CRYSTAL SETS TO SIDEBAND

Chapter 7C

Code Practice Receivers

BUILDING AN ALL-BAND SUPERHETERODYNE HF RECEIVER WITH MINIMUM PARTS

This project explored what could be accomplished with a "simplified" version of an all-band superheterodyne. This receiver was built in 2018, long after I built the complex receivers described in Chapters 13A and 13B. It uses some of the same circuit blocks described in those chapters.

In the 1950s and 1960s the inexpensive commercial ham receivers were roughly comparable to this simpler design. Back then radios were built with vacuum tubes instead of transistors. Compared to transistors, even "peanut tubes" were huge. So complex designs were heavy, expensive and not nearly as affordable and practical as they are today.

When I was an impoverished young ham in the 1950s, Novice class hams were encouraged to build their own CW transmitters by the ARRL Handbook. Homebrew regenerative receivers were presented as an educational project. At least that was my impression of regens. I believed then and I still believe that, if you're serious about talking to people, you need a superhetrodyne all-band HF receiver. Back then, building a superheterodyne "communications receiver" seemed much too difficult to consider - all those tubes, transformers, mysterious rectangular metal IF cans and triple-ganged, tuning "condensers."

As soon as I could afford it, I bought a used Hallicrafters S-38 superhetrodyne from a ham radio store in a nearby city. I took it home, tried it out and quickly decided that it was a miserable, insensitive radio. I returned it to the store and traded it for a used Hallicrafters S-40A receiver. The S-40A was a huge improvement and I was happy, more or less. From my perspective, its only serious fault was that it seemed inert to all frequencies above 20 meters. All I could hear up there was gentle static. Two of my friends had the same problem.

Just then Popular Electronics published an article on building a "pre-selector" for the upper HF ham bands. It was similar to the tuned preamplifier in the receiver described below. Of course it was designed with vacuum tubes instead of transistors. We built the pre-selectors and the 15 and 10 meter ham bands and Sputnik satellite frequencies opened up to us. I used my S-40A for several years before retiring it to the attic.

40 years later Bob, NØRN, was teaching a license course for beginning hams. He borrowed my old S-40A receiver, without the pre-selector. Bob used it in his lecture on ham gear. He hooked it up to an antenna and compared it side by side with a modern receiver. It became his example of how awful the old equipment was and why they should not buy old junk at a ham fest. When Bob was done with the S-40A, he returned it to me and I gave it to the local ham club for sale at the Ham Fest. Today my S-40A is probably in someone else's attic.

The receiver described below is roughly comparable to the S-40A with a pre-selector. An improvement is a single crystal filter which increases selectivity to about 3 KHz bandwidth, as apposed to the 10 or 20 KHz bandwidth of the S-40A. You will not hear all the stations that the DX hunters hear with their $5,000, hi-tech, computerized receivers. However, it will be adequate for communicating with reasonably strong stations. Much more capable receivers are presented in Chapter 13A and 13B. Unlike the receivers in Chapter 13, ***this radio covers the entire HF spectrum, not just the ham bands***. This makes it suitable for general short wave listening.

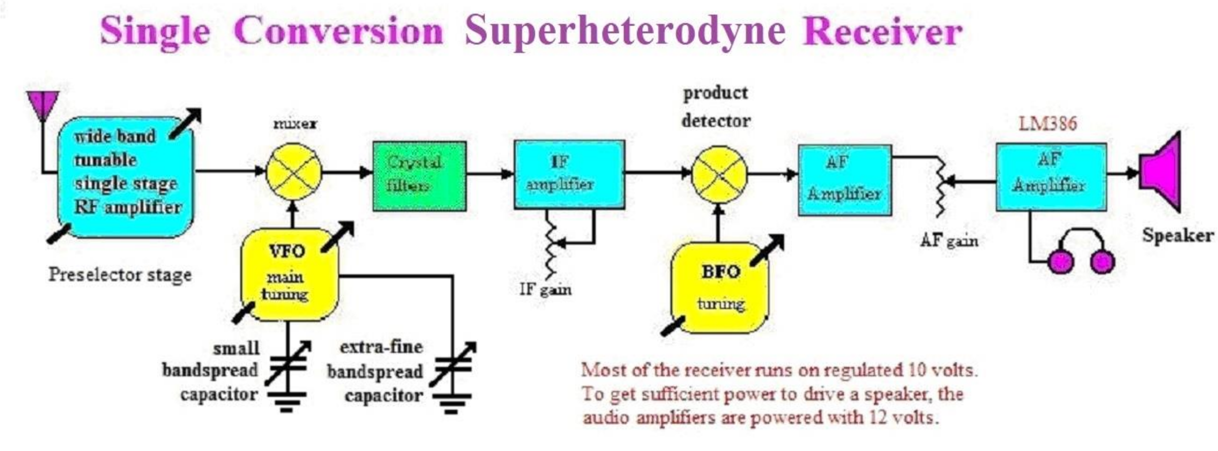
Because of the wide tuning range, I was able to use this receiver to receive the outputs from 6 meter and 2 meter converters. Compared to HF ham bands, VHF bands are huge. If I had down-converted 2 and 6 meters to specific HF ham bands, I would only have been able to receive narrow segments of the VHF bands. VHF receivers are described in Chapter 16C.

The trouble with a "simplified superhetrodyne" is that you'll soon want to add features and capabilities to improve performance. By the time you're truly happy with it, it won't be simple any longer. My advice is ... mount it in a big box!

The superheterodyne principle

When two audible sounds or electrical sinewaves are added together in a common medium, the waves combine to produce a complex waveform. This combination waveform includes two new frequencies, the sum and difference of the two original frequencies. For example, if a multiengine propeller driven airplane does not have its engines synchronized, audible beat frequencies are generated. Out of sync engines produce an unpleasant "wah - wah - wah" noise that torments the passengers. As an experiment, try hitting two adjacent keys on a piano. The resultant multi-frequency sounds are discordant and unpleasant.

In a superhetrodyne receiver, the main tuning dial tunes an oscillator which is mixed with the received signal to produce two new frequencies. One of these new frequencies is selected with an L-C filter and becomes the **intermediate Frequency, the IF.** In this way, all the received signals are moved to single frequency amplifier where they can be filtered and amplified. This method provides stability, selectivity and sensitivity. Working with a single frequency allows the use of fixed frequency crystal filters and high amplification. The IF signal is then passed on to a detector stage for conversion to an audible signal. Narrow band filters or modern digital filters are not practical with direct conversion, or regenerative receivers.



In the diagram above the desired raw antenna signals are first selected and amplified with the **pre-selector** stage. The pre-selector is a sharply tuned L-C circuit or tuned amplifier that passes the desired listening frequency to the **mixer** as shown above. The **mixer** stage is the first yellow disk on the left. The mixer is an amplifier or sometimes a passive circuit in which the two input signals, the VFO and RF antenna signal, are combined. The **VFO** or **local oscillator** is a tunable oscillator that also selects the desired listening frequency. The "main tuning knob" of a commercial radio tunes both the pre-selector and VFO simultaneously. Usually the tuning knob controls a dual or multiple variable capacitor that tunes both stages independently, but in concert. Synchronizing the tuning of these two stages is difficult for homebrewers. Commercial manufacturers formerly did this with custom-made, double and triple variable capacitors. Modern receivers use arrays of digitally switched varactors. This sophistication is not "simple." I soon learned that digital switches have capacitance and resistance and are much harder to use than ordinary mechanical switches. In the receiver described below I used separate pre-selector and VFO tuning.

In the **mixer** stage the antenna and VFO signals "beat together." In other words, they interfere with each other. The mismatched sinewaves collide causing the original sinewaves to reinforce some half sinewaves and cancel others. This produces a chaotic mixture of four signal frequencies. These are the original RF antenna signal, the original VFO RF sinewave plus the sum and difference frequencies of the original signals. The mixer then passes signals to the **IF amplifier** which selects either the sum or difference frequency.

The purpose of the IF amplifier is to provide the single frequency amplification and sharp tuning that every radio needs. As we've seen, TRF receivers can work well, but are hard to build. Basically TRF receivers are multiple pre-selectors in series and they are all tuned simultaneously. But even the best TRF receiver can't achieve the selectivity of **crystal filters.** Modern superhetrodynes need extra sharp tuning for CW which is difficult without crystal filters. Since crystals don't amplify, the IF amplifier and crystals work together. Modern hi-tech receivers move the frequency two or even three times with mixers and IF amplifiers. The last stage often uses computer processing to remove static, enhance the audio and generate optimal listening.

The **product detector** is essentially the same as the mixer in the direct conversion receiver in Chapter 7A. The differences are that one input is from the IF and is an antenna signal converted into a constant frequency IF signal. The second input signal is a **Beat Frequency Oscillator (BFO**). The BFO is nearly the same frequency as the IF, but the frequency difference is in the audio range. That means it produces an audible, musical tone, useful for making CW easy to copy. The BFO is manually adjusted to produce the best audio tone for CW or the most life-like speech from a single-side-band (SSB) signal. Finally the resulting audio signal is passed to an **audio amplifier.** This amplifier is just like those we used with the regenerative and DCR receivers.

Lots of controls and complex switching

A downside of a full spectrum HF receiver is that lots of knobs and switches are needed to cover the wide range of frequencies and modulations. Every signal received is different and a homebuilt receiver needs lots of switches thrown and knobs turned to receive it. It can be weak or strong, narrow bandwidth or wide bandwidth, CW, AM, SSB, USB, LSB, FM, or obscured by noise and other stations. Commercial receivers set up many of these adjustments automatically but homebuilts need manual controls.

To prevent images and reduce noise, an extremely sharp pre-selector is needed. A single L-C circuit cannot tune sharply enough to reject unwanted signals. I eventually used 3 simultaneously tuned, identical L-C circuits in series. The triple L-C covers 80 to 10 meters, but 10 meters is marginal. To cover higher and lower frequency extremes, different inductors are needed with the triple variable capacitor. Switching-in different inductors is complicated.

For frequencies above 40 meters **an RF preamplifier** is needed to boost the antenna signal. Below 30 meters, the preamplifier might need to be bypassed to suppress noise. This required a Double-Pole-Double-Throw (DPDT) switch.

CW, SSB, FM and AM modulation methods need separate detection circuits. Because CW and SSB need sharp tuning, the main VFO tuning is supplemented with a bandspread for tuning within a ham band. A super-fine bandspread is helpful to tweak the tuning to receive SSB. A product detector will detect all four modulation types, but tuning in AM and FM is not practical.

