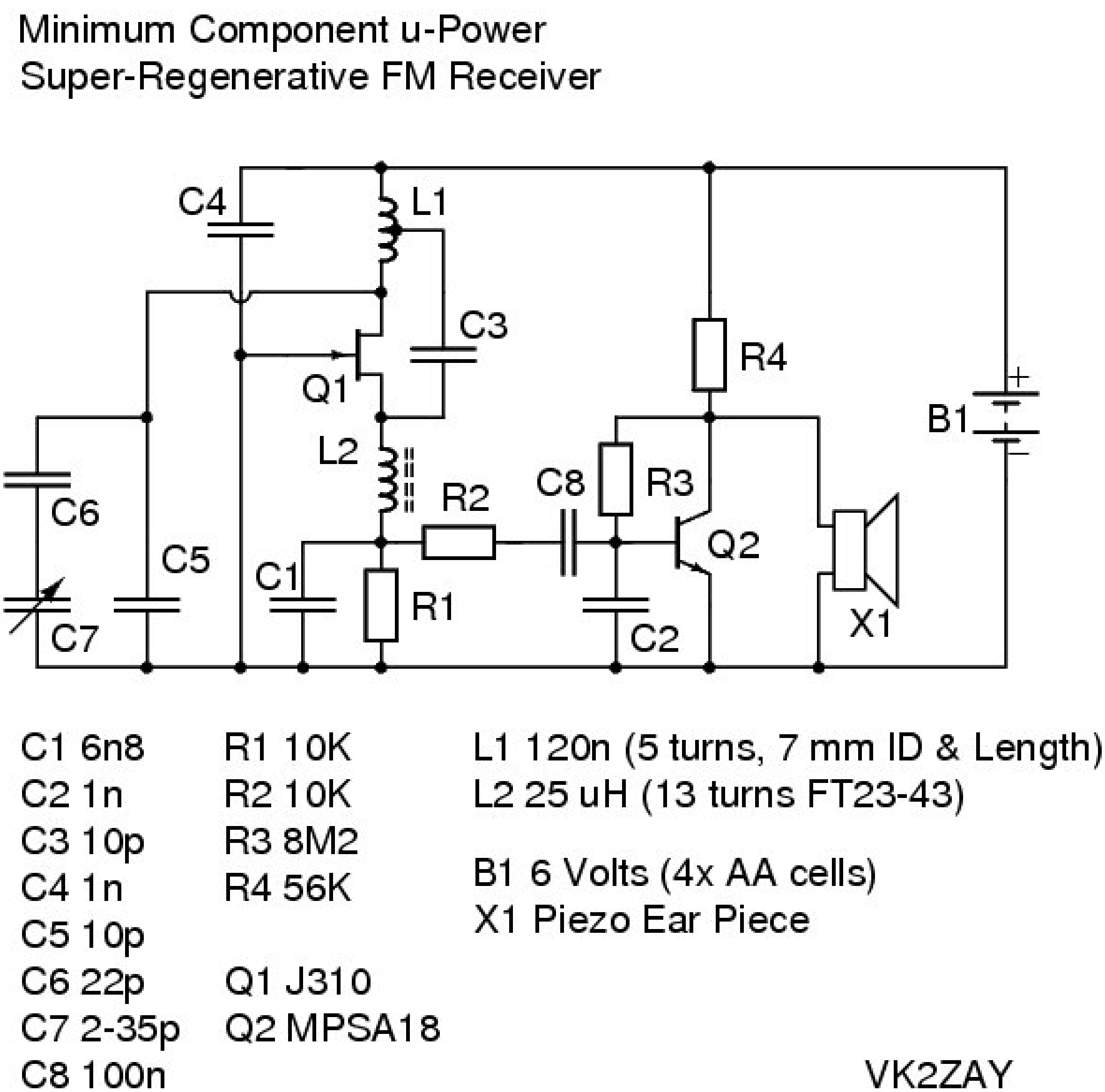
Micropower FM Broadcast Receiver

2007-09-08

It's been quite a while since I built a super-regenerative receiver for the FM broadcast band and I've been meaning to play with a different source feedback topology, so this little radio was thrown together on the Saturday of the APEC long weekend.

