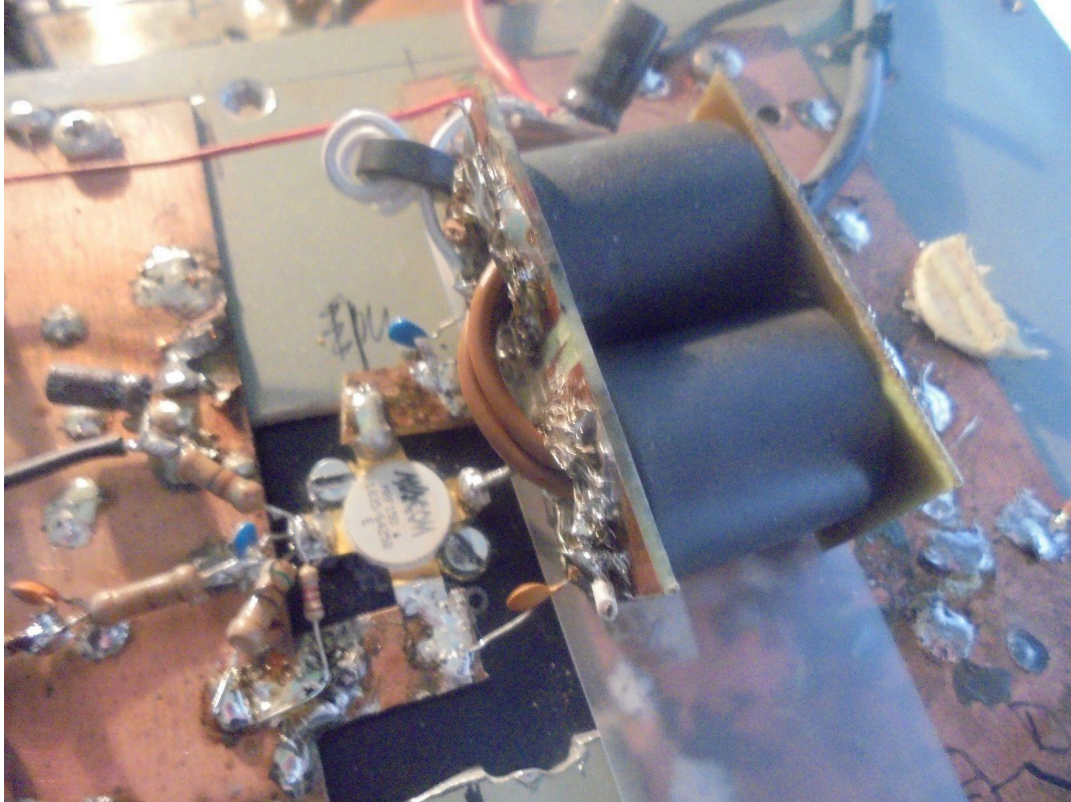
A Note on "Cheap" MRF510s

Before you get excited: yes, you will find "MRF510" transistors online for €10, €20, sometimes even €5. They are all fake. Every single one. If the price looks like 2010, Inside you'll find a random switching MOSFET that will either oscillate, blow up, or produce 3 watts and a puff of sadness. The real MRF510 cost real money.

In 2014 I bought myself a 2SC1969 transistor for my very first CW QRP transceiver. 2SC1969s were obsolete by the way in 2014 and the remaining stock therefore very expensive. But hey, I saw these 'cheap ones' at 7 Euro as I recall. And yes I did arrive. And it actually did amplify! But only audio frequencies. My first and only encounter with fake transistors. Yes not only Armani and Gucci get faked.

The problems don't stop there.

Unlike our friendly tiny QRP linear in the SSB transceivers, real power linears are not happy with a tiny FT50/43 toroid output transformer. They demand a larger low impedance transformer.



Above you can see the output transformer in my MRF510 linear. It is built from 2 FB43/1020 ferrite cylinders. If my memory serves me well, it took some effort to find these things online. The primary winding connected on the drain is just **one winding**. Most transformers use two tubes interconnected one on one side to form a U. This U is the one winding. I used the braids of an shielded industrial cable to solder a U. That is why my transformer looks like it is dredged from a canal. It looks horrible but works well. So will have to find large cylindric ferrites online and build tubes somehow.

This is the place for a small tip. In 2018 I did not know how to build a 'tube' and used a U formed from a 2,5mm² installation wire and it worked more than good enough! The tubes made from the braids later on did improve the power.



At this point you might think, 'This guy is telling me that building a powerful linear is no longer feasible.' And honestly? I could have taken the easy way out. I could have written up the DU1215S QRP linear in the SSB section, added the old MRF510 linear, and pretended my nose was bleeding. But that would be cheating. So instead I went looking for a path that avoids the expensive semiconductors, the extinct semiconductors, and even the ferrite crisis.

And I think I found one.

Our Path,

It is an amazing fact that we all can buy consumer electronics at low prices but not RF power transistors. I will present a path that works around over-priced semiconductors and even difficult to obtain and build transformers. There is always an incredible plot twist in every good book in the last chapter. This is the last chapter of 'Adventure in Analog, Mechanics (and a touch of chaos)' The plot twist is very near.

Push-pull IRF510 Linears.

Turns out that there are push-pull IRF 510 linears being built that produce between 25 and 30 W.. Like the one below. We have looked at the cheap IRF510 in the QRP Linear.

Amateur Radio Station
VE2TCP / G0KLA

Montreal
CANADA

Hardware Projects

- Variable Voltage 7amp Power Supply
- Gateway40 - ssb/cw 5w transceiver
- Simple Cheap 50 Watt PA
- The "First Transmitter"
- Simple Superhet for 40M CW
- 600W FET HF amplifier
- 3D Printing

Software Projects

- G0KLA Sat Tracker
- MSAT FoxTelem
- Software Defined Radio Tutorial
- Q21 Pacsat Ground station

Other Projects

- MSAT 50 Telemetry Challenge
- Visual astronomy from my QTH (placeholder)
- Underwater ROV for mine exploration

Workbench Notes

- 125
- 121 - Update on projects
- 121
- Jun 22 - Mir-Sat-1 First reception
- Jun 18 - Mir-Sat-1 Deploying Jun 22nd

A Simple Cheap 50 Watt PA



IRF510 push pull amplifier

I built this amplifier so that I could be heard above the QRN and QRM on 40 meters in the evening. I found I could work stations in about a 200km radius during the day with 5 - 10 watts, but at night I could work no one at all.

Many people build low power equipment and find amplifiers difficult. I have had my fair share of difficulty with obtaining high power. In fact, it was harder for me to create the 5-10 watts of drive that this amplifier needs, than it was to build and test this amplifier. My advice is to build straight forward building blocks and test each one to make sure that it is working. For example the final stages in the Gateway 40, which typically drives this amplifier, used Fig 2.93 in *Experimental Methods in RF Design*. It took me a while to get that circuit to work because I had used a wire wound resistor in one of the emitters by accident. I asked advice on the yahoo EMRFD group and finally got it working. I followed that driver with Fig 2.98,, which uses a single IRF510 and generates 5 watts easily, 10 watts with higher supply voltage.

This linear is a **well documented** one. It uses two IRF510s which do not cost a kidney. It is unclear to me what the highest frequency is. At least 30W on 40M, which is usable. Honestly, I only use the 40M band.

A single IRF costs 1,5 Euro tops. An IRF510 costs less than a coffee. That's why it's the perfect transistor for learning how to blow things up without crying.

There are many similar homebrew IRF510 linears to be found like the WA2EBY amplifier. I suspect they all **work reasonably well up to the 20M band**. The WA2EBY pdf claims 40 W up to 10M. I honestly have **reservations** about the claims I see on the first page. 40W from 160 to 10M..... hm.

https://www.radio-kits.co.uk/radio-related/Linear_PA/HF_use_FET_1.pdf

A" 3a Vraag het aan Copilot 1 van 4

By Mike Kossor, WA2EBY

A Broadband HF Amplifier Using Low-Cost Power MOSFETs



Part 1—With only 1 W of drive, you'll get over 40 W out—from 160 through 10 meters!