AM reception worked best for me with switches to turn off the BFO and simply bypass the product detector. In other words, an audio amplifier can't pass or amplify RF signals. Consequently, passing amplitude modulated RF into an audio amplifier, filters out the radio frequencies and just leaves the speech or music component.

CW needs narrow bandwidth filtering to separate out closely spaced RF signals and reduce atmospheric static. CW reception is best with crystal filters, audio filters or both. SSB needs a **pre-selector attenuator** to match the amplitude voltage ranges to the voltage ranges of the IF and audio amplifier stages. Without an attenuator, speech is rarely intelligible - more switches and tweaking. The high end of the 10 meter band is the only HF FM ham band. Narrow band AM and wideband FM detectors are presented in Chapters 13B and 16C.

Making superhetrodynes work

Superhetrodynes were the second great invention of Edwin Howard Armstrong as mentioned in Chapter 7B. The good news is that superhetrodynes are much easier to make work than regenerative receivers because each stage has only one job. When you first turn it on, if each stage is working, the whole receiver will work. You can even stuff it into a metal cabinet with a power line power supply. OK, you may have a small 60 Hertz hum problem with FM detection, but it will be easy to eliminate.

The challenge of superhetrodynes is the difficulty of separating the various frequencies so that you only hear the one you want. When superhetrodynes are misaligned, you're likely to hear more than one piece of the radio spectrum at once. However, a superhetrodyne is far less likely than a regenerative receiver to assault your ears with obnoxious explosions of noise. In my experience if you program the LM386 audio amplifier to the highest gain, it will be the only module of the receiver that still might blast your ears. I finally replaced the LM386 with the more complex analog amplifier used in Chapter 7A. This design has a more linear volume control and is much less likely to oscillate.

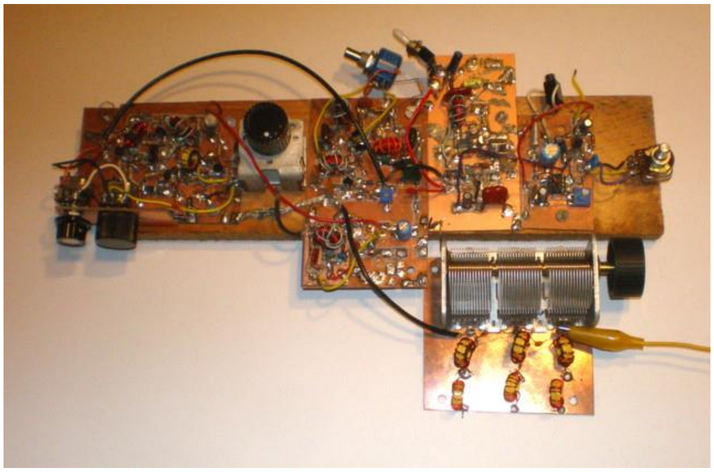
If your construction technique is crude and unshielded, like my breadboard prototype shown below, there will be two more frequencies that must be eliminated. If your IF is not in a shielded metal box, there may be a signal on your IF frequency that might seep into your IF amplifier. If such a signal is strong, it can be hard to eliminate. Lastly, if there is a really overwhelming signal in your neighborhood, such as a commercial AM radio station, that signal will also creep into your IF or directly into your audio amplifier. 60 Hz power line hum is yet another interference threat. Consequently, it's possible to hear **five** or more frequencies at once, instead of just the one we wanted.

Design philosophy

This receiver is a collection of modules that can be interconnected like toy "Legos." The reader may prefer other circuit modules and substitute them for the circuits I used. The complexity of this receiver depends on your goals and enthusiasm. For instance, a major weakness of the original breadboard design was a crude pre-selector. This pre-selector was the same basic circuit used in the single band pre-selector of the Direct Coupled receiver in Chapter 7A but it uses a three ganged, parallel, 365 pF variable capacitor. This delivers sharp tuning in each band. **The advantage of single-conversion is that it can tune all the HF frequencies**, from 1.8 MHz up to 30 MHz. This allows you to hear the foreign AM broadcast bands, 27 MHz CB radio, radio Moscow, over-the-horizon HF radars and anything else happening in the HF spectrum.

In the receivers described in Chapter 13A and 13B each ham band has its own complex, pre-tuned pre-selector and frequency converter. This insures that images and noise from outside the band are suppressed as much as possible. This is ideal for ham band reception but eliminates most other HF stations. If you are serious about building this "simplified" superhetrodyne, read Chapters 13A and 13B before you begin soldering. If you're only interested in the HF ham bands, maybe the Chapter 13 receiver is best for you.

As you look at the module schematics you may wonder, "Why did he use 75 pF or 220 ohms and not other values?" These are nearly always ballpark sizes and were what I happened to have in my parts drawers. These values worked OK in my breadboard prototype. If you were to use 47 pF and 150 ohms, they might work just as well. I'm not the world's greatest engineer and I don't calculate and fret over small details. Remember that we humans went to the moon with slide rules. Three digit accuracy is usually more than enough. The important issue is to ***place the decimal point correctly***!



Developmental superhetrodyne breadboard

The prototype shown above was working acceptably well for the CW bands on 80, 40, 30 20, 17 and 15 meters. So far I haven't heard any hams on 160 and 60 meters. The 12 and 10 meter bands have been dead, so I can only claim to have received my frequency generator on those bands. Using different VFO inductor and pre-selector parts it also worked well on the AM broadcast band. However, that modification cost me several upper ham bands. I changed it back to cover as many ham bands as possible. Listening to the bands above 15 meters may require switching to different pre-selector inductors. The loudspeaker and power supply are not shown. In the state of development shown above, CW and AM reception was very good. Tuning in SSB only became practical after I added an extra-fine bandspread capacitor to the local oscillator tuning.

Left to right, the little circuit modules are follows:

(1) The VFO with main and varactor bandspread tuning and buffer amplifiers.

(2) Antenna tuner/preamplifier, mixer and IF amplifier.

(3) Product detector and Beat Frequency Oscillator.

(4) Audio preamplifier and LM386 integrated circuit amplifier and speaker driver.

(5) The yellow test lead goes to an outdoor, long wire antenna.

During development the receiver was powered by a variable, 12 volt lab supply. I also confirmed that it works well with the QRP power supplies described in Chapter 8. Unlike the regenerative receivers described earlier, there was no 60 Hz hum and it is not effected by a nearby soldering iron or table lamp. Also, there is little interference from my local AM radio station. Hopefully a complex AM broadcast filter will not be needed when I package the receiver in a metal enclosure. When the receiver was in a bare breadboard form, an external 6 MHz suppressor was needed when Radio Cuba was broadcasting on 6.000 MHz, the IF frequency.

This receiver uses a single frequency conversion rather than two Intermediate Frequency conversions like the two receivers described in Chapter 13. One disadvantage is that, **unlike the double-conversion design, a vernier, analog dial cannot calibrate the whole spectrum with 10 KHz accuracy.** The best it can do is display the ham bands as marks on one or two spans of frequency. To tune in a ham band, the pre-selector tuning dial is set to a mark showing the bottom of the band. The bandspread can be calibrated to show minimum capacitance (higher frequency) and maximum capacitance (lower frequency). Unfortunately, the KHz range of the bandspread is small at low frequencies and large at high frequencies, so it can't be calibrated in KHz.

A fine-tuning bandspread allows us to tune in each station more precisely, much like the bandspread in the DCR described in Chapter 7A. If you have a frequency counter and can subtract (or add) the IF frequency in your head, you can monitor the listening frequency to within a KHz. I've been monitoring the VFO with an old Hewlett-Packard frequency counter. For example, with this receiver tuned to 40 meters, the VFO is tuned between 13.000 MHz and 13.300 MHz. Prior to building this, I had never actually done short wave listening with the luxury of a digital frequency readout. My old analog Army radio is equally precise, but you have to calibrate the analog scale for each one MHz scale and interpret the number. I'm impressed with how convenient digital numbers are - no thinking required!

An obvious project would be to build and program an Arduino-controlled frequency counter that will automatically subtract (or add) the IF frequency from the VFO frequency to read the received frequency. For instance, 13.000 MHz minus 6 MHz would become 7.000 MHz, just like the big boys' $5,000 receivers. Yes, a sensitive homemade receiver will probably hear the Arduino RF digital chatter. But perhaps the digital circuitry can be sealed in a filtered, shielded, metal vault and buried in the backyard to attenuate the noise - a new project!

The first VFO I built is crude and lacks the +/- 5 Hz per minute stability enabled by fancy temperature control and compensation. I justified this because a truly stable VFO is hard to build and the old time tube ham receivers had a wide reception bandwidth. Also, when the receiver drifts, you are the only person who might notice, not the fellow you're talking to. The disadvantage is that I gave up the noise reduction and selectivity of sharp audio and crystal filters.

Frequency Range

The main VFO tuning capacitor is a "365 pF" mechanical variable. After calculating what the lowest VFO frequency should be, I was surprised that it tuned much lower. When I measured my single "365 pF" capacitors, they turned out to be more like 470 pF maximum. This capacitor tunes the VFO and is tuned together with the pre-selector to select a station. In this receiver the VFO produces a constant sinewave signal which can be set to either 6.00 MHz **above** or 6.00 MHz **below** the desired listening frequency.

First, the pre-selectoris set to the desired listening frequency. For instance, 160 Meters is 1.8 MHz to 2.0 MHz. Next, the VFO is set to 7.8 MHz, which is 6 MHz **above** 1.8 MHz. To listen to 10 meters, 28 to 29.7 MHz, the pre-selector is first set to about 29 MHz. The VFO is then set to 6 MHz **below** ten meters which is 22 MHz to 23.7 MHz. For some midrange frequencies, the VFO can be set either above or below the desired frequencies. As a result ***the VFO dial needs two calibration scales, one for 6 MHz above and the other for 6 MHz below the listening frequency***.

Simultaneous VFO and pre-selector tuning

It would be convenient to have the pre-selector and VFO tuned by the same knob. The old commercial receivers from the 1950s had multi-gang, non-linear tuning capacitors that were custom designed to do this. Usually the VFO section was slightly smaller than the pre-selector section(s). Also, each of the multiple sections had trim capacitors to achieve near perfect matching of the two functions. Using my three equal section variable capacitors I tried to run the VFO and pre-selector together, but of course the two tuning curves were hopelessly mismatched.

To extend the frequency range of the VFO, there is another trick that you might use. You can disconnect the big 365 pF variable and use the band-spread capacitor alone for the main VFO tuning function. Now it tunes in 12 and 10 meters. The band-spread capacitor on its own can tune as high as 37 MHz when set to minimum capacitance. The band-spread capacitor has its own tiny band-spread capacitor. This is needed to separate the CW signals and tune in SSB signals. The circuit for the tiny band-spread is the same as the larger band-spread except that, instead of a 47 pF coupling capacitor, the capacitor for the extra-fine band-spread is just 4.7 pF.

