

CRYSTAL SETS TO SIDEBAND

© Frank W. Harris 2021, REV 15

Chapter 7B

Code Practice Receivers

BUILDING A REGENERATIVE HF RECEIVER

Regenerative receivers are another way to build workable CW ham receivers with very few parts. Like the direct coupled design, this method can produce an uncomplicated radio. As you'll see, regens are confusing to understand and difficult to make perform well. Done right, these receivers can, (in theory), be equal to homebuilt superheterodynes. Their advantage over superheterodynes is that there are no off-frequency oscillators to cause birdies - artifact signals - in the tuning range of the radio. Unlike the direct coupled receiver with its product detector, a regen can receive AM with good quality sound. A direct coupled receiver must be tuned perfectly for AM, which is rarely possible. I haven't had the chance to experience this, but I have read that regens will also receive FM modulation.

Before we go into details, bear in mind that the modern ARRL and probably the radio ministries of many countries do not encourage regenerative receivers. The oscillating detector transmits on the frequency it is receiving and the noise interferes with other people trying to use the frequency. It doesn't just transmit a carrier wave like CW, it re-broadcasts the signal being received plus all the nearby atmospheric noise. ARRL did an experiment in which they determined how many regenerative receivers could operate on 2 meters without interfering with each other. The answer was ten regens at once. In other words, 10 "channels" covered 4 MHz! Therefore on 2 meters each receiver interfered with 400KHz of bandwidth.

An overview of building a regenerative receiver

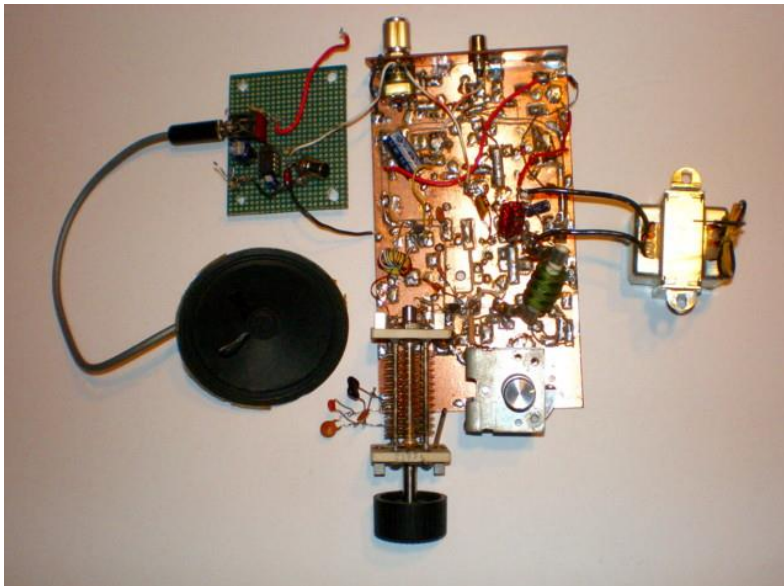
The challenge of regens is finding - by luck, trial and error - the right combination of parts, circuit and operator technique. I haven't succeeded in building a regen remotely as versatile as the superheterodynes described in Chapter 13. However, the breadboard regen presented here was certainly adequate for CW listening on 30 and 40 meters.

When I was an impoverished young ham I assembled an Allied Radio "Ocean Hopper" super-regenerative receiver kit. I bought it because it was cheap. I modified it several ways but it remained noisy and obnoxious to use. I concluded it wasn't good for CW, AM or anything else. At that time Allied Radio sold a first-rate 50 watt CW transmitter kit, so Allied had a good reputation. If they couldn't produce a useful design, I doubted regeneration was practical. I dismantled mine for parts so it wasn't a complete loss.

2. Chapter 7B, Harris



Ashish, N6ASD, sent me a schematic and audio recordings of his 40 meter CW regenerative receiver. He raved about its performance and I was inspired to try again. This article describes my recent attempts to explore regeneration. I tried 3 circuits before I got one to actually work. However, Ashish was right. My circuit was similar to Ashish's and was surprisingly good for listening to 30 and 40 meter CW. My breadboard prototype is shown below.



For reasons I can't fully explain, every time I build a regen, it seems to be dumb luck whether or not it works well. The breadboard version described below worked surprisingly well. When I rebuilt it with the same components in a handsome cabinet with a built-in power supply, it worked poorly. It had weak audio, instability, insensitivity and 60 Hz AC hum. To increase the probability of it working the first time, here are some suggestions:

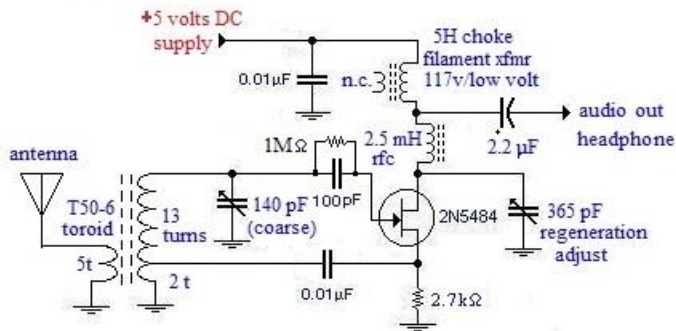
- 1. Run it on batteries.** AC supplies often supply hum which can be louder than the signals.
- 2. Place a variable 5 to 120 pF variable capacitor in series with the antenna.** This can be tuned to provide minimum interference from your local AM stations.
- 3. Add oscillation prevention features to your LM386.** If you use the ubiquitous LM386 audio

3. Chapter 7B, Harris

amplifier chip, put in the suggested circuit components suggested below. Yes, simple versions of the LM386 circuit usually work well, but the extra capacitors and resistors may prevent frustration later on.