Many articles have been written encouraging experimenters to use power MOSFETs to build HF RF amplifiers. That's because power MOSFETs—popular in the design of switching power supplies—cost as little as \$1 each, filtering) from 160 through 10 meters. To the basic amplifier, I added an RF-sensed TR relay and a set of low-pass filters designed to suppress harmonic output and comply with FCC requirements. The amplifier is built on double-sided PC board and requires *no tun-*

An Overview of MOSFETs

MOSFETs operate very differently from bipolar transistors. MOSFETs are voltage-controlled devices and exhibit a very high input impedance at dc, whereas bipolar transistors are current-controlled devices and

Push pull RD16HHF1.

There are a few close cousins worth experimenting with. The IRF520 and IRF530 behave very much like IRF510s and will stretch you into 17 m and sometimes 15 m with only minor retuning. According to Copilot.

And if you want to stay in the “cheap enough to blow up without crying” category while still reaching 10 m, the RD16HHF1 is the **real RF device** to try. You can experiment with these without taking out a bank loan.

Real RD16HHF1s cost anywhere between 10 and 15 dollars. If you see them being sold for say, **3** dollars, don't buy them. They are **fakes**.

Another cheap alternative is....



 Download de AliExpress-app

 Other/NL/
EUR



Linear RF Power Amplifier

70W 3.5-30MHz



Radiator not included

3.5-30MHz 70W Lineaire Rf-Eindversterkerkits Voor Yaesu Ft-817 Kx3 Ssb Am Cw Fm Radiostation 13.56M Rfid-Signaal

★★★★★ 4.3 9 Recensies | 44 verkocht

Welkomstdeal

€15.67 ~~€16.07~~ · Nieuwe klant

€31.74

Prijs is inclusief btw ; Extra 1% korting

Kleur: DIY KITS



Meer prijsinformatie ⓘ

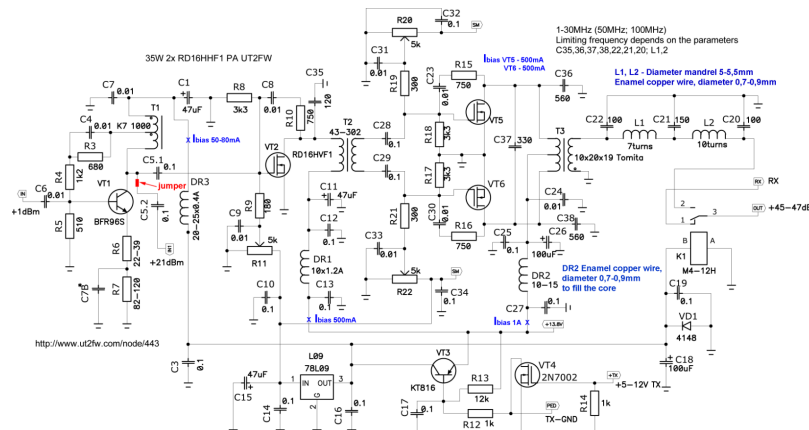
Just a quick check on the net tells me I could buy a comparable linear for my SSB and CW transceiver for a price that's a steal. The price does **not include the heat sink** in this KIT. A proper heat sink will cost 50 Euro, but you will have to buy one anyway. Does it work well? No idea. For 15.67 euro I might give it a go. When I look at the size of the two semiconductors in this particular KIT, I would guesstimate the power is around 35W instead of 70W.

- Worst case you'll end up with parts (the difficult **ferrite cores** for the input and output transformers)
- Medium case, 40W on 40 and 30W on 20M, you're in business.
- Even If it barely works as advertised, say 50W on 40M to 25W on 10M, you have made a once in a lifetime deal. This is just one KIT I saw in a very short search.

ON1MWS recommending a KIT is the greatest plot twist since Darth Vader said "I am your father."

I am not sure what I am going to do If my MRF150 ever fails. But I do know this, I am not going to pay close to 200 Dollars and wait for 6 weeks for one MRF150. And then might blow it up in one moment of carelessness. Sorry, Macon.

I think I'm going to practice on some IRF510s and finally graduate on RD16HHF1s.



Found a 2 X RD16HHF1 schematic, 35W up to 10M. This could become a plan if my MRF150 dies on me.

The options must be confusing,

- 1) linears made from push-pull IRF510s. Advantages, you can blow dozens of them up before you have a working linear. They are dirt cheap. Disadvantages, only 30W and performance drops quickly beyond 20M. But where is the fun? 40M and 20M. So do you **really** want a 10M capable linear?
- 2) Try a push pull RD16HHF1 linear. They cost on average 10 Euro, so you can blow some up but not as much as IRF510s. Your linear will perform up to 10M
- 3) My single ended MRF150 70W linear on my QSL page. Works well up to 10M (which I never use) Disadvantage, one MRF150 costs 150 Dollar in 2026. Only for experienced builders with a big wallet!
- 4) Chinese KIT gamble. Just roll the dice. Worst case: parts (Feritte transformers). Best case, a miracle.

What to do?

My advice if you start from scratch with no experience?

Do the Chinese roulette. If it works super. If it doesn't, you're getting cheap input and output ferries, which you can use in a push pull IRF510 linear. You can blow dozens of them up and still laugh. You will eventually have a modest linear that can go on 40M and 20M (where the fun is!). Once you have experience in **not** blowing up IRF510s you can graduate to RD16HHF1s if you really want 10M.

My advice in a broader context.

My SSB transceiver has a DU1215s (obselete) My linear MRF510 (too expensive) Forget about it.

You need a path that is **buildable in 2026**, affordable, realistic and educational.

- 1) A single ended IRF510 in the SSB transceiver and a 'Chinese roulette' linear. Cheap entry and your minimum outcome is cheap output and input transformers.

- 2) A single ended IRF510 in the SSB transceiver and a push-pull IRF510 if the Chinese KIT does not work.
- 3) Once you understand the behaviour of single ended and push pull linears and experience in not blowing up FETs, graduate to,
- 4) A single ended RD16HHF1 in the SSB transceiver and a push-pull RD16HHF1 in the linear.

This is what I would do in 2026. And the best part, the part I really like!

- Reuse the same power supply.
- Reuse the same heatsinks.
- Reuse the same ferrites.
- Reuse the box.
- Only the silicon grows up!

How to NOT blow up FETs?

RF power FETs are in fact very easy to use as we have seen in our SSB transceiver **So this section is a bit of a reminder.**

The only tricky part is setting the idle current. Every FET circuit will feature a trimmer pot to set it. The problem is that as you turn this trimmer your idle current will go through the roof and destroy your FET instantly.