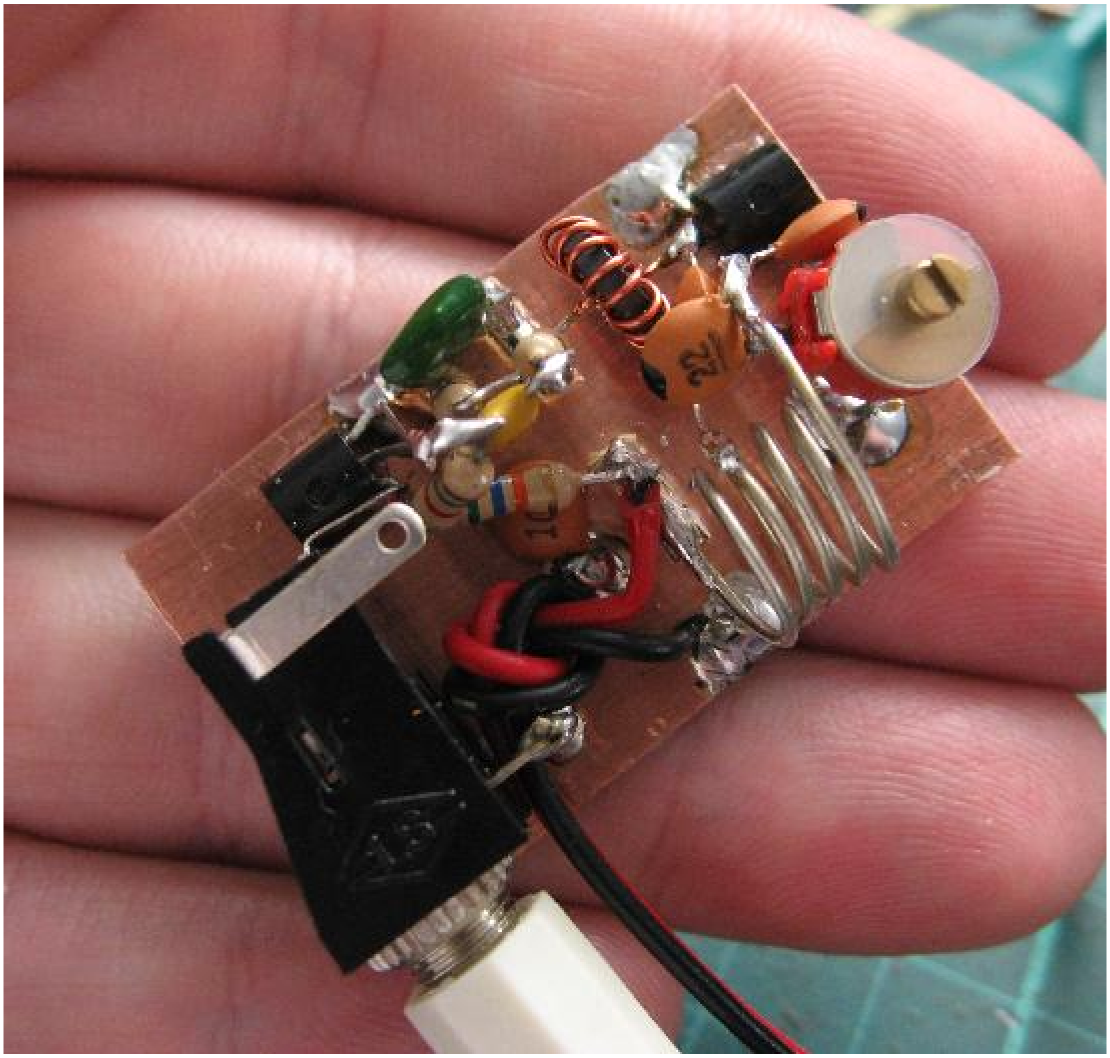
The topology is your classic grounded-gate FET VHF Hartley oscillator. The drain resonator inductance is centre-tapped with feedback to the source through a small capacitance. By tapping down towards the cold-end of the coil the feedback isn't as critical as your usual source-drain capacitor feedback and it tends to be far less difficult to get to work across a broad range of frequencies. The RFC to an RC source circuit to implement self-quenching is very traditional for super-regenerative detectors. The quench gets frequency-modulated somewhat by the drain current, so it varies with signal strength and the recovered modulation, this is typical for self-quenched circuits (simplicity has its price).



The detector alone provides sufficient audio to drive a crystal ear piece in a very quiet room, giving a true "single transistor" FM receiver. A largish resistor (~10 k) prevents the source circuit from seeing too much of the range. Some additional audio volume can be achieved by redesigning the quench circuit to utilize the piezo capacitance directly, but the source resistance has to be dropped quite a lot to achieve a viable quench frequency and the gain in sensitivity isn't as fantastic as one might hope. Still, give it a try, a single active device FM radio, pulling < 100 uA is mighty impressive!

The detector can operate with the source resistance approaching 1 M, even at extremely feeble currents it is still very sensitive. Best over-all performance was achieved with 10 K and 6.8 nF in the source circuit.

I decided to add a stage of audio gain, retaining the use of a high impedance ear piece to keep the current consumption as small as possible. I picked a super-beta transistor, the MPSA18, for the audio amplifier, and used a simple self-bias topology. This was all to keep the total receiver current consumption very small and maximise the battery life. The audio quality is quite acceptable (the usual super-regen' slope-detection distortion and quench inter-modulation with stereo sub-carrier, etc). There is no volume control, the super-regenerative receiver has an AGC-like quality because of its physics. The audio power available is on the low side, it is for quiet environment listening only; not exactly library-quiet, but not the local pub on Friday evening either!