4. Charles Kitchin, N1TEV, recommends building regens in plastic or wooden enclosures. This eliminates the stray capacitances that inevitably couple to a metal box. Charles has published several regen articles in ARRL publications including the 1998 Handbook.

Basic Regenerative Receiver



Simplified regen schematic

The circuit above is the heart of the successful version of the receiver I built. I have omitted many details for clarity. As you can see, it is a straight-forward, tuned JFET RF amplifier that amplifies the signal from an antenna. The amplifier is made to oscillate by the 0.01 μF feedback that connects the transistor source just above the 2.7K source resistor to a tap on the tuned transformer. Signal detection is accomplished just by amplifying the audio portion of the changing RF and AF signals on the drain. The audio signal is taken off the transistor drain and goes to an audio amplifier. Some articles claim the signal on the drain can be enough to power headphones without an amplifier. (I'm skeptical.) A 2.5 mH RF choke on the drain filters RF out of the audio signal and out of the power supply. The big multi-Henry inductor (filament transformer primary winding) is an audio frequency choke that keeps the audio from being shorted out by the power supply. The regenerative adjustment control is a variable capacitor that adjusts the intensity of the RF self-oscillation.

I used a 2N5484 JFET. Ashish used a J310. Other designs I have seen used other JFETs such as the MPF102. They all seem about the same - just be sure that if you have an N-channel design, you don't pick a P-channel JFET.

How regeneration works - perhaps derived from TRF receivers

Back in Chapter 4 you became acquainted with crystal sets. A regenerative receiver is a direct descendent of crystal sets, but is much more sensitive and selective. A Tuned RF Receiver (TRF) receiver can be described as a crystal set to which multiple, series tuned RF pre-amplifier stages have been added. Instead of just one tuned L-C filter, each series RF amplifier has its own L-C filter. By the time the desired signal has been presented to the diode detector, the signal strength is far greater and the bandwidth is much narrower than any crystal set. The difficulty

4. Chapter 7B, Harris

with the TRF design is that each amplifier in series must be tuned separately to the desired station. A perfect application for a radio like this would be a receiver permanently tuned to the WWV time station at 10.000 MHz.

I once found a marvelous 1920s AM broadcast TRF vacuum tube radio at a hamfest. It was mounted in an ornate wooden cabinet about 2.5 feet long and a foot wide. To tune the entire broadcast spectrum, 550 KHz to 1700 KHz, a system of shafts and gears tuned each stage synchronously. (I resisted the urge to buy it.) I'll bet the design worked well, but those gears would be difficult to fabricate in a home workshop.

Regens, the first big Armstrong invention

Back in 1914 our hero, Edwin Howard Armstrong, was probably working on a TRF receiver with an RF amplifier to increase the signal strength before presenting it to the detector. I don't know the real story, but I'll bet his vacuum tube RF amplifier suddenly began to oscillate on the frequency it was only supposed to be amplifying. Perhaps by serendipity he had just discovered the regenerative receiver. Unlike the average guy, Armstrong was curious enough to experiment with his mistake. He discovered that, when oscillating, this single tube was doing the work of multiple tubes in series. It was much more sensitive than a single RF amplifier stage and much more selective. The regenerative receiver was the first of his 3 great inventions. These were regenerative and super-regenerative receivers, the superheterodyne receiver and FM modulation.

Back in the 1930s impoverished hams often built regenerative receivers using vacuum tubes. One tube and one variable capacitor did the work of three or more expensive amplifier stages. In Chapter 14 there is a 1930s-style regenerative receiver I built using vacuum tubes from that era. It worked reasonably well for foreign AM broadcast shortwave stations, but was too unstable for CW reception.

Sharp tuning

Regeneration makes a signal stronger by feeding the output back into the input. As you know, when a loudspeaker in a public address system feeds back into the microphone, the result is a loud high pitched oscillation - a squeal or scream. The feedback is often launched by you speaking ordinary words into the microphone. All amplifiers tend to have some frequencies at which they have the most gain - a slight resonance effect. Notice that feedback doesn't amplify your eloquent lecture, it simply concentrates on one, single, high pitched, obnoxious howl. Once the howl begins, it doesn't need your voice to continue. You can shut off the oscillation by turning down the gain, muffling the microphone or pulling the plug. In effect, this public address system has become a regenerative amplifier selecting just one frequency to amplify.

Regeneration control

Since the oscillating amplifier is tuned to the desired reception frequency, the regeneration frequency can be monitored, or even directly calibrated, using a digital counter. In the diagram above the regeneration control is a variable capacitor. When the capacitance is set to maximum, it damps out the oscillation, suppressing it. When there is no oscillation, the receiver becomes a crystal set with one stage of pre-amplification. If AM broadcast signals are strong enough, they are received with excellent fidelity, just like a superhet - with no squeals or whistles.

To have some AM signals to listen to, I wound a high inductance coil that would tune

5. Chapter 7B, Harris

down in the broadcast band - 550 KHz to 1700 KHz. When an AM signal is weak, a small degree of oscillation can increase the signal strength. The sound quality can still be first rate. However, as you tune above or below signal frequency, you'll hear the familiar sideband whistles, just like a product detector. Fortunately, the zone with no whistle is so wide that the sound quality is stable, unlike an AM station tuned with a direct coupled receiver. As the signal becomes weaker still, considerable regen oscillation is needed to maintain signal strength. This increases the selectivity but the zone with quality sound becomes narrower and hard to tune. It becomes more like AM reception with a product detector.