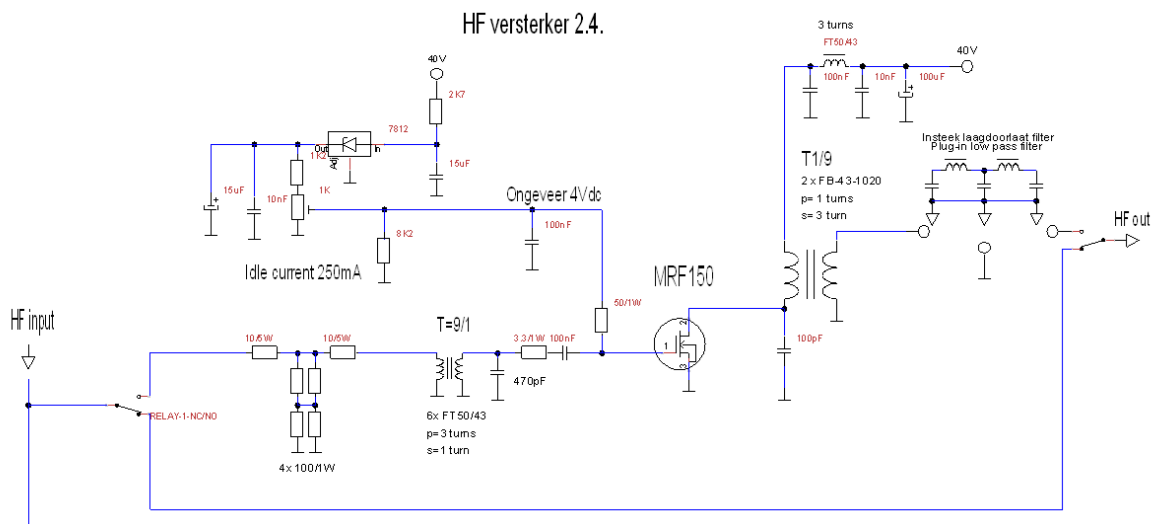
I got myself a 10 Ohm/10 W resistor. On both sides there is a WAGO connector. The + of every linear I have are connected through a WAGO connector with their power supply. So If I want to check out the idle current I insert my resistor in between the + of the linear and the power supply. Let's take my expensive MRF510 linear. The idle current should be 250mA. By measuring the voltage I can calculate the idle current. $U=I/R$. $0,25\text{ A} \times 10\text{ Ohm} = 2,5\text{ V}$. Once a year I check the current. Usually the voltage has dropped to about 2V. Then I adjust the trimmer to set it back on 2,5V. What **always** happens is that I overshoot.

So, why doesn't my expensive MRF510 get smoked? **Thanks to my resistor!** As the idle current goes 'all in' the voltage over the resistor rises. $1\text{A} = 10\text{V}$, $2\text{A} = 20\text{V}$, $3\text{A} = 30\text{V}$. The supply voltage on the linear drops spectacularly and my resistor starts to smoke, but my MRF510 survives!

Using the resistor and idle current has a bit of a learning curve, but once you have some experience it is quite ok. The IRF510 that costs half a coffee is the perfect training FET.

Appendix.

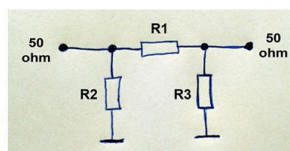
Scratch building a power supply for your linear is much easier. Check out my linear PDF on my page. A homebrew final Linear needs a DC Ampere meter in the power supply. Believe me, you want to know when things go wrong **fast**.



Notice the T/R arrangement of my MRF510. It is just one relay. The antenna is switched straight through. In transmitting things change. The output of the SSB QRP goes to the input and the antenna to the output of the linear. The relay is obviously switched by the SSB T/R switch.

What you will definitely need is a 50 Ohm attenuator pad before the final Linear. A push pull IRF510 or RD16HHF1 will need 2W input but your QRP will give more. So you start with a 50 Ohm attenuator. The final linear will not be over driven and there will be no discussion between the QRP and Linear over impedance. It's 50 OHm.

Pi-Network Attenuator Resistance Values For 50 Ohm impedance



dB	Calculated Value (Ohm)		Standard Value Used (Ohm)	
	R1	R2, R3	R1	R2, R3
1	6	904		
2	12	453		
3	18	304		
5	31	185	33	180
10	74	100	75	100
20	257	63	270	56

PI and T 50 OHm attenuator tables can be found online including even calculators.

Whatever you do, **shield the Linear!** An un-shielded Linear in the shack will lead to RF feedback. You will get roasted on air.

Our last stop is the boss that doesn't care about your feelings, your weekend, or your sanity, the tube regenerative receiver.

The boss that fights back.

Our SSB transceiver was a friendly boss. Tough, but you get a fair fight. **The tube regen** is the opposite. You don't build a tube regen. You negotiate with it. After a few hours you'll understand why radio clubs exploded in the 1920s and 30s. One human brain is not enough to tame this creature. Throughout this book I tried to be motivational. "Yes, you can!" Not this time.

This is a very challenging project despite the seemingly simplicity of the circuit. Regenerative receivers have not been used since the 1930s and there is a reason for that. No sideband cancellation, hum, no frequency stabilisation, squeals and many more drawbacks. In 2024 I had no project to do but I have a box of 1950s tubes in my junk for over 40 years. So I figured, why not try a tube regen for the 40M band.



And above the setup late 2025. Yes, it is the wurst homebrew radio that I have. My homebrew supers will run circles around it but boy, it is fun radio to use. You are reliving the experience from the 1920s and 1930s. The tube regen is being used for QSOs on 40M so it is not completely useless.

Building a practical regen radio is difficult. The regeneration gods must be with you. My solid state regen does it very well. Using it in a QSOs is easy with that one. The tube regen comes close after a long battle.

I had to use the tubes in my junk collection. There were **a lot of EF184**. A real HF tube and I also had a couple of EL84 for the LF amplification. I also had a gorgeous UY227 from 1927. However the filament died on me during 2025, so I had to use the boring looking EL184.

I am no expert in tubes nor regeneration radios.

The many articles of N1TEV are very useful to get a general idea but the theory and practical construction of **tube** (and also solid state) regens and oscillators is best explained on the website of **F5LVG**. There are also a wealth of actual build regens on his site. Olivier Ernst (F5LVG) has been doing this for 40 years and knows his stuff! There is no point repeating it here. Just visit the F5LVG website if you want to go deep into regenerative receiver theory.

There are many YT channels that will explain to you how a tube works. This book is not about repeating basic information. To understand my EF184s I watched this YT clip.

📺 Vacuum Tubes: Episode 5 – The Pentode From the Usagi Elektrics channel. Very useful.

In 2003 I built a tube audio amplifier (which still works) and this is only my second tube homebrew project. It is also my second regeneration radio. So I am **no expert** in either subject.

The EF184 incident.

I used them because I had several of them in my junkbox. cost 0 Euro...

why is the ef184 such a bad tube fro tube regeneration radios

The short answer: **the EF184 is a terrible tube for a regenerative detector because it has far too much gain, far too much transconductance, and therefore makes the regeneration point hypersensitive, unstable, and twitchy.**

Below is the detailed, cited explanation.

See I am no expert? I asked Copilot why the EF184 is so bad. Apparently my question was wrong. I should have asked, why is the EF184 so terrible. Don't ask me what 'transconductance' means nor the explanation. The transconductance feels so weird to me that I don't even find a spot for it in my Axiom box.

The short version:

Gain is voltage in → voltage out.

Transconductance is voltage in → current out.

They are related, but not the same thing.

I found this out **long after the regen was already working**, what did you expect?

