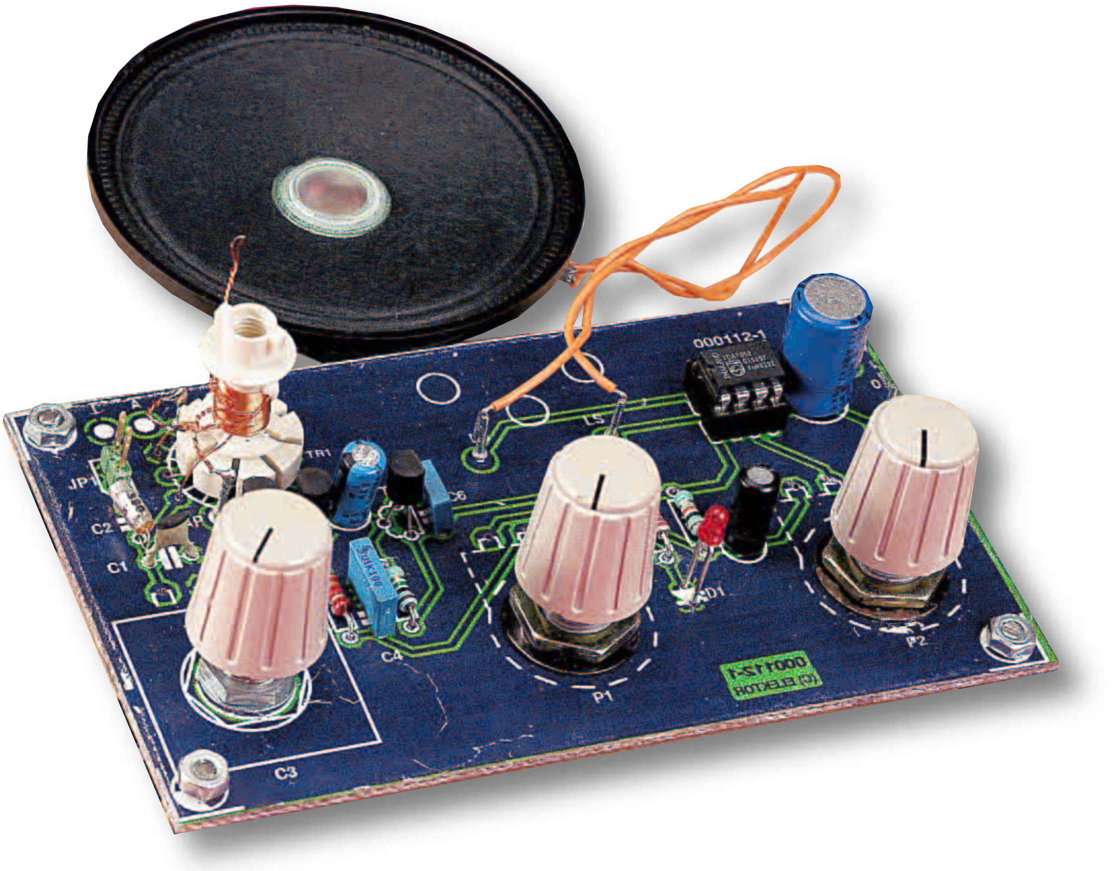
Regenerative SW Receiver

A shortwave receiver with very interesting characteristics

Design by B. Kainka



Building radio receivers is the classic introduction to electronics, usually by constructing simple detector type receivers for medium wave reception. However during the day there is not much to listen to. Almost as simple to build but much more interesting is the classic direct-conversion type short-wave receiver. Not only can it receive stations from around the world; this set pulls in SSB and CW transmissions as well.