When listening to CW or SSB, a small amount of regeneration produces easy listening. It sounds about the same as the superheterodynes described in chapters 13A and 13B. Ham signals are nearly always weaker than your local AM broadcast stations, so some regeneration will nearly always be needed. As explained earlier, you'll need to experiment to find the right feedback tap on the coil, the regeneration adjustment capacitance and operator technique.

Super-regeneration

A variety of regenerative receivers that some people find useful is a technique called super-regeneration. The amplitude of the RF oscillation sinewaves can be observed by watching the drain voltage on a scope. The degree of feedback is determined by how many turns are tapped at the bottom of the inductor. The more feedback there is, the more regen adjustment capacitance is needed to adjust and suppress it. As the oscillation of an oscillator becomes more vigorous, the current drawn can rise higher than the power source can supply. This can result in "motorboating." That means the oscillator becomes like a relaxation oscillator. It pulses on and off in a series of RF sinewave bursts.

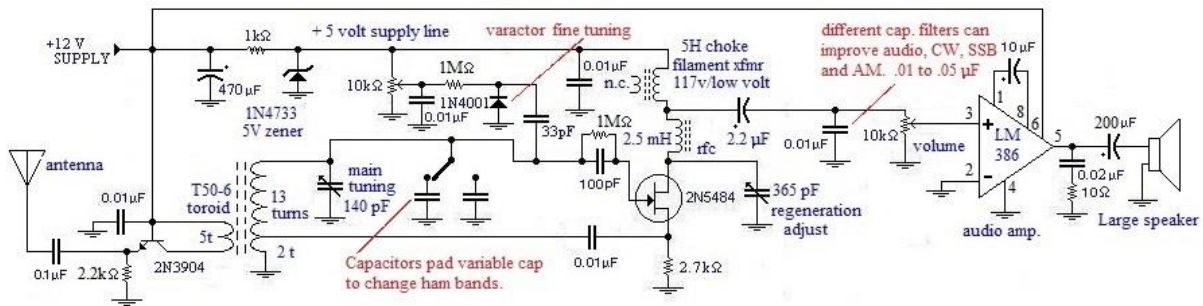
Now there **two** oscillations. One is at the received RF frequency and the other is at a very low, usually audible, frequency. As the burst rises, the "Q" (tuning sharpness) of the amplification rises. It reaches a peak just before the RF burst crashes and the oscillation quits until the next cycle. So perhaps maximum Q is the advantage of super-regen. There is a version of this design that uses an external oscillator to force the motorboating to occur at a frequency above 20,000 Hz. That makes the awful squeal inaudible - at least to humans.

Personally, I have always found the squeals and screeches from super-regeneration too obnoxious to tolerate. Notice that my breadboard prototype has an audio amplifier chip and a ***loudspeaker***, not a headphone. Use the largest speaker your audio amplifier will drive. That will provide the best bass response. If you mount the speaker in a roomy cabinet - essentially a reverberation chamber - the sound quality and volume will be optimum. Super-regeneration frequently and unexpectedly blasts your ears with ear splitting screeches that will eventually damage your hearing. I tried putting back-to-back Schottky diodes across the headphones to tame the assault. When using modern headphones, even 0.2 volts peak was too much sound for my ears. In summary, I prefer to limit the oscillation to regeneration and NOT allow super-regeneration.

Regenerative Schematic

Here is the complete diagram for the successful breadboard regen receiver I built. It is mostly a copy of a design in an article by Charles Kitchin, N1TEV, in QEX magazine, page 24, QEX, Nov/Dec 1998.

Complete Regenerative Receiver Schematic



One of the attractive features of this design is that it can cover 2 or 3 hambands by simply changing the tuning capacitance across the coil. Parallel capacitors can be switched in across the tuning capacitor. My breadboard regen shown above has a small variable capacitor, 30 pF. By soldering in different groups of parallel capacitors, it easily covered the 30 and 40 CW bands.

The design in QEX uses a small 10 pF variable as a bandspread tuner and large variable capacitors to cover wide swaths of the short wave spectrum. Ashish used a 1N4001 power rectifier as a varactor bandspread. The 1N4001 has about 30 pF of capacitance. Ashish biased his with regulated +6 volts DC and tuned it with a 10K pot. (See Chapter 10 for more about varactor tuning.) When calibrated with a digital frequency counter module, this system has the potential to be quite modern in appearance and occasionally performance. I would still be cautious of the digital counter generating RF noise on the signal.

The design I used takes the audio signal off the drain of the JFET. This works well, but requires the large transformer/inductor. The audio may also be taken off the source lead, just above the 2.7K resistor. This eliminates the transformer and is the successful design that Ashish used. I started out with the source driven audio, but my first regen didn't work, probably because of sloppy construction. In desperation I tried the drain take-off design. The audio voltage signal is much larger on the drain than on the source, so Ashish used an additional transistor series audio amplifier to drive his LM386 amplifier chip. Because of the larger output voltage signal on the drain I didn't need the hand-wired transistor audio stage.