The complete receiver pulls around 500 uA from 6 volts. Four of your average bargain-store dry cells should run the receiver for at least a month continuously. Band-name alkaline cells might run it for a very long time indeed.

Tuning is achieved with a small alignment screwdriver, or similar insulated tool. The trimmer rotor is "grounded", but hand-capacitance is still slightly present because of the very high frequencies and gains involved (i.e. minor circuit layout strays).

Some effort was put into setting up the trimmer bandspread to cover the FM broadcast band (i.e. picking C5 and C6 to make C7 tune 88-108 MHz). I spent a lot of time doing the algebra to try to come up with a way to calculate the circuit stray capacitance and the actual tank inductance by trial frequency measurements with different fixed capacitances. The solution is truly horrible; involving finding a parabola that fits three points, which means solving a determinate of a 4x4 matrix equated to zero... I gave up after a few hours of wading through my sign and subscript mistakes, the whole experience leaving me feeling somewhat defeated!

I really wanted to achieve a result I could use to write a calculator, not unlike the VFO helper one which I did the parameters just by measuring the frequency produced after a few capacitor swaps. I'll revisit this I think. Anyway, the geometry of the coil (7 mm diameter and length) gives about 120 nH using the Wheeler formula, and my inductance meter agrees. Some empirical capacitor swapping and trimmer jig twiddling later I arrived at a bandset (C5) of 10 pF and bandspread (C6) of 22 pF, giving a tuning range of 86-110 MHz, give or take. The stray capacitance that fits this is around 4.5 pF if I've done the math right. For comparison, my capacitance meter says the detector drain looks like 21.8 pF, but that is without a drain current, having the inductance disconnected, being measured at AF, etc... I'm happy, it tunes the whole band well.

Notes

Component substitution: The J310 is obsolete, I just happen to have a lot of them. Any RF FET should be a suitable replacement. The MPF102 is quite suitable. The MPSA18 could be replaced by any NPN signal transistor if you don't mind burning a bit more current. I'd recommend a low-noise device with good gain like the BC549C or BC550C. You'll obviously need to experiment (calculate) new resistor values for the audio stage if you change the transistor, the circuit is not particularly B independent.

You might like to play with the quench frequency by altering R1 and C1. The selectivity is at a minimum 4 times the quench frequency. Lower quench frequencies become audible and will mix down higher signal components. If you want to place the quench below 15 kHz you'll need to add much better filtering, perhaps a Sallen Key filter or two. Higher quench frequencies reduce the gain somewhat, so pushing it too high is a bad idea. The FM stereo MPX signal has energy to around 56 kHz, more if there are SCA services. Typically the quench is set around 30 kHz (8 kHz into the lower L-R sideband), but as discussed it will vary with signal strength and the modulation. The quench will tend to mix down the L-R sidebands and/or beat with the pilot tone at 19kHz. The result can be absolutely horrible to listen to, especially when the quench is getting pulled around by the modulation or the L-R sidebands are especially intense (lots of stereo difference content). For purely mono signals the recovered audio can be reasonably high fidelity if you position the slope properly. For AM signals (i.e. The Airband) the receiver is especially affective.

L2 is not especially critical, it is just an RFC to isolate the RF signal at the source from being shunted by the quench oscillation capacitor. Anything that gives > j1 kΩ of reactance should be fine, so 1.6 uH or more is sufficient, perhaps a little less would still work. The 10 pF feedback capacitor is about -j160 Ω at 100 MHz, anything at least 5-10 times larger in magnitude than that should be fine. The RFC specified has about j15 kΩ of reactance. A few turns on a ferrite bead will work, as will an RFC wound on a high-value resistor. Just make sure the inductor's self-resonant frequency is far above the frequency of interest so it is still inductive. It is difficult to make an inductor too large at VHF that would upset the circuit that isn't already looking very capacitive.

L1 and the associated C5,C6,C7 capacitors can be changed to put the receiver anywhere you like from high-HF to low-UHF. My particular receiver topped-out at 235 MHz with the 120 nH coil (indicating a stray capacitance of around 4 pF which is in reasonable agreement with the bandspread capacitor calculations), but could go much higher with smaller inductances.

Putting the radio on 10 metres is an interesting idea, it isn't especially difficult to build a miniature AM transceiver using this as the receiver, if you had enough poles on your TR switch/relay you could use the same transistor for the TX and RX, even the same tank. Similar ideas were explored years ago when frequency stability standards weren't what they are now. I've seen articles describing construction of 2 metre HTs using pairs of nuvistors or acorn tubes with free-running LC oscillators on TX and RX, switching around the cathode circuit to achieve either super-regeneration for RX or plate-modulated smooth oscillation for TX.

29 comments.

Attachments

title	type	size
Circuit Diagram Source	application/postscript	16.509 kbytes

 XHTML | CSS | CSS toggle