The pre-selector can serve as attenuator

An advantage of separate pre-selector tuning is that **the pre-selector can be used as an attenuator to reduce noise and tune in Single Sideband** stations. To tune in sideband signals on a hamband, I first set the VFO to the desired band, either 6 MHz above or 6 MHz below the band. Next, I tune the pre-selector to the single point on the pre-selector dial for the desired band. You should be hearing a rush of lower pitched, static noise at that setting. This tells you that you should begin to hear amateur stations. Using the VFO band-spread capacitors, tune across the phone band portion of the band. For instance, on 40 meters the phone band is 7.125 MHz to 7.300 MHz.

When you encounter a sideband station, it will sound like the usual un-intelligible "Donald Duck" squawking. Even when you tune carefully with the band-spread and BFO, it will often still sound like squawking and you won't understand a word. Now adjust the pre-selector to slightly off-frequency so that the hiss of static disappears. ***With a weaker signal, the audio will not exceed the voltage span of the amplifiers.*** Now SSB will be much easier to adjust to clear speech using the super-fine band-spread tuning. Unfortunately, weak SSB signals are often the same level as the atmospheric noise, so they simply can't be received intelligibly.

Similarly when listening to CW, loud code stations may be heard along with loud atmospheric static. By slightly misadjusting the pre-selector, the Morse code will still be strong enough without the distracting static. Sometimes the IF gain potentiometer may also be used this way.

IF frequency choice

Notice that, the higher the IF frequency, the easier it is to build a pre-selector. Modern HF ham receivers use Very High Frequencies (VHF) for the first conversion. In effect, the first conversion becomes a complex but highly effective pre-selector. For example, if the first IF were 100 MHz, listening to 10 MHz requires the VFO to tune to 90 MHz. That is because the *sum* of 90 MHz plus 10 MHz = 100 MHz. The other possible received frequency a 100 MHz IF could amplify would be the *difference* between the two input sinewaves. 90 MHz can be *subtracted* from a 190 MHz signal to equal 100 MHz. It is ridiculously easy for an L-C filter to select 10 MHz and reject 190 MHz. After pre-selection, the signal frequency can be moved to lower frequencies with a second IF, such as 9 MHz or 6 MHz. Crystal filters can be used at these frequencies to achieve a narrow bandpass for CW. Unfortunately, 100 MHz primary frequency crystals don't exist, so 100 MHz crystal filters can't be built.

In the receiver described here the single IF frequency is 6 MHz. Therefore the pre-selector L-C filter needs to suppress signals that are 12 MHz away. Any sum or difference 6 MHz frequency entering the IF amplifier is amplified while all the others are (hopefully) rejected. Rejected frequencies include the VFO frequency, except when the VFO tunes through 6 MHz. I was puzzled the first time I encountered the 20 meter CW band loud and clear just above a VFO frequency of 8.00 MHz. But of course 14 MHz minus 6 MHz = 8 MHz. Or, you can listen to 20 meters at a VFO frequency of 20 MHz. 14 MHz plus 6 MHz = 20 MHz. ***The pre-selector is the master received frequency control***. Where you hear the band on the VFO dial depends on the pre-selector which can only tune one frequency at a time, not two.

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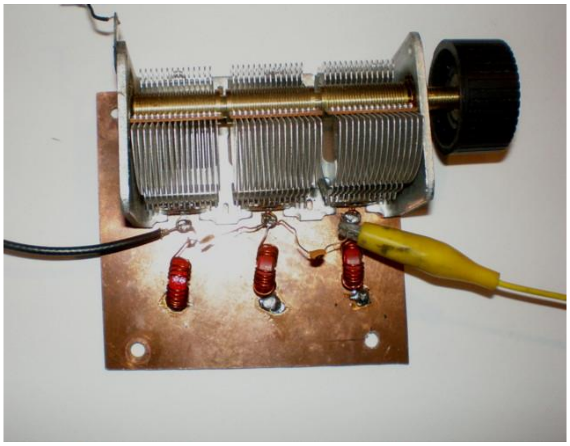
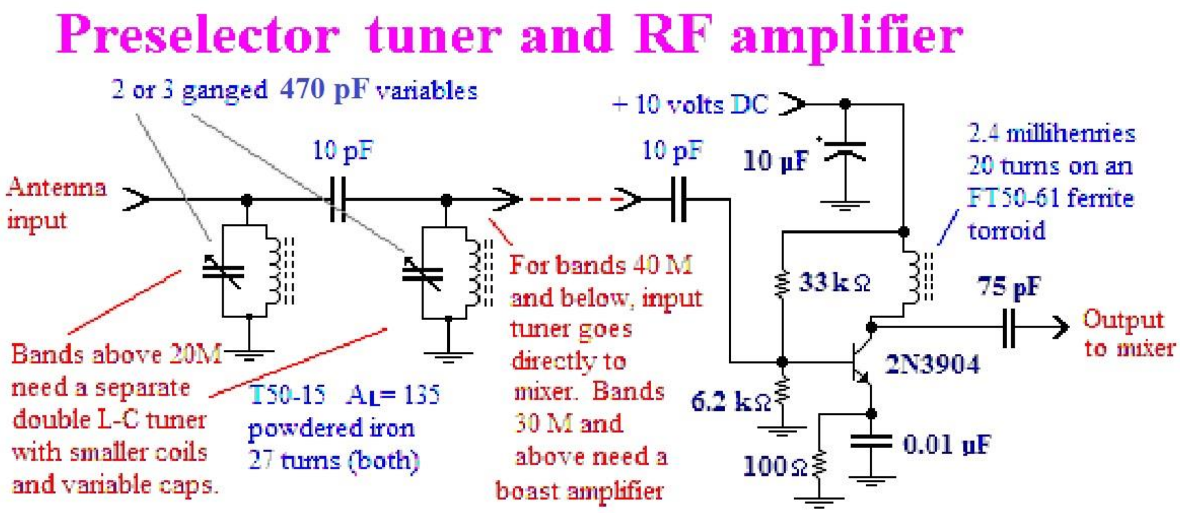
CIRCUIT BOARD SCHEMATICS

The pre-selector and RF amplifier

A major difference between this receiver and the ones in Chapter 13 is that the input pre-selector I used is not pre-tuned for each ham band. In Chapter 13, each ham band has its own dedicated, multiple set of tuned L-C circuits. In this receiver I first tried a single tunable L-C filter, but it was not nearly selective enough to avoid images and leakage from strong signals. Next I used two 140 pF variable caps tuned independently. This worked OK, but I switched to triple ganged (simultaneously tuned) 470 pF variable capacitors which cover a wider span of bands - 80 through 15 meters. I also changed the 45 pF capacitors between sections of variable caps to 10 pF. Surprisingly this didn't seem to cost me any signal strength. Two parallel tuned 470 pf capacitors don't seem much less effective than 3 parallel tuned caps, but I haven't made any measurements. A good source for old-fashioned mechanical capacitors is RF Parts Company - www.rfpartsco.com .



The toroid inductors determine the tuning range. Sadly, it doesn't seem to be possible to cover 160 meters to 10 meters with one set of inductors. If you can figure out the needed complicated switching system, you can cover the entire HF spectrum with 2 ranges of tuning. At this point in my R&D I was soldering in different coils - not very convenient. The inductors described below on the diagram are the most versatile I have tried, they cover 80 meters up to 15 meters.



T50-6 powdered iron toroids with 8 turns will tune 15 through 10 meters. T50-2 toroids with 14 turns will tune 40 meters through 15 meters. 160 meters and below requires LARGE inductors. A T-68-15 (A_L = 180) with 35 turns will cover 60, 80 and 160 meters. A clever idea is to put 3 toroids in series so that they are equivalent to the lowest frequency toroid. Then for each range, you short the appropriate nodes to ground.

Analog integrated circuit switches and transistor switching

I experimented with switching pre-selector inductors using a CMOS 4066 analog integrated circuit switch. These chips can often be used as ordinary switches but are controlled by binary, ON/OFF logic voltages. Each chip has 4 Single-Pole-Single-Throw (SPST) switches. The design concept was to have logic circuits organize combinations of connections for each band range. In summary, ***it didn't work worth a darn***. The digital switches have significant resistance and capacitance that destroyed the tuning selectivity of the L-C circuits.

I also tried using NPN transistors to short the nodes between pre-selector inductors to ground. When turned off, these transistors have essentially infinite resistance. Unfortunately, they have PN junctions like a varactor capacitor and 6 to 42 pF capacitance remains. How much capacitance depends on the transistor type - 2N3904, 2N2222, etc. Again, ***the tuning selectivity was degraded with transistors in the circuit***, whether they were turned ON or OFF.

Tune for the quiet spots

When tuning in a ham band, first set the VFO to the frequency that will add or subtract with the IF frequency (e.g., 6 MHz) to select the desired frequency. As you tune near the correct frequency, you should hear the background static noise rise slightly. As you tune to the center of the point where the pre-selector and VFO differ exactly by the IF frequency, 6 MHz, the static will drop to a relative "trough" of silence. That is where reception is ideal for that frequency. As you tune farther, the static noise increases again, then trails off.

Broadband amplifier

The above broadband amplifier on the right is my usual generic, all-frequency, RF amplifier module. In this application it drives a high impedance input JFET mixer, so I just took the output directly off the collector. The output from this module is often a 4 turn transformer secondary. That also worked here but with slightly less signal strength. For frequencies above 40 meters, the amplifier is usually needed to boost the signal. Below 30 meters atmospheric noise is much higher and an amplifier is often counter-productive. I used a DPDT switch to connect or disconnect the amplifier to test whether the amplifier is helpful or just noisy. We can leave the pre-selector preamplifier powered when it is switched out of the circuit without degrading performance. A triple throw switch is not needed.