"Grounded" gate JFET amplifiers

All regenerative receivers should be equipped with an RF preamplifier preceding the oscillating stage. This is because a regen receiver is oscillating and therefore transmitting on the frequency it is receiving. When you are tuned to a station, you are actually rebroadcasting everything you are hearing in your headphones, noise as well as the desired signal. The preamplifier attenuates this noise, but doesn't eliminate it. If you don't believe this, fire up your superheterodyne ham radio and tune it to the same frequency. Now turn the regen on and off. The presence of the amplified signal and noise will be obvious. To a lesser degree, a direct coupled receiver is also broadcasting its VFO on the ham band frequency. The DC receiver interference is a single, isolated carrier - a whistle - on one frequency, not a wide band of noise. Ideally both these designs should have a pre-amplifier to help isolate the oscillators from the receiving antenna. Since there is no simple way to tune both the regeneration stage and the preamplifier simultaneously, the pre-amp must be broadband - untuned.

Three ways to wire transistor amplifiers

You probably wondered how the regen RF pre-amplifier shown above works with that goofy wiring scheme. The answer needs a full explanation. There are 3 ways to wire transistor amplifiers: The usual and most versatile way to wire an amplifier stage is to place the transistor emitter on the ground side. This is called a **grounded emitter** or "common emitter" amplifier. (To avoid confusion, let's consider base/emitter/collector to be interchangeable with gate/source/drain.) The transistor collector is wired to the supply voltage through a high impedance like a resistor or a tuned circuit. The driving signal comes into the transistor base from the small signal source referenced to ground. Common emitter amplifiers have high input impedance and high output impedance. In other words, they work well with small input voltage signals and produce large output voltages. ***Voltage gain is always high.*** They do not necessarily produce high current gain.

Emitter follower (or source follower) amplifiers are similar to the common emitter, but the output signal is taken off the emitter, not the collector. The advantage of the emitter follower is that the ***current gain can be very large*** even though ***the voltage gain is always less than one.*** Emitter followers are good for driving low impedance loads, like 8 ohm loudspeakers. In other words, the emitter follower has high input impedance, but low output impedance.

And finally, **grounded base** (or grounded gate) amplifiers use the emitter (or source) as the input and the collector (or drain) as the output. These amplifiers have low input impedance and high output impedance. Notice that, as a big current enters the source input, the base current (or gate voltage) is forced upward and this voltage increase is the input that turns the transistor ON. ***The current gain is always less than one, but the voltage gain can be quite high.***

Vacuum tubes

Very high power HF amateur radio amplifiers are usually vacuum tubes. The final stage of these amplifiers are nearly always wired **grounded grid, the equivalent of grounded base.** Tubes handle extremely high power well, so archaic vacuum tubes are still important for this application. Typically a 100 watt modern transceiver is used to drive one of these 1,500 watt HF amplifiers. The output of the transceivers is generally matched for 50 ohm loads. This means they deliver big RF currents but relatively small RF voltages. Big vacuum tubes run at thousands of volts, so the goal is not to increase current, just the output voltage. By driving the cathode of the tube, the same current appears in the plate coupled output, but the RF voltage has been raised 10 or more times.

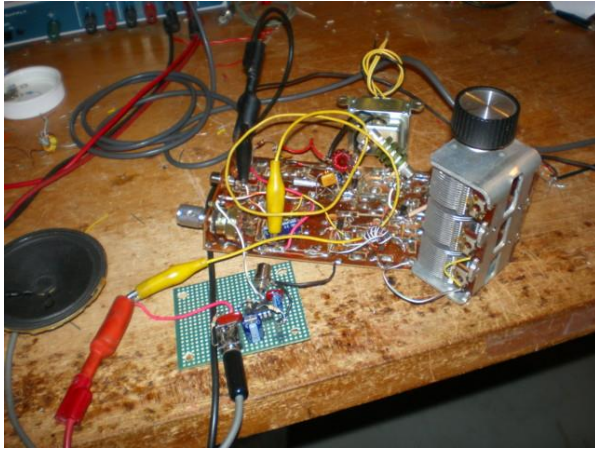
Of course your question still remains: If the gate in the regen pre-amplifier is wired to the positive supply voltage, how can that be a "grounded gate?" Notice that every power supply always has capacitors to ground that short the RF across the DC supply. From the point of view of RF current, the ground and power supply are at the same RF voltage, essentially zero RF volts, and therefore "grounded."

A regenerative AM broadcast receiver

I mentioned earlier that I wound a new inductor and padded it with larger capacitors to move the tuning range down to standard broadcast. Specifically, it was an FT50-43 ferrite toroid core with 32 turns tapped at 5 turns. The amplifier input winding was 7 turns. The tuning capacitor was two sections of a triple variable capacitor connected in parallel. The RF parts

8. Chapter 7B, Harris

catalog described it as three "365 pF" capacitors. When I measured the actual capacitance, each section was 536 PF! Therefore two sections in parallel gave me 1072 pF. This combination was able to cover the entire broadcast spectrum.