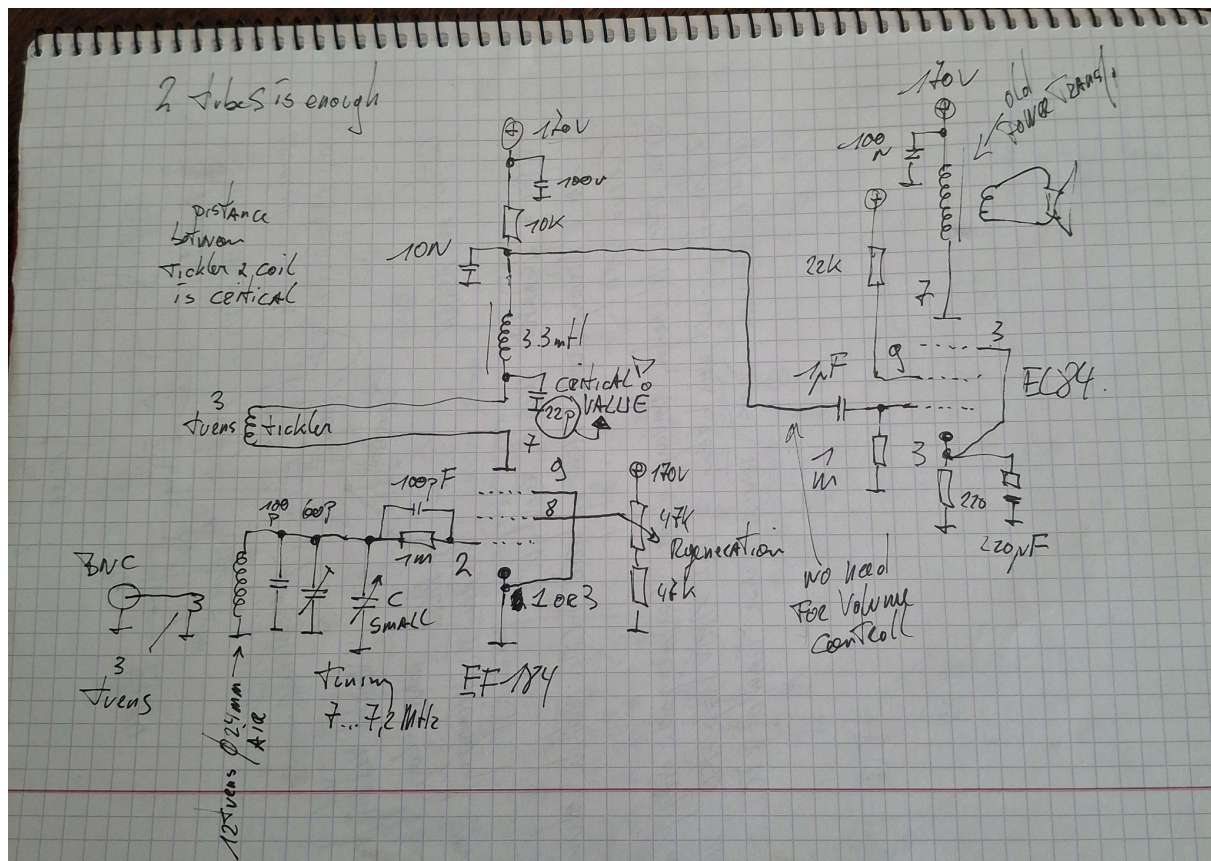
Why the EF184 feels "terrible" in a regen

Because it's **too good** at what it does.

I accidentally used tubes that are way too good for a regen. It is the regen equivalent of putting an F1 engine in a lawn mower. Yes it runs but is tricky to lawn your grass. Maybe I just had bad luck with the tubes in the junk box. Maybe calling it a final boss is an exaggeration. But for me, second tube project, second regen, limited theory, it was difficult enough. In the end, the EF184 regen works. That's the result.

The best tubes are EF86, 6AU6, 6NS7, 6J5, 6SK7. gentle, high-mu, low-noise, and happy at low plate voltages according to Copilot. Just so you know. Olivier F5LVG uses all sorts of Russian tubes.

To have any success I think that starting with a two tube regen is the way to go.



This setup actually worked very well. There is no HF pre amplifier. The EF184 is an oscillator with a tickler coil. Getting this oscillator to work was a hard job as I did not have examples. So difficult that at one point I **shelved the project for some months**. I felt like a guy who stumbled into a fight with a monster he didn't understand. It might have gone better with more suitable tubes than the EF184s in hindsight.

The circuit is basically the same principle that I used for the solid state receiver. A circuit from N1TEV. However getting a tube oscillate seems to be much more tricky than a FET.

Eventually I made **the tickler coil movable** in respect to the main tuning coil and used a **variable capacitor** where now the 22pF capacitor is.

That way I could fiddle with the setting until I found a goldy lock setting. This was my strategy. Make everything adjustable and fiddle with it until it works. Very scientific isn't it? The distance and capacitor values are critical. If you find the right values you get rewarded with a good regeneration oscillator. The variable capacitor was swapped with a 22pF capacitor once I knew the correct value.

The oscillation level on the anode of the tube must be very small, as I had learned from my solid state regen. Just a little oscillation is needed for decoding CW and SSB.

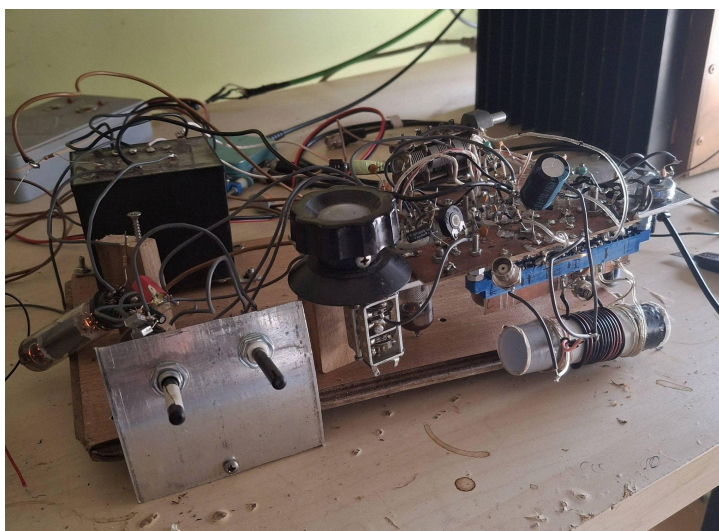
The EL84 is just a standard LF amplifier. The transformer for the LF amplifier is just a huge old power transformer with many taps on it.

It is probably also a good idea to limit yourself to a limited bandwidth. Just the 40 M band in my case. You are just asking for problems by trying to build one that spans a larger portion of the shortwave spectrum

Good regen control.

If the solid state regen (chapter 5) and this tube regen has taught me anything is that the oscillation must be minute. What you need to achieve is that when you bring your regen from non-oscillating (AM mode) to oscillating (CW and SSB) it must happen smoothly. What I mean is that if your regen goes from non-oscillation to large oscillating in one jump it won't work. A large oscillation means that your tiny antenna signal gets drowned in the oscillator signal. I can easily observe this in this regen. My regeneration is controlled by varying the voltage on the screen grid. I hear garbled sounds = HAMS. Just turning the oscillation up at minimum decodes the CW or SSB stations. If I turn my potentiometer further up (larger oscillation) the sounds get more and more silent until they disappear all together.

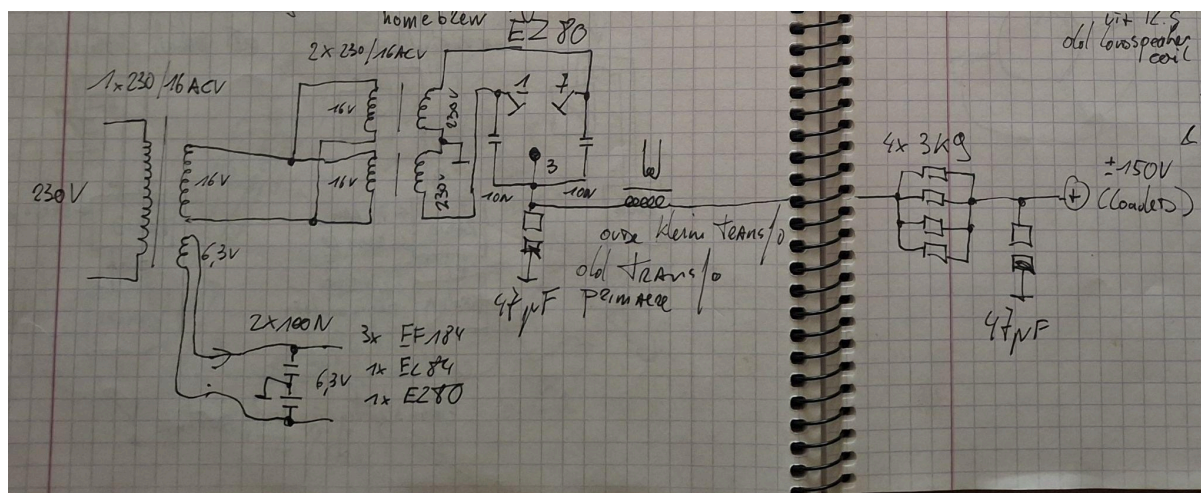
This version was built as a mock-up.