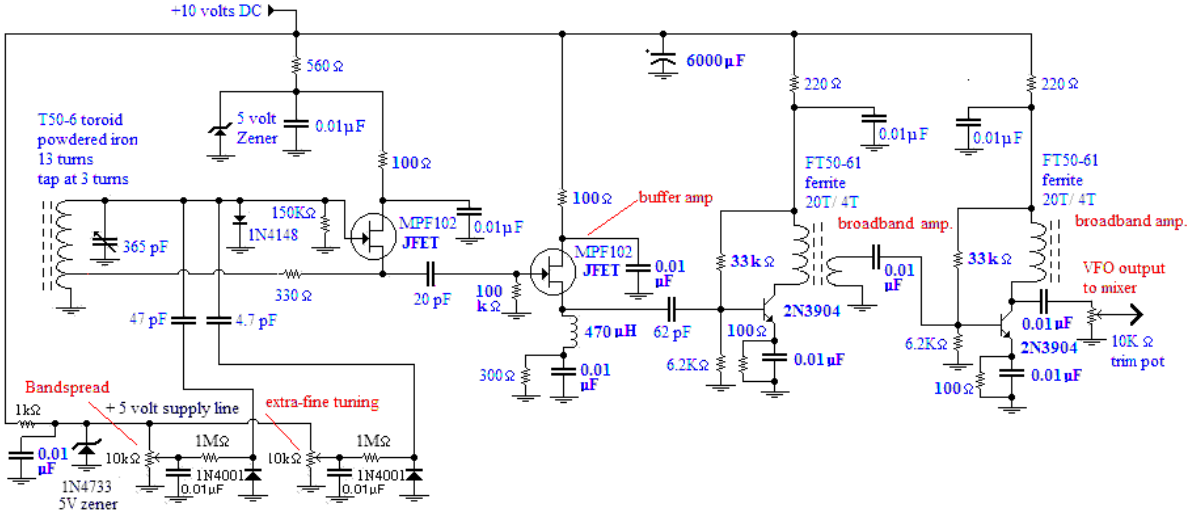
As you know, ferrite toroids easily produce **big inductances**, **millihenries**. Powdered iron toroids produce **small inductances, microhenries**, 1/1000 as much. The calculations for inductance and coil turns are the same for ferrites, but A_L for ferrites is in millihenries, not microhenries. For the broadband amplifier, the amount of inductance isn't critical. A small 470 microhenry choke will usually work OK.

The Variable Frequency Oscillator VFO

Chapter 10 is devoted to building very stable, low frequency VFOs with a small range of frequencies, such as 5 to 5.5 MHz. The VFO with the 365 pF capacitor in this super-hetrodyne can sweep from relatively low frequencies, 7.6 MHz, all the way up to 27 MHz. I first treated the VFO like any other circuit module. I made no heroic efforts to isolate it and keep it from drifting. And it does drift - hundreds of Hertz per minute. By subtracting and adding the IF frequency to the VFO frequency, it can cover 2.6 MHz up to 33 MHz. Covering 160 meters and standard broadcast would need extra capacitance to lower the VFO frequency range down to 6.55 MHz.

This VFO is very much like the VFO in an ordinary table radio. Even the VFOs in FM radios are built this casual way. FM table radios receive a +/- 75 KHz bandwidth (150 KHz!) signal, so drift is not a big problem. Also, they are equipped with a varactor controlled feedback system to "lock in" the desired station. When the VFO drifts, the feedback readjusts the VFO. In this HF application I am assuming that a bandwidth of 3 KHz is adequate. A single crystal filter will produce this degree of filtering. If you use sharper crystal filters, this VFO will quickly drift out of the pass band - I tried it. Without strict interstage isolation using metal shields and power line bypass filters, sharp, multi-crystal filters are useless. The signals outside the desired bandwidth will couple capacitively right around a multiple crystal filter.

Wideband VFO for Simplified Superheterodyne



Low frequency VFO sinewaves are much larger than high frequency VFO sinewaves

Why so many stages? A design difficulty with this module was that every amplifier and oscillator tends to have a built-in voltage rate-of-change that depends on the amount of stray capacitance and stray inductance in the circuit. It's like waving your arm faster and faster. The number of waves per minute is limited by on the weight of your arm, your strength, the speed of muscle contraction and the speed of nerve conduction.

As the VFO frequency rises higher, the peak voltage of the sinewave decreases. This occurs because there is less time for the sinewave to rise to the same height as lower frequencies before it must turn around and descend again. Ideally, the voltage waveform would have the same peak voltage over the entire range. When I watched the oscillator output voltage on the scope, the high frequency end of the range had less than 10% of the peak voltage at the low frequency end. To correct this I put in three untuned (broadband) stages of amplification. If the amplitude at any one stage is too high at low frequencies it will cause a distorted sinewave which will result in unwanted "images" - unwanted frequencies received by radio. You can always use fewer turns on the secondary winding on the third stage. The ideal output would be a one or two volts peak, pure sinewave over the entire VFO range.

When I was working on my SSB transmitter, I learned that **ordinary bipolar transistors such as the 2N3904, amplify little signals much more dramatically than big signals**. Looking at the data sheets, this also seems to be true for the MPF102 JFET. While a big input sinewave voltage will be amplified perhaps three times in one amplifier stage, a tiny little sinewave might be amplified ten times. After two extra stages of untuned amplifiers, the high frequency end of the VFO range became large enough to drive the input to the mixer to convert the incoming signals to 6 MHz. Meanwhile, the low frequency end of the range was not saturated into square waves and not distorted. Now it works over the entire frequency range.

Improved VFO

My first version of this VFO is diagrammed above. ***Changing temperature*** is the main reason VFOs drift**.** Heat causes components to expand and alters semiconductor performance. The original entire circuit was on the same board and not isolated thermally from the rest of the receiver. An improved, but more complicated version decreased frequency drift **using the techniques is described in Chapter 10**. The core oscillator and first buffer were moved into a small, cast metal box to decrease the rate of temperature change. The last two stages were unchanged. Instead of running the oscillator and varactors on voltage regulated by ordinary 5 volt Zener diodes, it uses temperature compensated LM336-2.5 and LM336-5 precision Zeners. The oscillator runs on just 2.5 volts to keep it cool. The varactor band-spread tuners are run on 10 volts regulated by two precision 5 volt regulators in series. The resistors feeding the regulators are kept outside the box to keep their dissipated heat away from the oscillator and JFET buffer. The last two amplifier stages are outside the oscillator box since amplification doesn't effect oscillator frequency drift. These VFO design principles are described in Chapter 10.

Receiving FM signals

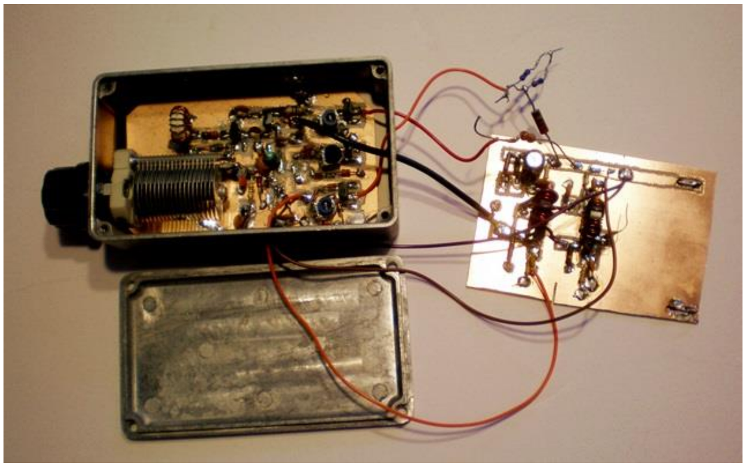
The main reason for building the improved VFO was using the receiver with the 2 meter converter presented in Chapter 16A. It was much less important for HF reception. Optimum FM reception requires a stable VFO. Also, you may have noticed the huge 6,000 µF electrolytic capacitor on the VFO supply line. When receiving FM, any tiny 60 Hz noise in the received signal or the receiver VFO frequency is interpreted by the FM detector as a signal. The big capacitor suppresses *almost* all the hum. I tried 12,000 µF but the extra improvement was slight. FM detectors detect the slightest frequency shift so are much more sensitive to hum than a product detector.

With the top lid removed the receiver, the hum was insignificant. But with the lid on, much of the hum returned. The enclosed chassis volume resonates with the low frequency and restored the hum! Oh, great. Apparently I also need a 60 Hz notch filter on the audio. However, as explained, this FM hum difficulty is only significant when used with VHF or UHF converters.

Temperature compensation adjustment

The LM336 regulators have a precision voltage adjust input for a pot. The data sheet says this adjustment should be adjusted to exactly their nominal voltage, e.g., 2.500 volts. This produces the best thermal compensation. By adjusting the trim pots to above or below the nominal value, sometimes the frequency drift can be stabilized around the desired frequency. In other words, the chip compensation circuitry can often stabilize an entire, small, isolated circuit and not just the chip itself. When the trim pots are not adjusted, the frequency of the oscillator will relentlessly drift up or down. In my particular VFO, the most stable frequency settings were at 2.500 volts and 10.074 volts. Your VFO will probably be most stable at different settings. In Chapter 10 I used an additional thermistor stabilization circuit. That might also increase the stability of this circuit.

Frequency drift is proportional to oscillator frequency. That is, 5 MHz will more stable than 15 MHz. As a result, the stability of this VFO is only fair compared to the system described in the Chapter 13 receivers. At 15 meters the frequency of this VFO wanders around the same kilohertz, but it usually returns to the same neighborhood. The good news is that an audio filter and a double crystal filter for CW are now usable if they are not particularly sharp.

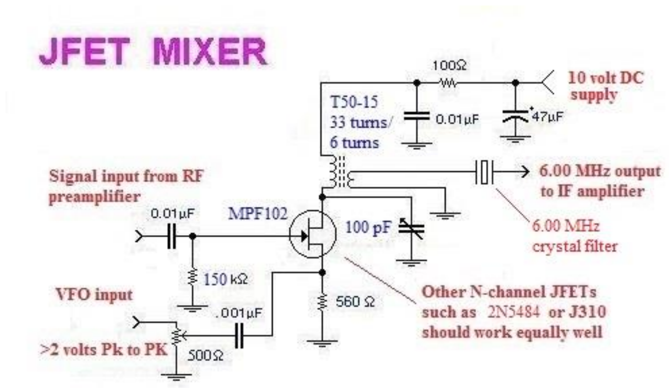


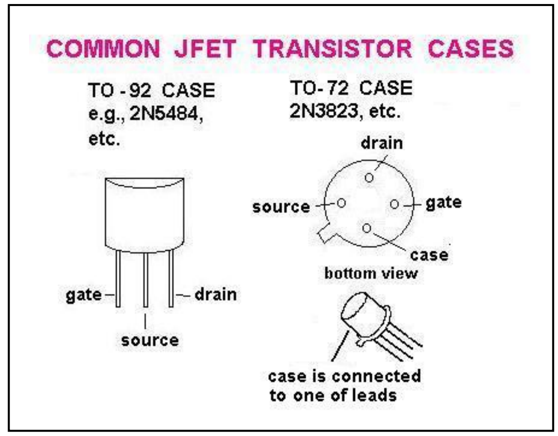
A drawback of this new VFO is that the small box I used is too small for the 365 pF variable capacitor, so I used a 140 pF variable. This restricts the range from 4.5 MHz up to 28.5 MHz, the bottom of the 10 meter band. This change cost me the 80 meter band, unless I want to add a switch to add capacitance (or inductance) for these lower bands. A varactor variable capacitor would be more stable than the mechanical capacitor. Unfortunately they have too little range to cover such a wide range of frequency. The varactor-tuned VFO described in Chapter 10 only tunes from 5.0 MHz to 5.6 MHz. A wider range one in Chapter 16D tunes a 1.2 MHz range.