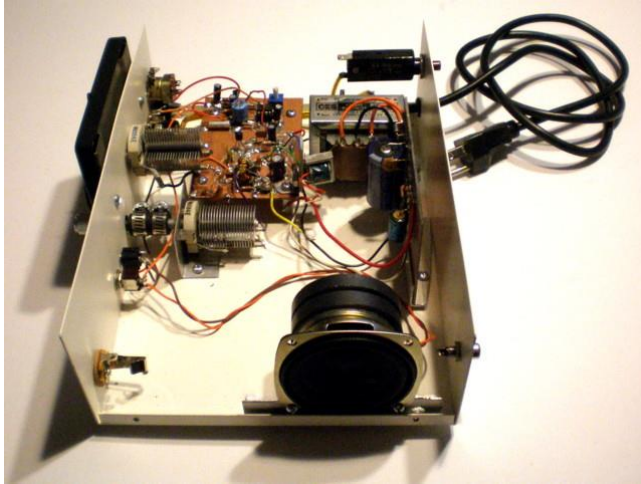


This haywire broadcast regen let me explore how well regenerative receivers detect AM stations. I found the AM detection excellent for strong stations, but noisy for the weak ones. In summary, it is a usable broadcast receiver that picks up my entire local spectrum of 20 or more stations with good audio fidelity on most stations. The downside is that tuning in the weaker stations requires tweaking the tuning capacitor, the regeneration control and the audio volume to find the right combination of settings. Ordinary superheterodynes are MUCH easier to use. This was an interesting experiment, but I wanted to return my regen to 30 and 40 meters and mount it in a proper enclosure.

Attempting a practical regen

After I had my breadboard regen working well, I salvaged all its parts and rebuilt the same circuit and components into a fancy cabinet that was intended to be usable on the air. The empty portion of the cabinet on the right was reserved for a QRP transmitter.





... And then the fun began. Nothing worked the first time. How can such a straightforward re-assembly be so difficult! Ok, I did have one small wiring error, but beyond that, nothing worked as well as the breadboard. This teaches us that regens are extremely sensitive to small changes in stray capacitance and inductance. Probably I should have run it on batteries and the box should have been plastic. Live and learn?

More LM386 troubles

The LM386 thought up some brand new glitches for me to explore. The good news was that, when I read the fine print in the data sheets, I wasn't the first to notice these "limitations." The worst was that, if you don't connect a 0.1 μF cap from pin 7 to ground, the amplifier may suddenly quit amplifying and draw big currents. If you use a big capacitor, like 5 μF , it makes the instability worse. I burned up the chip with this error before I studied the data sheet. (It is wise to buy more than one of every fragile component.)

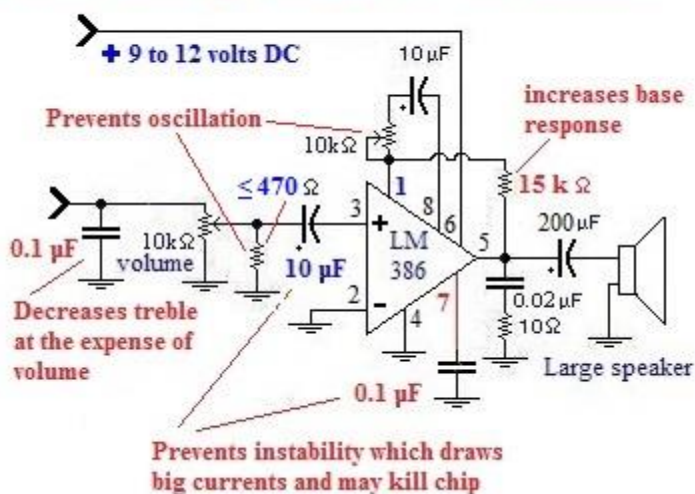
The first thing you need to know about this chip is that ***THE INPUT NEEDS A LOW SOURCE DRIVING IMPEDANCE***. If the output resistance of the amplifier or microphone source is higher than about 470 ohms, it may begin to oscillate at high frequencies. If your signal source impedance is too high, try putting resistance from the chip input to ground until it stops oscillating. When there was no connection to the input, mine oscillated at about 300 KHz and drew nearly 100 mA DC. The chip became very hot and would burn up if the oscillation continued.

Another issue is that the inputs and output of the chip are directly connected to transistor bases and collectors inside the chip. Just like biasing single transistor class A audio and RF amplifiers, it is vital not to add to or subtract DC bias currents from the DC currents present inside the chip. Otherwise the amplifier may turn full OFF or full ON. The simplest solution is to isolate the input and output lines with capacitors so that the internal DC bias currents are not altered. In my case, the currents from the 10K Ω pot on the input were intermittently causing the internal transistors to saturate and draw big currents ... again.

Another annoyance is that the LM386 always seems to deliver far too much shrill treble audio. All the CW seems to squeal at 1,000 Hz or higher. A 0.1 μF cap bypass on the input seems to help. The data sheets suggest wiring a 15K Ω ohm resistor between pins 1 and 5. Resistors smaller than 10K Ω may cause instability. This addition was a big improvement.

The strangest error I discovered was that I have been wiring my LM386s wrong. I've been using pin 2, the negative input, to drive the amplifier for several projects. This works, but I just noticed in the actual data sheets that it is customary to use the positive input, pin 3, to drive the amplifier. I have corrected all schematics in this book. Below is my most bullet-proof way of wiring LM386s:

Preventing LM386 troubles



60 Hz hum

One "improvement" I tried was running the receiver on a built-in power supply instead of batteries. The power supply was the same LM317 regulated supply described in Chapter 8. The power transformer radiated 60 Hz hum to the large audio choke, impressing a huge hum on the audio. It turns out that large iron inductor transformers make wonderful magnetic antennas. I greatly decreased the hum by using a small audio speaker transformer primary instead of the large iron filament transformer primary. The little transformer needs to be as far from the power transformer as possible. The little transformer should have the same primary winding inductance as the big transformer. If it is too small, it shorts out low frequency sounds making the atmospheric noise high pitched and piercing.