The two tube regen worked surprisingly well. Pretty sensitive and due to the lack of excessive amplification, very stable. No sudden squeals or motorboating. A LF volume control was not necessary. The sound is always maximum! But with headphones I never got the feeling that it was too little. It is amazing that you can receive the 40M band with just two 1950s tubes.

Power supply,

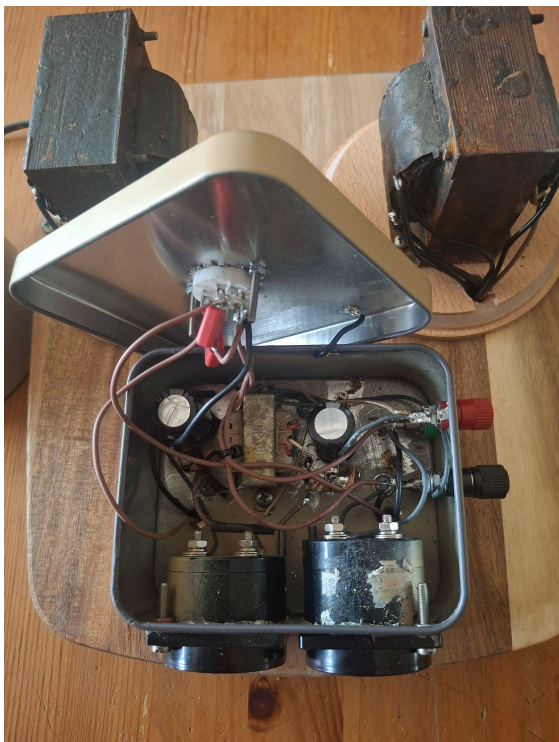
First of all, be careful! **Tube power supplies are no toys.** I was shocked several times.



Yes, I made it myself extra hard by building a tube power supply! I simply used old power transformers from my junk. The first transformer is a toroid one from an old light fixture. These toroid transformers have the advantage that you can wind your own custom secondary on it. So, I used some installation wire and wound a winding to get 6,3 VAC for the filaments. The output of the toroid is 12V and is increased with a second custom winding to 16V. This 16V goes to very old 16V/230V transformers. They must be ancient! These two transformers act as insulation transformers. The outputs of these are combined to feed the EZ80 rectifier tube. A bit complicated but it cost me 0 Euro.



The cool voltage readouts are super cheap on Aliexpress.



Left, the innards of the power supply and right the toroid power transformer. Notice the homebrew secondaries on that one.

A long battle against power hum,

A difficult problem to solve is 50 Hz hum. When not countered the hum will be overwhelming. It is a typical problem with receivers that have no frequency conversion, like DC receivers and our regeneration radio. To reduce the hum to an acceptable level many arrangements must be done. Every single measure reduces the hum a little bit.

-10NF capacitors over the diodes. This prevents the HT from getting modulated with the power hum.

Our regen is also a transmitter. The power supply will 'receive' the regen and this RF gets back to the regen via the rectifiers. The rectifiers will modulate 50 Hz on the HT which you will hear on the radio.

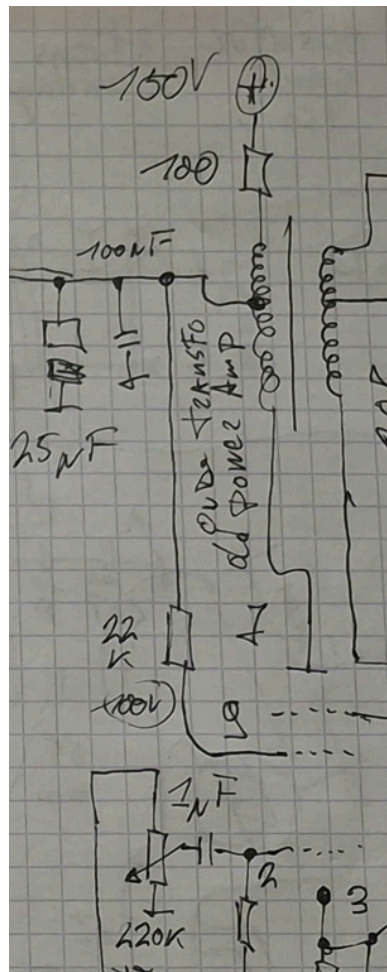
The RF will be shorted with 10 NF capacitors over the diodes, so then there is no modulation.

-After I replaced the ceramic capacitors of the oscillator with NPO capacitors (probably polystyrene) the last remaining 50 HZ was gone. I have no explanation but I am not complaining! So use **polystyrene capacitors in the oscillator**.

-Shield the oscillator and audio pre-amplifier. Just touching the oscillator tube resulted in a deafening hum. Idem for the audio pre-amplifier. The HF pre-amplifier seems to be immune. The EF184 has luckily an HF shielding built in (pin6) HF amplifier, oscillator and LF pre-amplifier are shielded with this internal shield. This resulted in a significant reduction of hum. If you use a tube without an internal shield you could use a metal tube that is slipped over the tube. Yes then you can no longer look at your gorgeous tube..

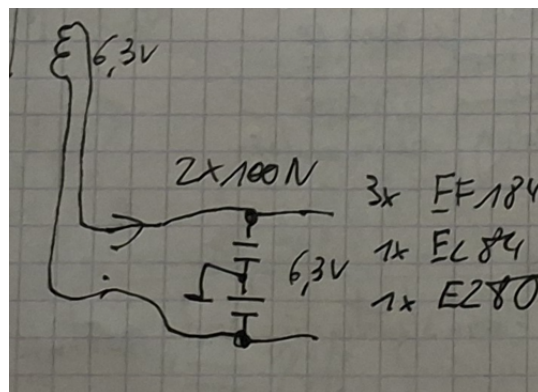
-Use shielded audio cable for **all** the audio connections. Tube are high impedance and will pick up power hum if not shielded.

-Filter the HT as much as you can. The datasheet of the EZ80 is very clear. Maximum capacitance is 47uF. But I have put a second 47uF capacitor but it is connected via a 1K/1W resistor to limit the surge current when turned on. If you leave out the resistor your EZ80 will be destroyed quickly.



This way I squeezed in another 25 uF. The surge limit resistor is only 100 Ohm.

-Balance the filament voltage to ground. At first I used the classic resistor potentiometer but found a capacitor divider better. Less hum for me.



The hum is now more than acceptable with all of these points covered.