Mixer

My present version of this receiver uses a JFET tuned mixer. Notice that the signal input goes to the gate and is amplified by the transistor. The VFO signal is attenuated by a 500 ohm pot. The pot is tuned for best balance between VFO and input signals. Use the minimum VFO signal level that gives you maximum audible signal.

The earliest version of this receiver used a dual gate MOSFET mixer, the NTE454. This is the same mixer circuit used in Chapter 13A. In this Chapter 7C receiver the MOSFET worked well, but when large toroid inductors covering 80 and 160 meters were used in the preselector, the mixer oscillated at certain low frequencies. I could still hear ham bands alongside the loud oscillations, but this was unacceptable. When I used small, high frequency toroids for 30 meters and above, it worked well. In summary, the JFET mixer shown below works OK over the whole HF ham spectrum.





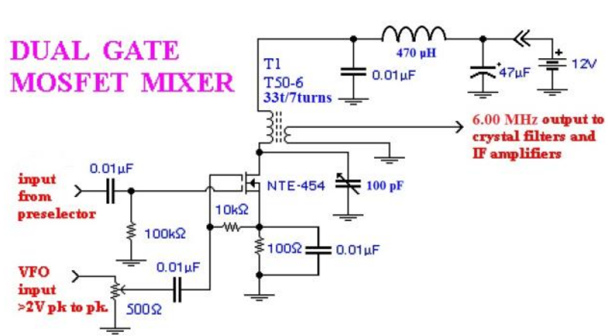
If you're like me, you'll have trouble remembering which JFET lead is which. As you may already know, a TO-92 plastic case shown on the left in the picture is also used for many common bipolar transistors. When we look at the ***flat side*** of a bipolar transistor plastic case, the leads are often labeled - EBC (Emitter, Base and Collector), left to right. With JFETs I turn the transistor around with the ***rounded side*** toward me. It isn't too hard to remember that the source is in the middle, no matter which way it's turned. The drain is analogous to a collector. When facing the ***rounded side***, the drain is now on the right, just like a bipolar collector. The remaining lead must be the gate and that is on the left. Metal case JFETs often have a 4th lead for grounding the metal case. The order of these pins is confusing, so I look it up whenever I use one of these.

The dual-gate MOSFET mixer

After I switched to the improved VFO in the cast metal box and 140 pF variable capacitor, I could no longer tune down to 80 meters. Also, lately my main use for this receiver has been with the 2 meter converter. When used on 2 meters with the JFET mixer, it worked OK, but tuning all the variables had to be precise. The frequency, IF gain and volume control all had to be set just right for a hi-fidelity signal. Since I had no use for 80 and 160 meters, I switched back to the dual-gate mixer used in the Chapter 13 receivers. Sensitivity was improved and tuning adjustment was much easier than with the JFET mixer.

Switching Drain and Source leads on a dual-gate MOSFET?

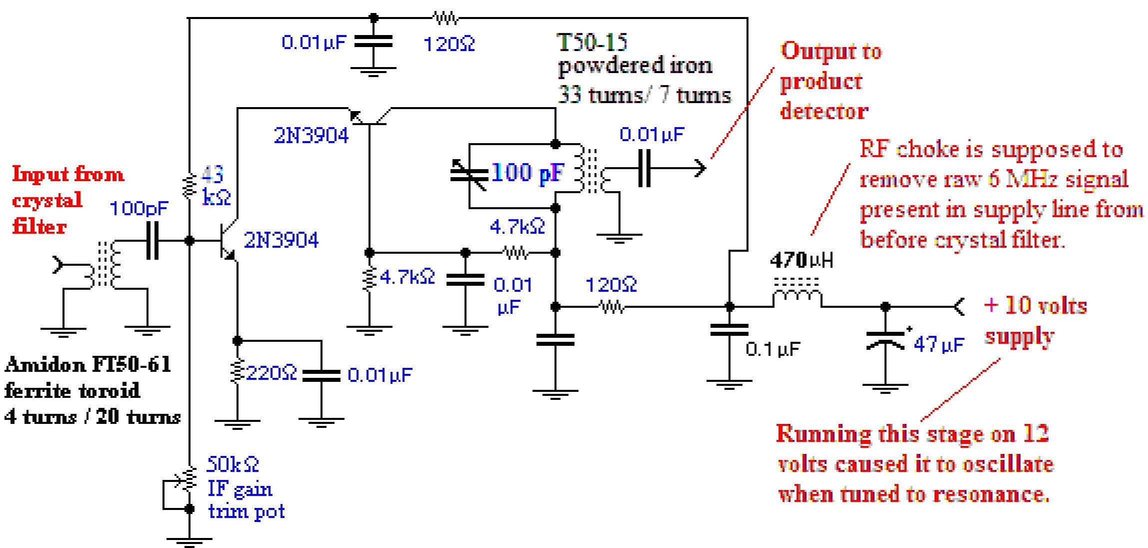
I accidentally soldered the MOSFET into the mixer with the D and S leads reversed. I started to fix it, then I wondered whether it really mattered. After all, supposedly the MOSFET is just a single bar of N-channel silicon with capacitive gates on the sides. Does it really matter? Apparently not. Mine works great!



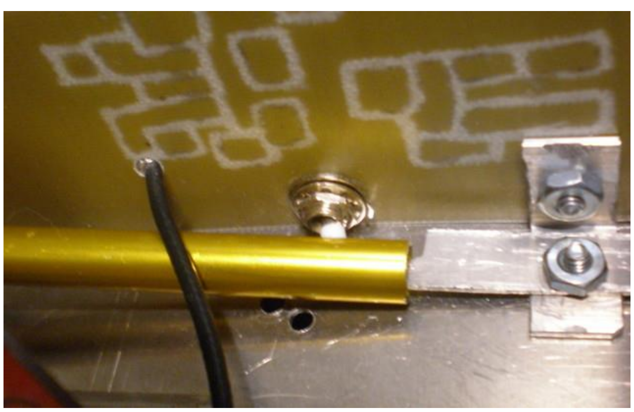
IF Amplifier

Just like my IF adventures in Chapter 13A, I had a hard time finding an IF that worked for all circumstances. The IF amplifier presented below is just a single cascode 6 MHz tuned amplifier stage. To achieve the needed frequency selectivity, I rely on the single 6 MHz quartz crystal between the tuned mixer and the IF amplifier. The quartz crystal is the green module in the block diagram at the beginning of the chapter.

IF amplifier for 6 MHz



Reception of wideband and narrowband signals using the crystal shorting switch



A new feature of this IF circuit was a shorting switch across the 6 MHz crystal. This greatly improved the reception quality of HF shortwave ***AM*** stations. Switching from the CW product detector to AM consists of simply feeding the IF output into the audio amplifier. The only audible signal component in an IF signal is the varying amplitude - and voila! This is the simplest possible AM detector design - no diodes needed. The AM component is weak so having too much IF gain is not a problem. However, when the 3 KHz bandwidth is suddenly increased to 10 KHz or more, the volume of noise will greatly increase and the IF gain needs to be turned way down.

The switch was in the center of the circuit board and inconvenient for switching. A 6 inch long aluminum tube with a hole in the side allows me to operate the switch from the front panel. The thin strip of aluminum sheet metal at the end of the tube keeps the switch handle positioned in the hole.

Earlier I was frustrated with the difficulties of making remote electronic switching that would let me switch HF bands. Three SPST switches engaging one aluminum tube like the one above could perform that function from the front panel. A rotary switch is the usual solution, but I didn't have room on the front panel.

In Chapter 16C I used this receiver for receiving down-converted 2 meter FM ham signals. The rules are same as above: The Foster-Seeley FM detector described in Chapter 16C has an additional 6 MHz amplifier which effectively adds another IF amplifier stage. When IF gain is too high, feedback occurs caused by capacitive coupling between the various stages. For example, with the enclosure lid off, just leaning over the open box can launch the feedback squeal. For the loudest, clear output we can use the same tricks learned for tuning in SSB: The pre-selector knob can be used like a volume control. Tuning away from the exact resonant frequency prevents feedback. For strong signals, reception is easier to adjust with the RF antenna amplifier off. The IF gain control is similar. Too much gain provokes feedback. Perhaps isolating each module in separate, grounded enclosures might eliminate this difficulty. As you can see, super-heterodynes quickly become complicated when we add capabilities.

How about a 455 KHz IF?

If you happen to have an old ceramic 455 KHz IF filter, using 455 KHz for your IF might be a practical choice and would have a narrow 3 KHz bandwidth. Unfortunately 455 KHz ceramic filters are rare items today. 455 KHz is what the old vacuum tube ham radios in the 1950s and 1960s used. You can find 455 KHz IF transformers in any old junked AM radio. In Chapter 17A I describe building a 457 KHz oscillator made from one of these transformers for a practice avalanche beacon. This circuit could easily be adapted to serve as the BFO.

Are there big signals on your IF frequency?

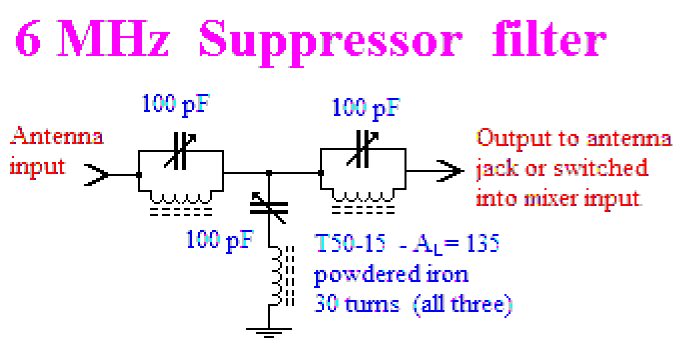
Any HF IF frequency below 30 MHz will include whatever HF frequency you pick for your IF. So when the BFO is turned on, a super-loud whistle will be heard when you try to listen to that frequency, e.g., 6 MHz. If you turn off the BFO and connect the output from the IF amplifier directly to the audio amplifier, you can listen to AM signals on the IF frequency with good fidelity and no whistles. No "detector stage" is needed.