The antenna effect of a large iron core transformer is directional and rotating the audio choke can significantly reduce the hum. I also tried eliminating the iron inductor entirely. I just connected the small 470 μH RF choke to the 5 volt line directly. I took the audio directly off the drain of the JFET oscillator. This greatly sacrificed audio volume so I amplified it with a single transistor audio amplifier stage. I used an amplifier like the first audio stage of the transistor audio amplifier in the DCR receiver described in Chapter 7A. This worked, but there was still way too much hum.

My Belgian friend Danny Bossuyt, ON1MWS, has also been building regens. He commented on my regen 60 Hz hum by saying, "Sorry Frank. I do not have the 60Hz hum! Haha! I have a big 50Hz hum/problem." (Check out Danny's impressive homebrew station at qrz.com.)

Varactor capacitor bandspread

11. Chapter 7B, Harris

I also put in the 1N4001 diode varactor bandspread as diagrammed above. When I used a 62 pF capacitor instead of the 33 pF capacitor Ashish used, it could cover 50 KHz of 40 meters or 50 KHz of 30 meters - convenient tuning ranges. When I tuned with the large 140 pF variable capacitor, I could cover the whole 40 meter band plus several short wave commercial AM stations just above 40 meters.

AM Radio Interference

Another challenge has been interference from my local nemesis, AM radio station KVCU at 1190 KHz. They recently acquired new call letters and raised their output power. Searching the Internet, I discovered that KVCU now runs 5,000 to 6,000 watts and the antenna is located about 2 miles away. They even overwhelm our modern commercial AM radios and can be heard in the background of AM stations with nearby frequencies. So the interference isn't limited to my homebrew receivers. I suspect their transmitter is not properly tuned. If I touch the input of the LM386 amplifier, I can hear the station. At least now they play pleasant tunes instead of non-stop rap music. When I turned the regeneration level way down, the regen receiver becomes a glorified crystal set and I hear KVCU loud and clear no matter where I tune the tuning capacitor. Notice that more feedback increases the selectivity of the receiver.

You may remember that the DCR receiver in Chapter 7A had the same trouble which was solved with a complex filter to suppress the AM interference. The antenna input diagrammed above has a 0.1 μ F blocking capacitor. I put it there mainly because the circuit I copied had one. I suppose it helps protect from static electricity. A simple, huge improvement in RF interference was to replace the 0.1 μ F cap with a 5 to 120 pF trim capacitor. I adjusted the capacitor for the minimum interference that still preserved the 30 and 40 meter signals. When set too low, it makes all the signals disappear.

Is regeneration worth bothering with?

In Chapter 17A I describe a battery powered, 10 meter AM walkie-talkie that uses a crystal controlled regenerative receiver. This circuit worked quickly with far less R & D than my original breadboard. So maybe this design will work properly for others without investing a week of trouble-shooting, cursing, unsoldering and modifying. Unfortunately crystal control means you are stuck on one frequency. That's good for a walkie-talkie, but not so good for a CW receiver.

I eventually got my "fancy" version of the 30 and 40 meter regen working - sort of - and compared it with my big receivers. I carefully tuned the regen up and down 40 meters. Then I put the same antenna on my superheterodyne (Chapter 13) and also my ancient Collins Army R-388/URR receiver. No comparison! **My regen is junk.** Yes, I could put in lots more circuit fixes and extra stages that might improve it ... somewhat. But that would defeat the goal of a *SIMPLE*, easy-to-build CW receiver. However, I still must admit that, if the regenerative gods are with you, you might get lucky and build a good one.

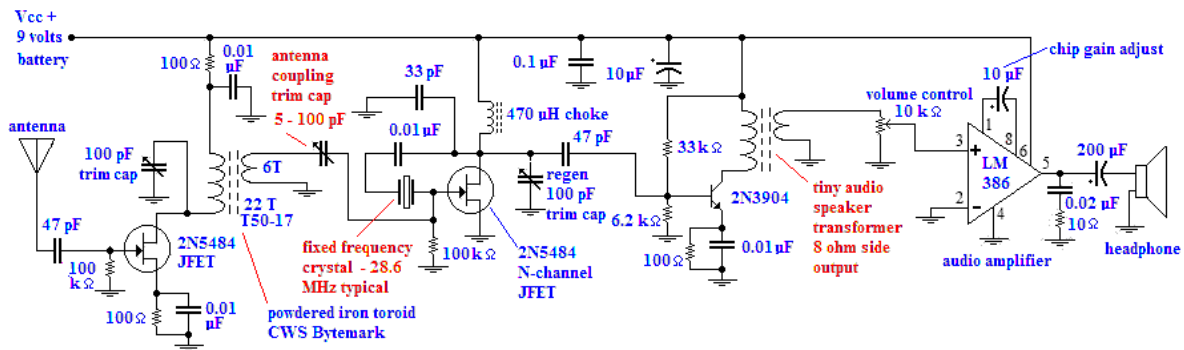
In conclusion, my limited experience is that I have found the Direct Coupled design (Chapter 7A) simple and reliable. DCR is based on the product detector which I have now used many times. Product detectors are just a kind of mixer. They deliver an audio signal instead of an IF frequency signal. For me, product detectors have always worked IMMEDIATELY. One even worked when I rotated the 4 lead MOSFET transistor 90 degrees and wired it wrong! My next project will tear the regen board out of the fancy cabinet and try to replace it with a relatively

simple superheterodyne that can accomplish the original goal.