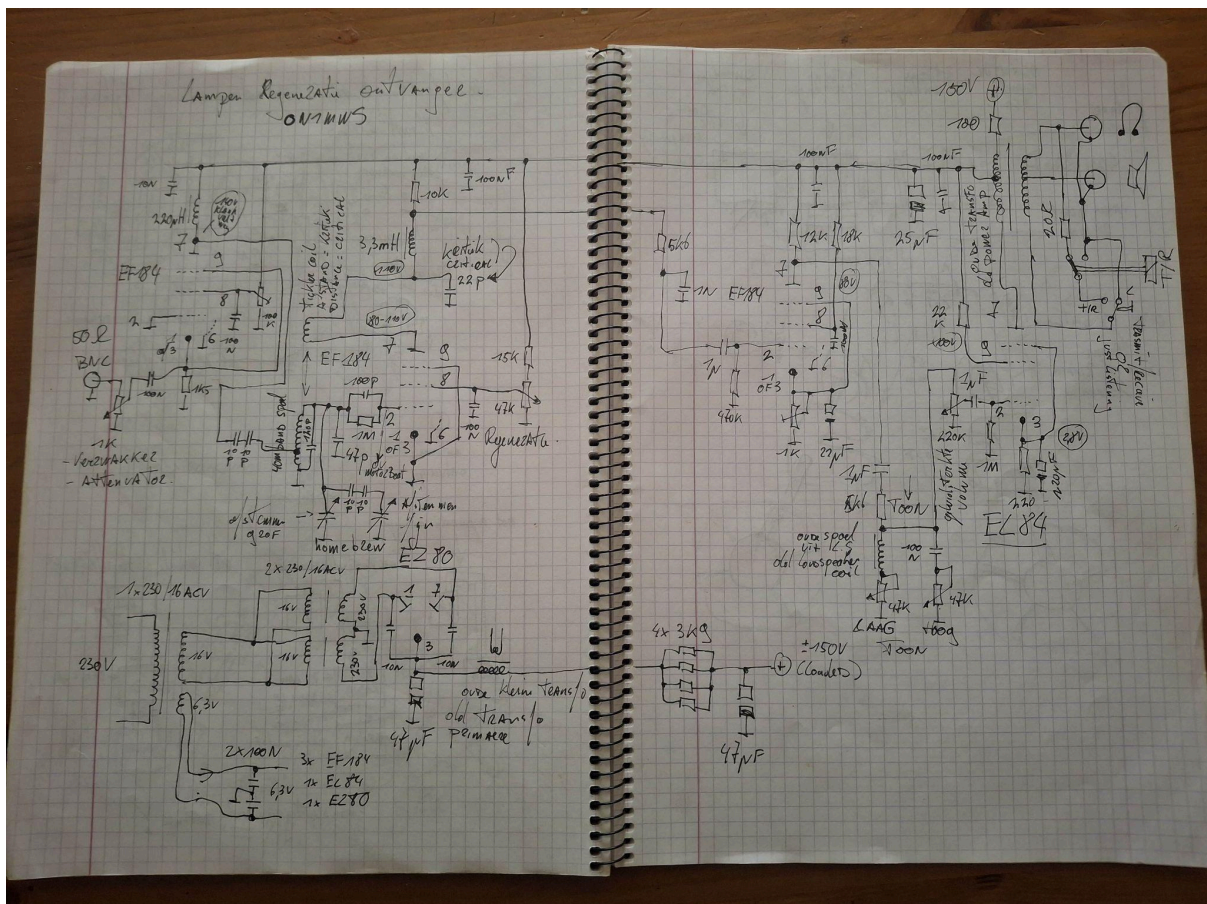
Once you have a good two tuber, you can go for more.

After you have a two tube regen you have passed a difficult hurdle. You have a working regen oscillator.

A HF amplifier that isolates your antenna from the oscillator is probably necessary. Without it your regen will transmit on the frequency. For this I used a grounded grid amplifier. It does hardly amplify but it is an improvement. Tuning my magnetic loop antenna has much less impact on the radio.

Also another EF184 is used as a LF pre-amplifier. The extra tube gave the ability to add a tone control between the LF preamplifier and final LF amplifier. I did try passive treble-bass controls that I found on the net but they gave too little control, so I made my own 'extreme' high and low tone control filters. It is possible to get rid of some hum and QRM but **don't expect miracles**. A regen will never compete with a super with crystal filters that eliminate the opposite sideband.

Below the 4 tube version. One EF184 is the HF amplifier/isolator, one EF184 for oscillation, one EF184 as LF preamplifier, tone control and finally the EL84 as LF amplifier.



Notice the antenna attenuator. It is actually a necessary feature that you need when you encounter a large signal. The output is coupled to the oscillator as loosely as possible. Two 10p capacitors in series and on a low tap on the main tuning coil.

The difference between the 2 tube and 4 tube version is less influence from my tunable loop antenna and more overall amplification. The latter means that a volume control is necessary. When the LF filters are turned wide open the volume must be reduced to avoid motorboating.

The 4 tube version is only marginally better than the 2 tube version.

The tube regen has a very dim view on T/R switching.

After a transmission you want to be back listening as soon as possible. Turning the regen off, during transmitting, is out of the question. It would take minutes to receive again. At first the T/R switch turned the antenna off and switched the output for the headphones over to a 20 OHM resistor. That did not go well. The regen was blown away during transmission. After the receive switch it took about 5, 6 seconds to receive the station again. Not practicable.

Olivier Ernst, F5LVG, wrote to me to try to put two diodes antiparallel over the antenna input. This helped a lot. The regen now could receive back after 2 a 3 seconds. Olivier also wrote to try to solder two series diodes over the main tuning coil. Two series sets back to back, so 4 diodes. Idea is that the voltage over the main coil can never be bigger than 1,2V (2X0.6) Now the regen can receive back after 1 second.

After I put the transmitter to receive, I have to quickly tune down a bit to hear the station again and then gradually tune back up while I listen. With some practice I can do that in one 1 second. Not perfect but more than manageable.

These were the ideas given by Olivier; which work. However I will try my own idea later on. Switching of the RF amplifier and oscillator (and leave the filaments on) during transmission. I would like to get rid of the diodes as I would like to pretend that semiconductors are not yet invented.

Getting drift under control,

At first the drift was about 100 HZ/minute, which is frankly a lot to listen to a HAM band.

There were many drift reducing measures from the start.

- A large air coil.
- The coil has a smaller width than the diameter.
- The coils 5 CM from the 'hot' tubes.
- The capacitance is as high as possible.
- Ventilation holes in the oscillator enclosure.

The drift would likely be better if you would use a regulated solid state power supply but I wanted the full tube experience.

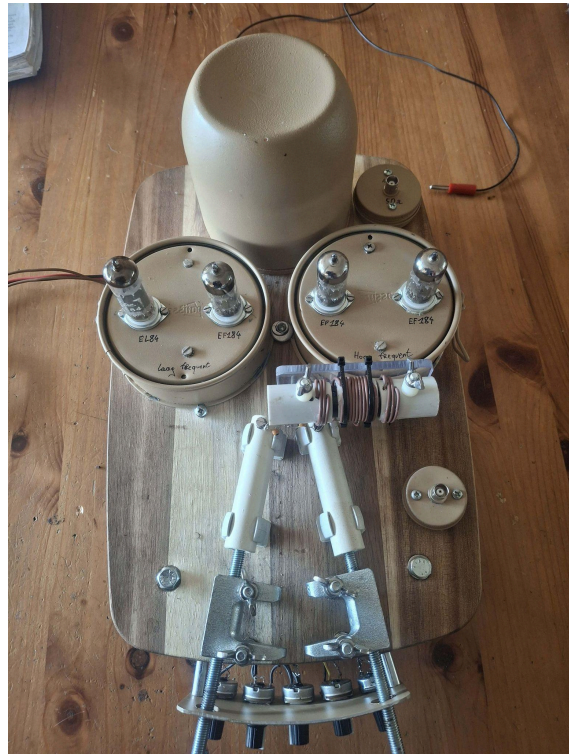
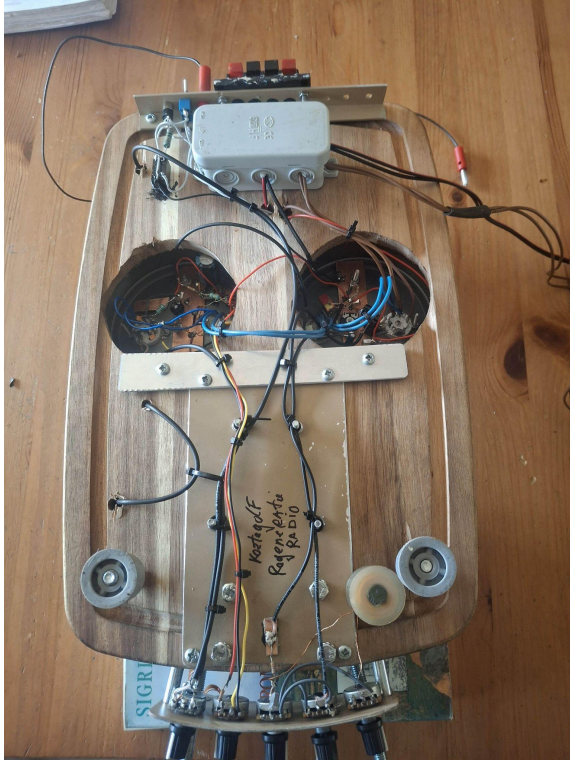
On the recommendation from Olivier Ernst, F5LVG, I bought NPO capacitors. These types have a much better (less) response to temperature. After I replaced every single capacitor in the oscillator the drift went down to 31 HZ/minute.