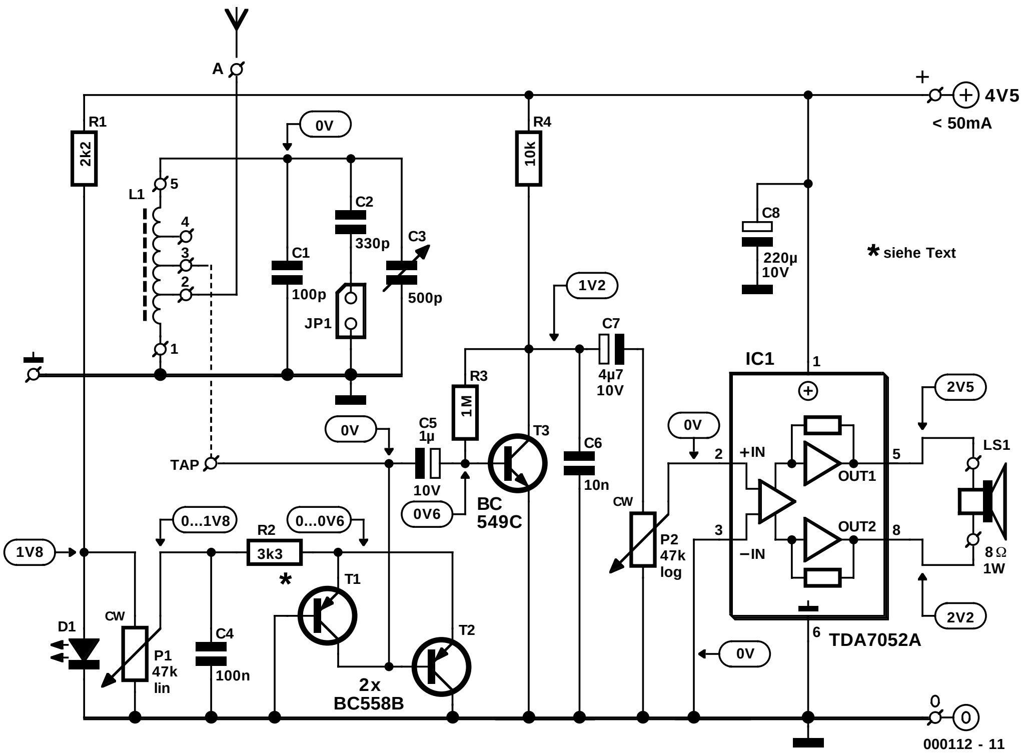


Figure 1. Circuit diagram of the Direct-Conversion Receiver.

Back in the mists of time when radio communication was still in its infancy, the earliest radio sets used just one valve, either a triode or pentode, and were based on the direct conversion design, often employing 'Audion' demodulators. Apart from the tuning knob there would be a second knob that controlled regeneration in the tuning circuit. Those skilled at using the radio set were able to draw down signals from the ether: The BBC Home Service, Radio Luxembourg…

Nowadays in the age of the superheterodyne it is all too easy to overlook the merits of those early designs. Using modern components it is much simpler to build such a radio, not only simpler but also the resultant set is better! With just one coil, three transistors and an integrated amplifier you can build a simple short wave receiver that has remarkable performance.

Principles

The direct conversion type of receiver simply amplifies the received signal at its antenna, and demodulates it. Unlike the superheterodyne receiver there is no frequency converter using a fixed intermediate frequency (IF).

The disadvantage of the direct conversion receiver design is its poor selectivity. It usually has one or two tuned circuits that must be tuned to the desired transmitter signal. With a superhet, its fixed IF means that the IF filter does not need to be adjusted to change frequency. Here you can use a filter with almost ideal characteristics since it does not need to be adjustable e.g., a ceramic filter

By use of a simple trick in the direct conversion receiver we can overcome its shortcomings. The amplified output signal from the tuning loop is coupled back to the input of the circuit. This positive feedback loop has a regenerative effect and boosts the Q or quality factor of the tuned circuit, thereby greatly increasing the selectivity of the radio and reducing the tuned circuit's damping loss. The optimal operating point for the circuit is just when the circuit is on the verge of oscillating, i.e. the positive feedback is just less than damping effect of the circuit. Increase the feedback anymore and the circuit starts to oscillate, the receiver has turned into a transmitter! You may think this effect is a disadvantage but for receiving SSB and CW signals it becomes an advantage: the oscillating tuned circuit acts like a BFO and regenerates the missing carrier frequency, allowing these signals to be demodulated.