BUILDING A "SIMPLE" superheterodyne HYBRID WITH A REGENERATIVE DETECTOR

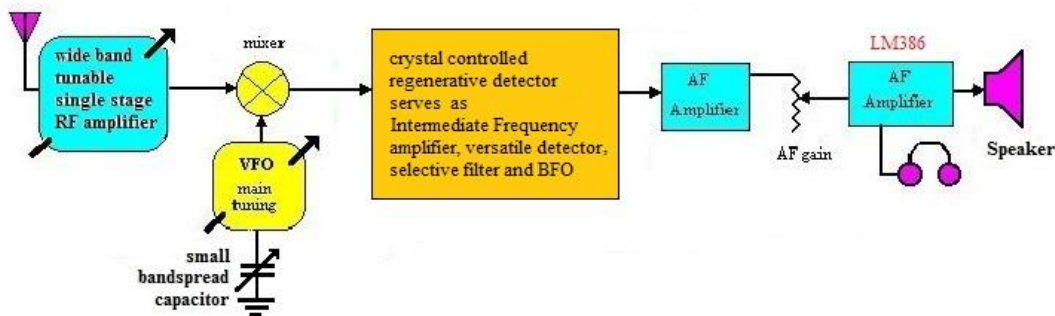
The 10 meter AM receiver described in Chapter 17A, has a crystal controlled regen/detector that seems to work well. The limitation of crystal control is that it only receives signals on the crystal frequency. This is useful for a handheld walkie-talkie, but impractical for a general coverage receiver. However, it does lend itself to serving as the Intermediate Frequency amplifier in a superheterodyne receiver. Intermediate Frequency amplifiers are supposed to operate on a single, narrow frequency.

10 Meter Crystal Controlled Regenerative Receiver



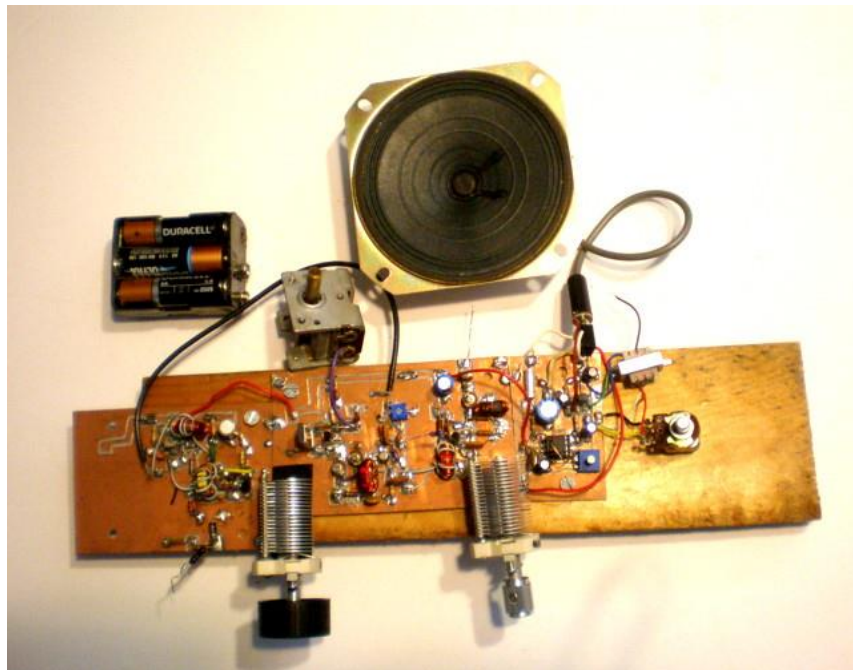
The concept of a crystal controlled regenerative detector in a superheterodyne has the potential to work well. A quartz crystal is inserted into the feedback line that makes an RF amplifier regenerative. The detector is the JFET in the center of the diagram. Notice that the crystal is the only resonant device in the regenerative detector stage. The antenna signals are amplified and selected by a tuned RF pre-amplifier which narrows the frequency reception to a few hundred KHz.

Single Conversion Hybrid Regenerative Receiver



My attempt at a more sophisticated regenerative receiver used a superheterodyne front end with a simple VFO for main tuning and a mixer to move the signals down to a constant

frequency regenerative receiver. Rather than use crystal filters, multiple IF amplifier stages and a separate detector and BFO, I tried to accomplish all these functions with a single, crystal-controlled, regenerative amplifier/ detector. The detector then passed the audio signal to an audio preamplifier and a LM386, just like the previous regenerative receiver.



All the stages appeared to work with test signals from an AM modulated RF frequency generator. I had some 6.00 MHz crystals, so that became my IF frequency. 6.00 MHz is another microprocessor frequency for which the crystals are readily available for less than a dollar. But as often happens, the regen stage worked poorly for actual signals. The regen and VFO oscillated properly and each stage did what it was supposed to, but the only signals I could receive were from my frequency generator 18 inches away.

Aside from insensitivity, the reception was plagued with the usual screeches and sudden explosions of sound that makes headphones plugged into regenerative receivers dangerous to your ears and sanity. Like my old "Ocean Hopper," the noises were my main reason for giving up on this design.

Since this design didn't work, I won't confuse anyone with its schematic. A complete old-fashioned superheterodyne design now looks increasingly attractive. See Chapters 7C, 13A and 13B.