Later on I also replaced the 2 10pF capacitors that connect the pre-amplifier loosely to the oscillator with one 5pF NPO capacitor. Pure progress. I let the regen warm up for a half hour and set up my frequency counter. The frequency drifted up 100 Hz up and then 100 Hz down the starting frequency in one hour. This 'minor' drift is only true if the regeneration level is set

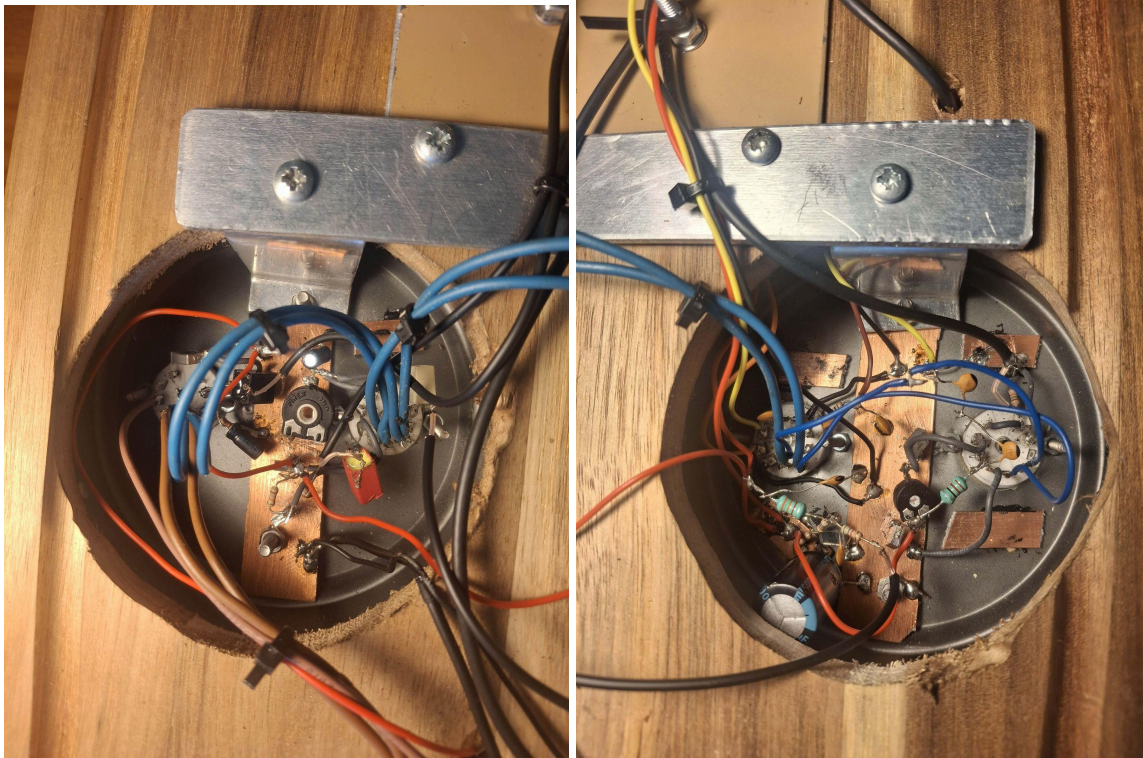
just above minimum. The maximum audio volume is also just at minimum oscillation, so that works out great.
Drift is not so great. But just good enough for a QSO.

Construction,

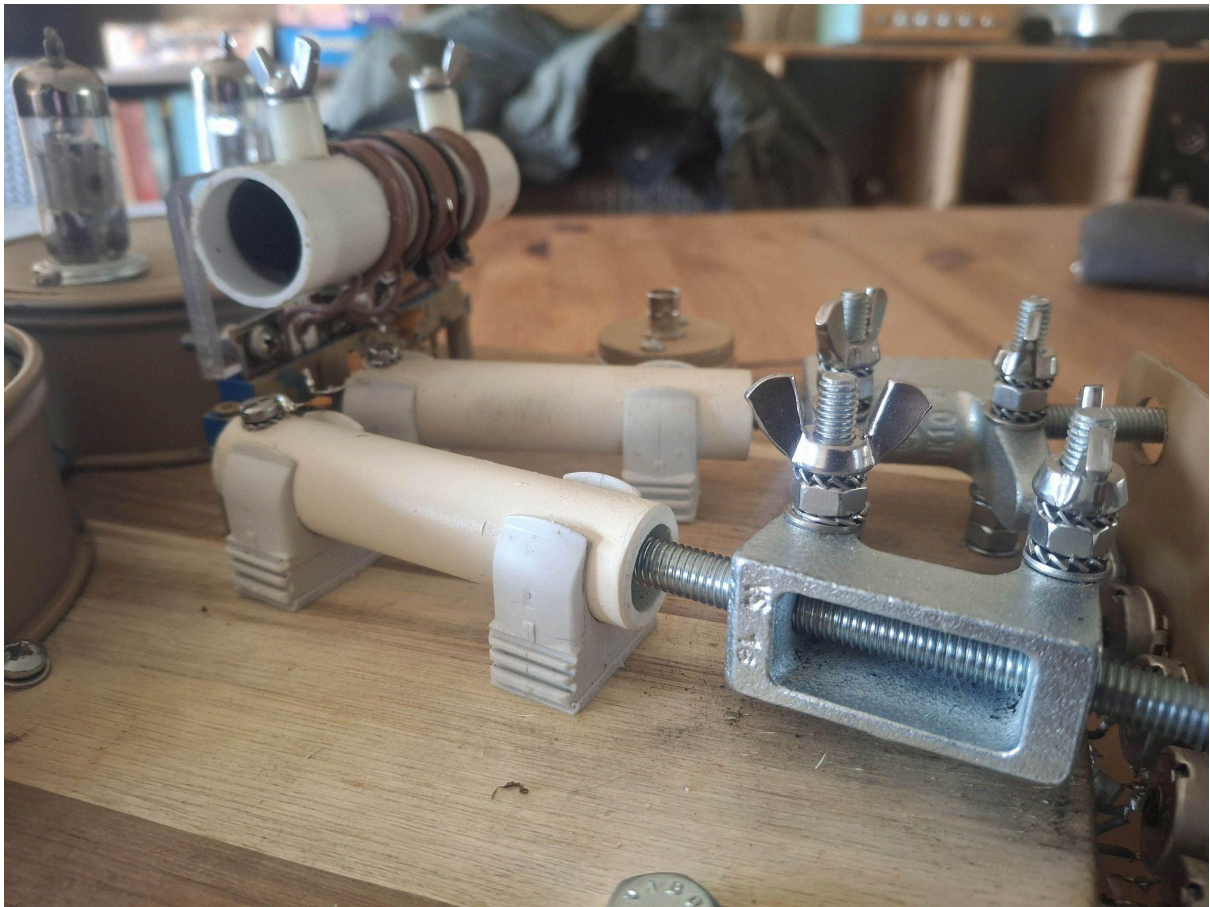
Pictures will tell the tale.



As usual I avoided ground wiring. All ground is interconnected with aluminium plates and brackets.