I picked 6 MHz because I already had the crystals. 6 MHz crystals are mass-produced, cheap microcomputer crystals. The 6.000 MHz IF worked well the afternoon I first completed the receiver. But that night I could hear Radio Cuba no matter how I tuned the VFO or adjusted the pre-selector. I learned on-line that Radio Cuba often broadcasts on 6.000 MHz frequency.

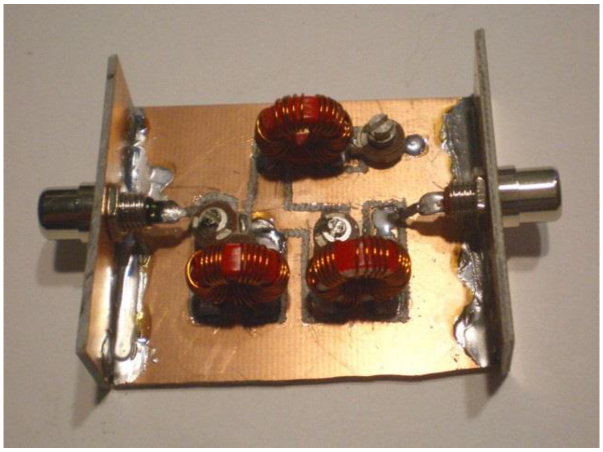
Because I couldn't turn it off, I immediately thought of the old novel, "1984," by George Orwell. It's about a dictatorship that ordered all citizens to have their government-issued TVs turned on continuously. When the citizens watched TV, the TVs had cameras that were watching the citizens. The programming on Radio Cuba reminds me of Radio Moscow in the old days - nostalgia! No matter what your politics are, Short Wave Listening is interesting, educational and fun. This full coverage receiver will allow you to do old fashioned S.W.L. exploration over the entire HF spectrum.

In an attempt to silence Havana, I tried 8 MHz crystals for the BFO and IF filter. When I tuned the VFO to 4 MHz, which is the top of the 75-80 meter band, the VFO produced a screaming 2nd harmonic signal in the IF that made the 75 meter band unusable. I also tried 4 MHz crystals which were even worse.

A suppressor for an unwanted frequency



If you don't wish to listen to non-stop Radio Cuba, here's a filter that will snuff it out. To adjust the filter I set my frequency generator to 6 MHz, then just adjusted each variable trim capacitor for minimum sinewave output. You could also use your BFO as a 6 MHz frequency source. Put a high impedance load on the filter, say 1,000 ohms, on the output and watch the sinewave voltage across the resistor as you adjust each trimmer capacitor. This filter will exclude 6 MHz while admitting any frequency more than 10s of KHz away. Of course it could also be tuned or redesigned to suppress other frequencies. The AM interference suppressor described in Chapter 7A is an example. If you have a specific local AM station that is driving you crazy, a sharply tuned filter like this should solve the problem.



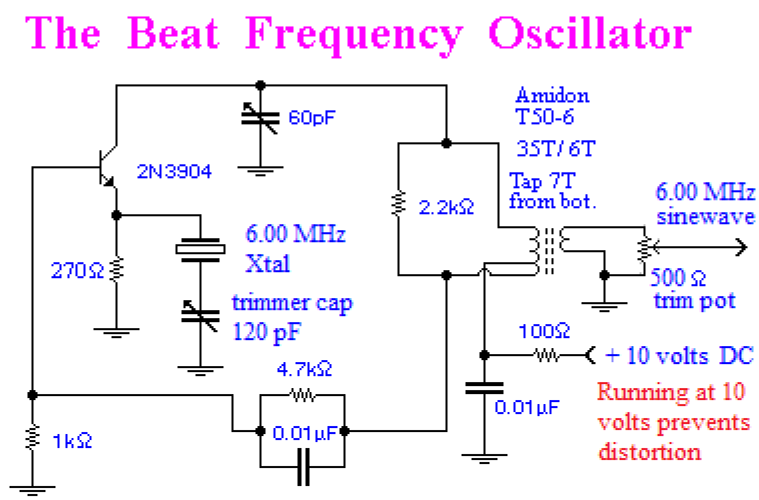
Ideally, filter like this can be switched into the radio whenever needed. The best location is at the antenna signal input to the mixer stage. The desired mixer inputs are the VFO and antenna signals that are *NOT* 6 MHz. The receiver pre-selector is adjusted to capture desired signal frequencies that are either 6 MHz **below** or **above** the VFO frequency.

The suppressor can also be plugged into the antenna input jack and then the antenna can be plugged into the suppressor. If the 6 MHz station is very strong and the shielding is poor, then the 6 MHz signal may reappear in the pre-selector stage, **after** the 6 MHz suppressor. This sounds unlikely but in my first all-band receiver described in Chapter 13A, I had trouble with a local AM radio station delivering non-stop rap music. I put the AM suppressor filter between the 80 meter pre-selector and the mixer stage. Connecting it externally to the antenna input jack was less effective. If you're plagued with AM radio station interference, (550 KHz to 1.7 MHz), a similar AM band suppressor filter is described in Chapter 7A.

Later: Once I had this "simplified" receiver optimized and fully shielded in an aluminum chassis and fitted with an improved pre-selector, Radio Cuba disappeared entirely. The filter is no longer needed for 6 MHz, but it can always be tuned for some other HF frequency. Actually, as you probably noticed, I enjoyed the detour into listening to Radio Cuba. And of course, now that everything is working properly, I can tune to 6 MHz, VFO = 12.000 MHz, and listen to Cuba whenever ***I*** want.

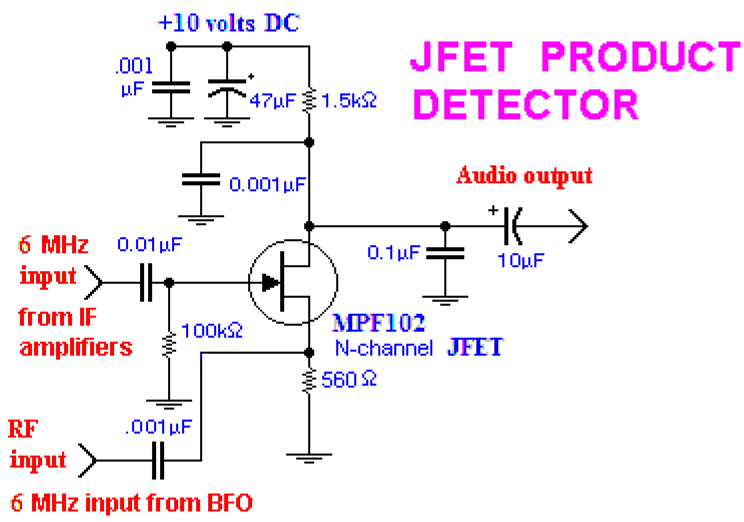
CW and SSB reception - The Beat Frequency Oscillator (BFO)

The BFO is essentially the same oscillator used in the QRP described in Chapter 6. The only significant difference is that the output has an amplitude adjustment pot. If you would like to make the tone of audio whistle adjustable, the trimmer cap could be replaced with a physically large variable capacitor. I eventually used a panel-mounted 45 pF mechanical capacitor which worked well. The BFO crystal was close enough to the IF crystal frequency so the BFO could tune above and below that frequency, thereby adjusting the tone. A varactor capacitor made from 2 ordinary 1N4001 diodes - about 50 pF - should also work.



Product detector

The product detector is the same one used in Chapter 7A. If the BFO input to the product detector is too high amplitude, the audio will have a constant tone that can't be eliminated just by adjusting the frequency trim cap which is in series with the crystal. Lowering the BFO voltage and/ or adjusting the 500 ohm BFO trim pot can prevent this.



The AM detector

Occasionally I like to listen to AM foreign broadcast stations. It turns out that "an AM detector" is surprisingly easy. All I had to do was turn off the BFO and feed the IF amplifier output directly into the audio amplifier. Since the audio amplifier can't pass RF frequencies, the only frequencies remaining in the signal are audio. I am amazed how many years it took for me to realize this. Question authority!

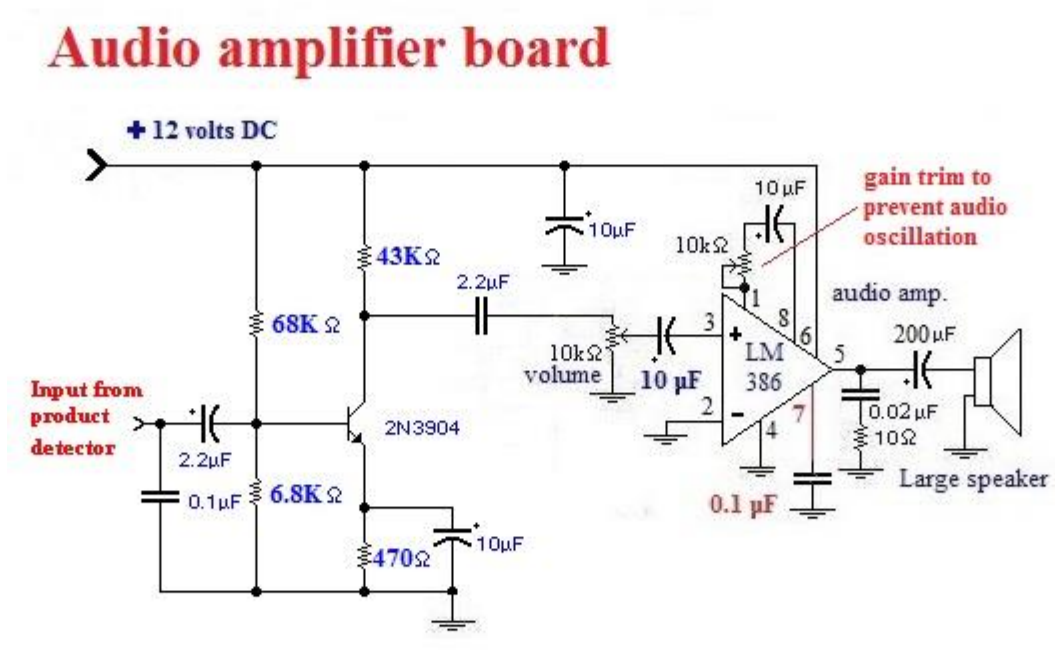
Most product detector schematics isolate the audio amplifier from RF by putting an RF choke, typically 470 µH, between the product detector and the audio amplifier. I took out the RF choke and could not detect any change in performance. Once again, question authority!