ATTEMPTING A VHF 2 METER REGENERATIVE RECEIVER

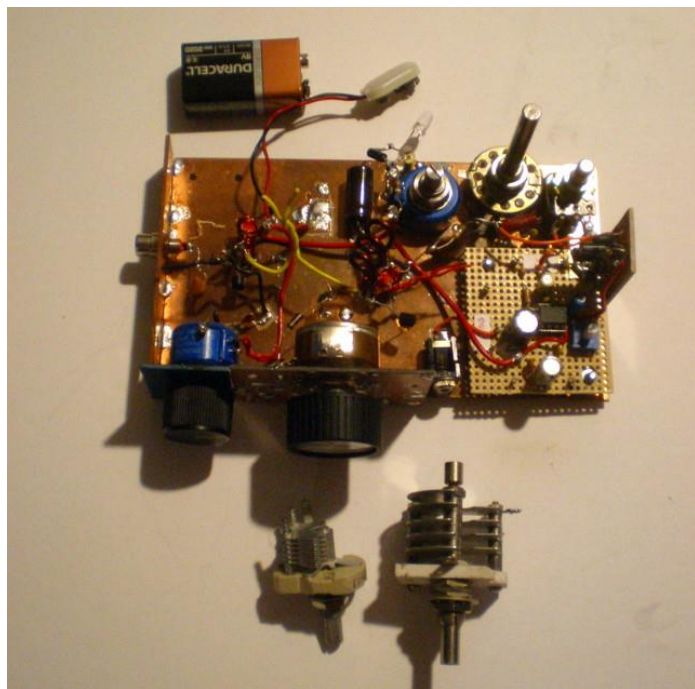
Since I enjoy frustration, I was seduced by another regen design by Charles Kitchin in the 1998 ARRL handbook, page 17.80. I have never succeeded in building a VHF receiver or transmitter using my usual PC board, transistors and gouge board techniques. I have made oscillators that worked as high as 50 MHz, but I could never get higher. I assumed the difficulty

14. Chapter 7B, Harris

is simply capacitive coupling to other parts. Yet there in the ARRL handbook was a VHF design that was very similar to the schematic of the regen diagramed above. How could this possibly work?

One novel aspect of Kitchin's 2 meter receiver was that it was all "dead bug" construction with the oscillator and amplifier high above the PC board where they could only couple weakly to the copper sheet. The ground connections solder the components to the copper sheet, while the connections between components are 1/2 to 3/4 inch away. Kitchin cautions that it probably won't work in a metal enclosure. The other surprising feature was that the L-C circuit used big parts. The coil was 3 turns of heavy 12 or 14 gauge wire in an inch long coil wound on a pencil. Notice that thick wires wound in a coil have less inductance than skinny wires, like 20 gauge or thinner. This is consistent with the old days when regens were built with vacuum tubes, big coils and large variable capacitors. Another feature of Kitchin's design was that the interstage coupling capacitor and a feedback capacitor were simply short pieces of insulated hook-up wire twisted together. This is exactly what I used in Chapter 11 to make 1 or 2 picoFarad capacitors.

I was further encouraged by an article which I found on-line by Alan, VK2ZAY. Alan Yates built Kitchin's VHF regen design and, after a few modifications, he got it working well on commercial FM frequencies, 87 to 107 MHz. Like me, he had to add an audio preamplifier in front of the LM386.



The good news was that my regen actually oscillated at VHF frequencies. I was able to run it as high as 135 MHz - a new record for me! Another difficulty with working with VHF is that you can't put a scope or a frequency counter probe on an oscillator or amplifier without snuffing out the signal. The alternate plan is to listen for the signal using a modern commercial calibrated VHF receiver. That's how I learned that the regen was oscillating at 135 MHz.

In an attempt to get up to 2 meters, 146 MHz or so, I tried the various variable capacitors shown above, including a varactor. All efforts failed. My best attempt used the large capacitor

with the big plates seen above at the lower right. Since I seemed to have it working for the aircraft frequencies, I listened for a while to the local Unicom frequency, 122.8 MHz, but never heard a thing. However, with an 18 inch high antenna I was barely able to hear my signal generator from a foot away. Once again, this was not a useful radio.

How do real VHF engineers do it?

This of course brings up the question, why do our little VHF handhelds, cell phones and TVs work so well? Examining the few examples of VHF circuit boards I own, I see no obvious reasons why they would work. My best guess is that the stray inductances and capacitances have become part of the design. Looking at portable FM radios - 88 to 110 MHz - I noticed that the coils are tiny and could have been wound on a match stick or perhaps a pencil. They are typically 4 to 10 turns, the larger diameter, the fewer turns. They are often wound on a tiny cylinder of fibrous, cotton-like material. The little coils are usually potted in beeswax. I suppose this prevents them from vibrating, but perhaps it has other virtues. Also, the VHF circuits were on single sided boards and were (relatively) widely separated from other components. Instead of having large areas of grounded PC board, the grounds for the VHF parts of the circuits are quite minimal and kept away from the resonant L-C circuits. We don't just "wind a coil" or "insert a capacitor" for VHF. So far possible, we should position the wire or capacitor so that *the stray reactances become part of the L-C circuits*. All the FM radios I took apart had plastic enclosures.

I used to work with an engineer, John Gibilisco, who had worked for Tektronix designing oscilloscopes. To get UHF frequency response John described "transformers" that were just short snippets of wire that approached each other at specific angles! If I ever learn how to do that, I'll write a Chapter on building circuits for extremely high frequencies.