The homebrew tuning capacitors are two M8 treaded rods that are turned in or out a 13mm aluminium tube. The rods are ground, the tubes the 'hot' side. The rods turn in steel girder brackets that provide a 50/1 gear reduction. There is no friction and the homebrew capacitors are temperature stable (as I learned from the solid state regen) They are just as good as a commercial capacitor but are cooler. They must be about 30 pF. You can obviously use commercial tuning capacitors.

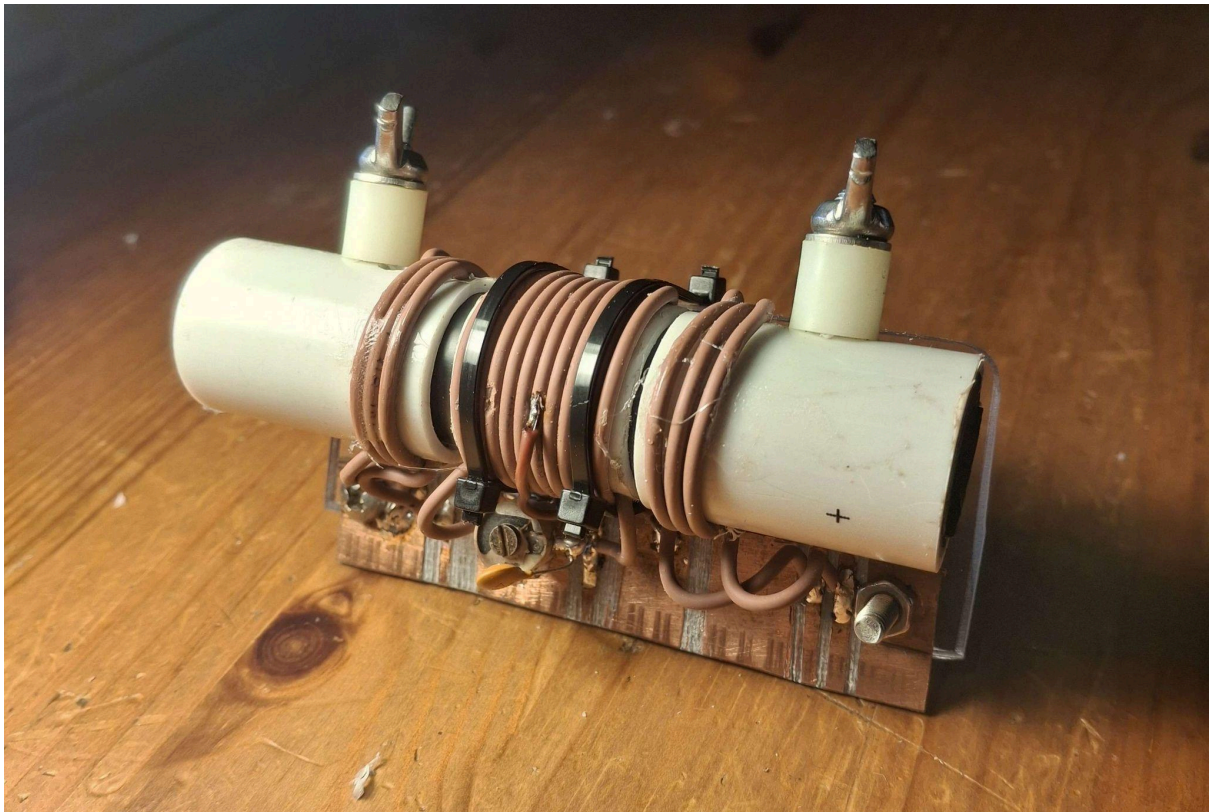


The coils are wound on a 25mm plastic tube. The 25mm tubes can be moved along a 20mm plastic tube. Thus giving an adjustable setting. The movable coils can be fixed with a bolt/butterfly nut, once set. The right coil is from my frequency counter. I would strongly advise to make your coils movable one way or the other. Not to use them as regen control but to be able to do an easy 'factory setting' setting that also can be changed later on. The setting is extremely critical.

The main coil has 10 windings, the tickler coil 3. The right coil, sometimes used for the frequency counter, also has 3 windings.

I could take my coils apart and take pictures of how I made mine. But I struggled so long to get it right that I don't have the guts. The tube regen just sits there thinking: "Go on. Take it apart. Make my day." Yes I am scared of a smug, vindictive 1920s troll.

The whole coil ensemble is connected via an edge card holder. In theory I can swap coils for different ones for different bands. I doubt that this tube regen will work much higher than 10Mhz anyway.



Tuning the tank circuit is easy.

Just let the regen oscillate and measure the frequency. I have the coil on the right for that. Then tune for your band. Notice the trimmer below the coil. My regen tunes from 7 to 7,25 Mhz. For once an easy chore.

Conclusion,

It drifts a lot, no sideband cancellation and too much bandwidth and doing a QSO is difficult (but manageable) . My regen is a radio that can not be copied. This is truly a one-off. But my regen is somehow calm. It just does its thing without squeals and howling. It's a happy regen, but with the normal limitations of regens.

Yes, it is truly the analog Boss no matter which tubes you use. The SSB, built from predictable blocks, is easy compared to this. Building tube regens is not a beginners project.

I enjoy every minute using it. This homebrew tube radio lets me relive the early radio days from the 1920s and 1930s. It is incredibly fun to use it.

Final piece of advice, ignore all EF184s in your junk box.

<https://www.youtube.com/shorts/QHpLtkMhGmA?feature=share>



From left to right, tube power supply, solid state power supply, tube regenerative receiver, SSB transceiver and linear. All the Bosses in a neat row.

Epilogue.

Archaeological Field Report, Preliminary Classification Attempt

Site: Wingene dorp, Sector B

Object ID: WF-22-Ω

Provisional Classification: Undetermined electromechanical device.

Lead Researcher: Dr. H. Verbruggen, Institute for Post-Industrial Archaeology

Date: 11th Cycle, Post-Digital Era

Following three weeks of excavation at the Wingene dorp, our team uncovered a remarkably intact artifact composed of metal cans, early 21st century kitchen utensils, unmachined metal and a dense cluster of copper wiring. The object appears to have been assembled with deliberate intent, though the purpose remains unclear. No two experts agree on its function.

Initial hypotheses include:

- 1) Ritual apparatus used by a sect devoted to “oscillation,” a concept frequently referenced in nearby inscriptions.
- 2) Scientific instruments for measuring forces or energies are no longer recognized in contemporary physics.
- 3) Communication devices intended to contact distant tribes, deities, or possibly the builder’s neighbour.
- 4) Folk mechanical art created for reasons that remain psychologically opaque.

The construction techniques are inconsistent with mass-manufactured objects of the Early 21st Century. Instead, the artifact shows evidence of individual craftsmanship, including file marks, improvised fasteners, and a mechanism that appears to rely on the controlled movement of air within a hollow cylinder, with what appears to be done with a large ‘steering wheel’, a method previously unknown in the literature.

Radiocarbon dating of the wooden base suggests the object was created during the “Analog Revival Subperiod,” a time when small groups of enthusiasts rejected digital convenience in favour of hands-on mechanical experimentation. This aligns with the discovery of handwritten notes nearby, containing diagrams, philosophical reflections, and warnings such as ‘do no touch while oscillating’

The research team remains divided. Some insist the object is a radio. Others argue it is a shrine. One junior researcher, after prolonged exposure to the device, declared it ‘fascinating’ and requested to keep it in his office. He has since been placed on sick leave.

Until further evidence emerges, the artifact will be catalogued under the newly proposed category:

Class V-3: Esoteric Analog Constructs (West-Flemish School)

Future scholars may succeed where we have failed. For now, the object remains what it always was:

an inexplicable creation, and a reminder that the past was stranger than we often assume.

Post-scriptum: Memoir of Stubborn Engineering

For anyone still reading after the archaeologists gave up: This book was never just about circuits. It was about the way people build: the small wins, the detours, the mistakes, and the one rule that kept everything moving.

Stubbornness beats brilliance.