When I was using the LM386 audio amplifier circuit, I lost a lot of audio volume by eliminating the signal path through the product detector. When I switched to the all-transistor audio amplifier, the volume was much too weak when I bypassed the product detector. So now when I want AM detection, I simply turn off the power to the BFO oscillator. The product detector serves as an extra stage of audio amplification.

In Chapter 16A a Foster-Seeley FM wideband detector is described for use with this receiver. I needed an FM detector for use with a 2 meter converter. It turned out that the Foster-Seeley FM detector works much better - much louder - for AM than the simple approach described above. This is because the Foster-Seeley has an extra IF amplifier stage which increases the audio component. A difference in operation is that the IF gain must now be more precisely adjusted for optimum reception.

The audio amplifier

I first used the LM386 chip audio amplifier circuit described in Chapter 7B. As before, the maximum gain setting can result in a howling audio oscillation. This was tamed by the 10K trim pot connected to pin 1 of the LM386 chip. Ideally, the volume control pot is an audio type with a logarithmic characteristic, rather than a linear taper. A audio taper potentiometer will insure that the control will not always be set to nearly full volume.



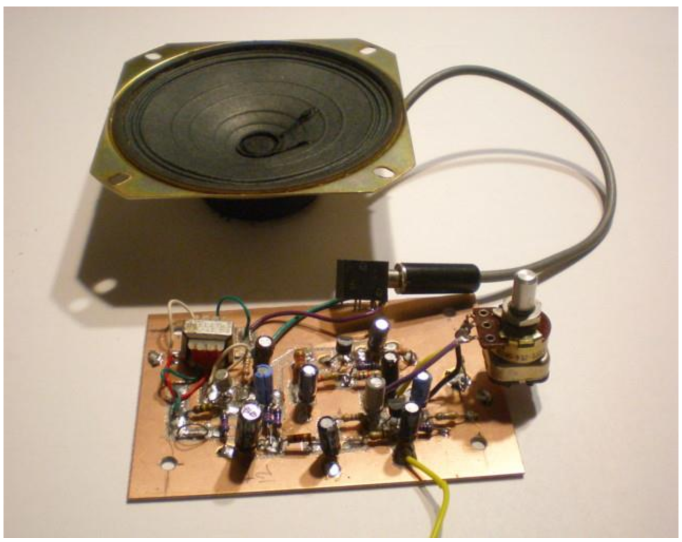
After using this amplifier in the receiver for a while, I now appreciate the discrete transistor audio amplifiers used in Chapters 7A and 13. The old discrete transistor design has an automatic gain control which makes the volume control more linear. The chip-free amplifier isn't constantly on the verge of oscillating. Notice that the LM386 oscillation isn't always audible. I have often observed a 300 KHz oscillation that overheats the chip and obliterates the audio frequencies. A "simple" LM386 amplifier isn't necessarily trouble free.

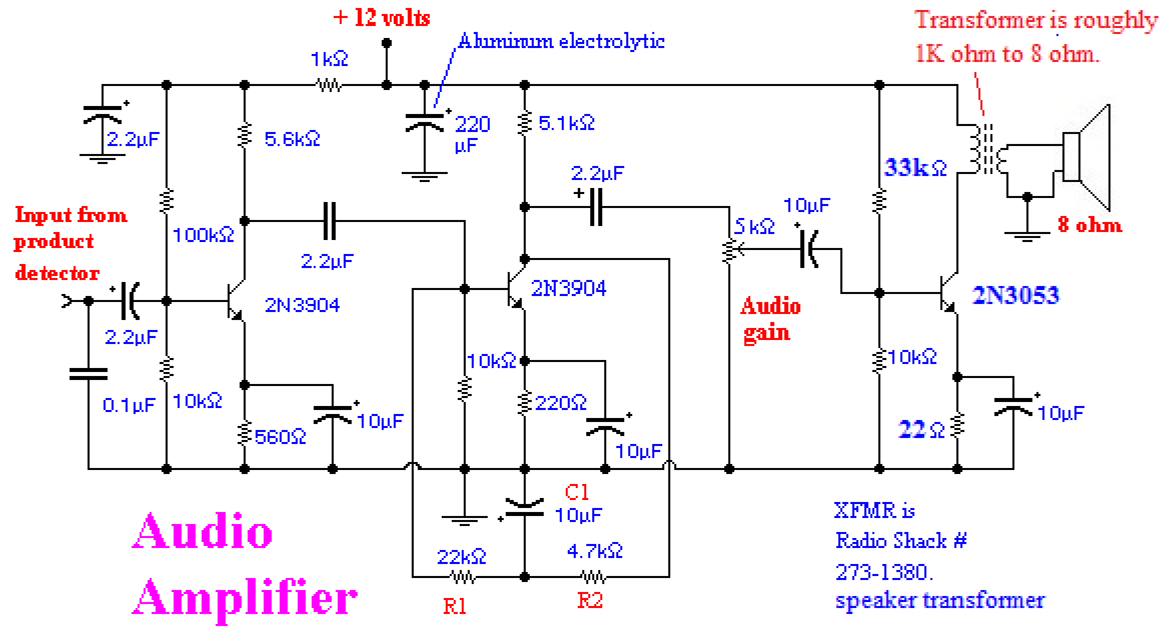
LM386 "atmospheric" noise

I was working on the receiver and forgot to connect the product detector to the LM386 amplifier. I turned it on and heard the usual hiss of static. With no input signal, where did it come from? I set the pre-selector and VFO to the desired band and tuned around - no signals, just the hiss. Apparently LM386s with no input can make static that sounds just like everyday atmospheric static. So now we know that mixers make noise, RF amplifiers make noise, LM386s make noise and even warm resistors make noise. When I touched my finger to the input of the amplifier, it immediately turned into a crystal set receiving my local nemesis radio station. The radio station wasn't a surprise, but I'm not going to live with artifact noise. There's plenty of real atmospheric noise. Consequently I switched to the discrete part analog amplifier shown below. When that amplifier is disconnected, it just delivers silence.

Discrete parts audio amplifier

The amplifier shown below is more linear, easier to adjust and less likely to oscillate at high settings.





Nearly any crude amplifier will work OK for listening to CW. But if you want to listen to AM and FM voice and music, it is essential that the amplifier be **high fidelity**. In other words, the audio signal delivered to the loudspeaker must be a sequence of smooth, wavy sinewaves. Triangle waves and square waves have sharp angles. They sound terrible and distort speech. Also, in order to listen comfortably with a speaker, it must be **loud**.

This is a loudspeaker version of the amplifier used in Chapter 7A, page 10. The output transistor is now biased ON in class A mode with the 33K resistor. Class A operation means that the output transistor is half turned ON and drawing about 30 mA continuously. A small 2N2222 metal case transistor works well here, but because of its small size, it runs hotter than blazes and is hard to heat-sink. I replaced it with a 2N3053 output transistor. This is a TO-5 case transistor, the same type and diameter used as driver transistors in the QRP transmitters presented in Chapter 6A. I placed a small clip-on heat sink on the 2N3053 and it runs much cooler.

If you wish, you can replace the Automatic Gain Control (AGC) circuit consisting of R1, R2, and C1 with a single 100K resistor going from 12 volts to the 2N3904 base. This works well but is more likely to saturate and cause distortion. Another possible difficulty is that, with +12 volts Vcc, the amplifier may oscillate if the driving impedance is too high.

Finding parts

Now that Radio Shack is gone, you'll need to find a source for speaker transformers. Mine came from an old salvaged portable radio. They typically have a 1,000 ohm primary with a 4 or 8 ohm secondary for the loudspeaker. The primary is often center-tapped, but driving half the winding produces noticeably less volume. ***The more output sound you need, the more iron the transformer needs to have***. For this application a transformer about 2 cm wide will be plenty large. Tiny transformers less than one cm long will probably saturate and distort.

By the way, if you're wondering what the "impedances" of your speaker transformer windings are, simply measure them with an ohm meter. "4" or "8" ohm "impedance" output windings are simply 4 and 8 ohms resistance, not abstract L-C-R impedances.

I don't scrounge parts from obsolete or broken electronics simply because I'm cheap. The real value of salvaged parts is the variety in your parts drawers. If you routinely strip old electronics and you happen to need a 2.2 μF or a 47 μF cap, you probably already have several of each. I often complete entire projects without buying new parts. When I order parts it is usually ***after*** I finish a project to replenish my part collection. Some parts like RF transistors, powdered iron toroids and manual variable capacitors with 1/4 inch shafts usually must be purchased.

Troubleshooting distortion

If you aren't happy with the quality of voice or music, unplug the amplifier. Drive the audio amplifier board with an audio sinewave signal generator. Using an oscilloscope, watch the output voltage signal across the loudspeaker leads. Because of the huge turns ratio of the output transformer, 125 to 1, the peak voltages across the speaker terminals will only be 100 to 200 mV. The waveform shape should be smooth waves - no triangle waves or square waves. It is hard to hear mild distortion with your ears, but it's easy to see on a scope. As you vary the sinewave input amplitude, the sinewave output should remain pure over the range you intend to use.

If you see distortion on the scope, look at the static DC voltage on each 2N3904 collector. That is, measure the resting DC voltage with no audio input. These transistors should always be half turned ON, between 5 and 7 volts on the collectors. Raise or lower the two +12V-to-base resistances to reach this range.

Because the output transformer has very low resistance, this tiny resistance will cause the resting 2N3053 collector DC voltage to be nearly +12 volts. Look at the 2N3053 collector voltage ***during operation*** and the sinewaves should be approximately centered on 6 volts. Unlike the 2N3904 stages, the 2N3053 DC bias resistance - e.g., 33K - needs to be determined during operation. The sinewaves should not rise to the +12 volt supply limit and not descend to full transistor saturation, about 0.5 volts. Running the whole amplifier on 6 volts can work well, but it will only generate 1/4 the audio power and is more likely to saturate and distort.

speaker vibration resonance

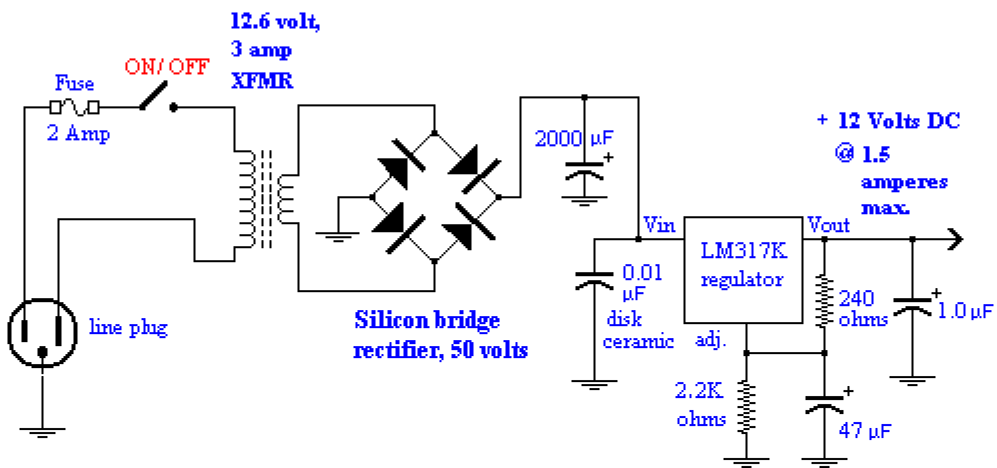
I mentioned earlier that 60 Hz hum is not only caused by electrical signals, but can be mechanically amplified or resonated by the enclosure. If the volume is set high, the vibration may trigger an electronic oscillation which is increased and maintained by "microphonics." Microphonics are mechanical vibrations that generate an electrical signal in the audio amplifier circuit. Putting hands on the enclosure dampens the vibration, but that's hardly a solution.

Speaker magnet size

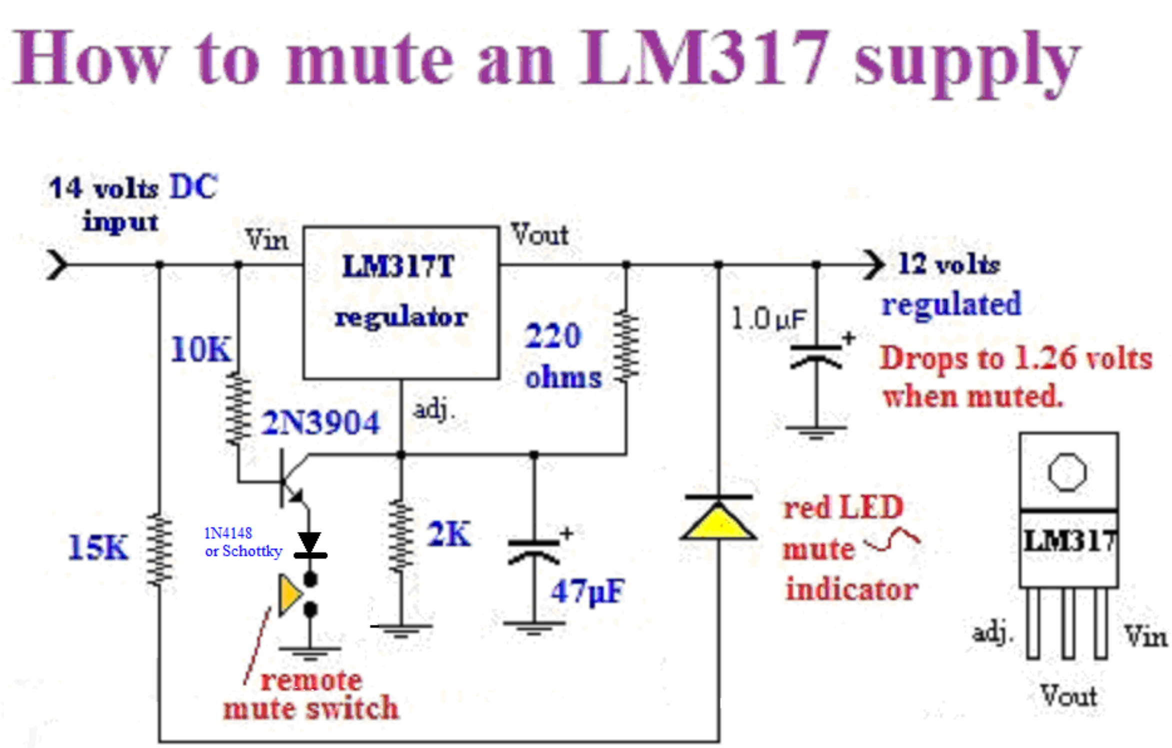
Older small loudspeakers have a small permanent magnet, typically about 2 cm (3/4") across. Modern small loudspeakers found in stereos or computer external speakers have *huge* permanent magnets, almost as wide as the paper cone diameter. The speaker in my receiver came from a small modern stereo. It has a 3 inch diameter cone with a 2.5 inch magnet. The strong magnetic field reacts with tiny currents and makes a big sound. Older speakers with small magnets need more drive current and a wider paper cone size to produce the same volume of sound. Logically, the large magnet should also improve bass response - low frequencies, such as 60 Hz hum ... Just what we need.

Power Supply

My previous "big" ham station receivers and transmitters were all powered by a large common 12 volt storage battery or a high current 12 volt line-powered power supply. The average homebuilder would probably rather plug it directly into the house current. The QRP power supplies suggested in Chapter 8 are adequate. I tried them both with this receiver and there was no audible 60 Hz hum whatsoever. This is in contrast to the regens in Chapter 7B which had a huge hum problem with the same supplies.



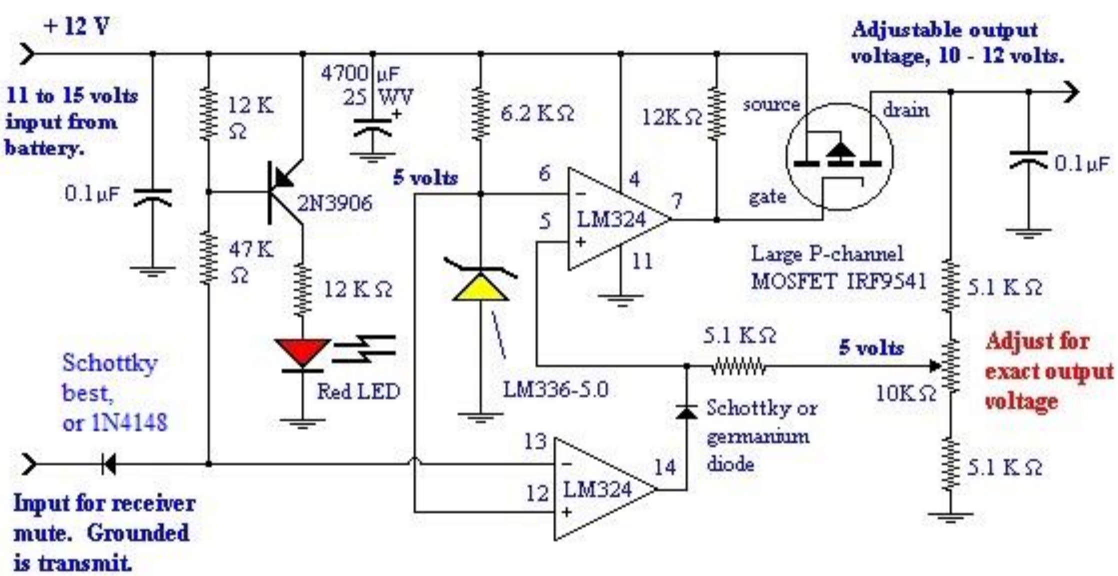
Muting the receiver for use with a transmitter



If you plan to use this receiver with a transmitter, you shouldn't have to turn off the receiver manually every time you begin transmitting. The microphone or transmitter activating switch should have a switch to ground that connects the antenna to the transmitter, activates the transmitter supply and silences the receiver so it doesn't screech in your ears. The circuit above shows how I muted the receiver. It's as simple as I could make it. With more parts you could completely turn off the 12 volt supply voltage and turn the LED completely OFF. The LED is just barely visible in dim light when operating at 12 volts, but is very bright when the supply drops to 1.26 volts. The LED could be completely turned off with a 5 volt Zener diode and smaller resistor in series with the LED.

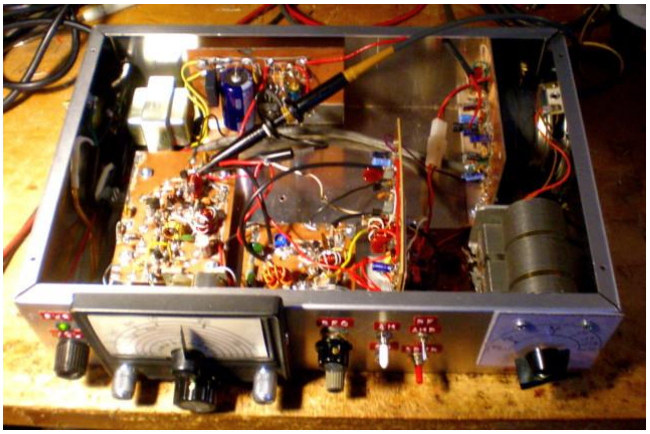
A more precise regulator

Starting with same transformer and rectifier, you could replace the LM317 regulator with the more precise regulator shown below. This supply also has mute capability. Better regulation should improve the VFO stability slightly. However, much better solutions to VFO drift are the ones described in Chapter 10.



Low Dropout 12 Volt Power Supply with Mute Capability

I finally mounted the receiver in a pretty metal box and unlike my regenerative receiver ... it still works! **Its best feature is the ability to quickly check out all the major HF CW bands to see which ones are active**. SSB is still difficult to tune and, compared to the dozens of CW stations I hear every day, SSB stations lately have been scarce and weak.



I like to operate the receiver with the frequency counter probe monitoring the VFO. It is inconvenient to add or subtract the IF frequency to find the right ham band. However the last 3 digits tell me exactly where I am in the band. Below shows operation in the 20 meter CW band. In other words, 20.036 MHz minus 6 MHz is 14.036 MHz. One of my next projects should be to replace the Hewlett Packard counter with a home assembled counter. I have never pieced one together starting from ICs out of a catalog. That should be interesting. Later: ***Frustrating*** more accurately describes my attempt to build a digital counter.

So far, I have not found many exotic foreign AM broadcast stations strong enough to enjoy. Mostly they have been religious sermons and good old Radio Cuba. I was hoping to hear the WWV time station at 5.000 MHz or 10.000 MHz easily. The signals are huge, but apparently the Coordinated Universal Time announcer has been eliminated.

In conclusion,

If you wish to build a ***SIMPLE***, practical CW receiver with the fewest man-hours of effort, I still recommend the direct coupled receiver (DCR) design described in Chapter 7A. Yes, the superhet is superior in several ways, but it isn't nearly as easy to build and troubleshoot. By now I'm sure you've noticed that a design like the super-hetrodyne is never *DONE*. Every improvement comes with more complexity and defeats the goal of "simplicity."