The Circuit

The circuit in **Figure 1** shows the circuits clear layout. The receiver consists of a resonant loop, a two stage HF amplifier (T1 and T2) with variable gain and feedback (regeneration circuit). Transistor T3 demodulates the signal and an integrated circuit amplifier drives the speaker.

The resonant loop is a parallel resonant circuit consisting of a coil in parallel with some capacitors. In this circuit, there are three capacitors in parallel to the coil C1, C2 and C3. For tuning the radio there is a variable capacitor, while the other capacitors are connected in parallel to the coil to give the tuning range. C2 is connected via a jumper, when the jumper is in place C2 is also in parallel with the coil and alters the tuning range of the receiver.

A variable capacitor is used for tuning the radio. If you take a look at most modern receiver designs, you will find varicaps are generally used for tuning. The capacitance of

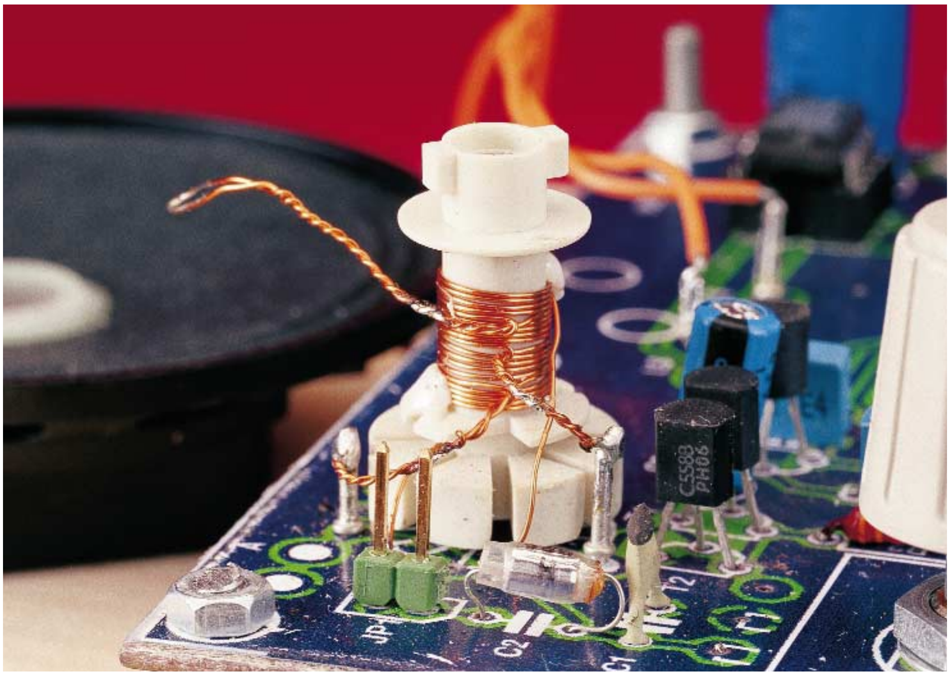


Figure 2. The single coil is simple to build.

a varicap is a function of the voltage across it. These devices are fine if you are using a PLL for the frequency tuning but they are not ideal for manual tuning using a potentiometer. Their operating voltage needs to be very stable and they cannot match the specification of a good air-spaced variable capacitor.

The coil winding has three taps to enable the connections of the antenna and the regeneration circuit to be adjusted.

The regeneration circuit itself looks very simple but requires closer inspection to fully appreciate its workings (see the text box). The stage employs feedback, the input (base of T2) and output (collector of T1) are connected together at the coil at point ‘TAP’. The overall configuration works like a negative dif-

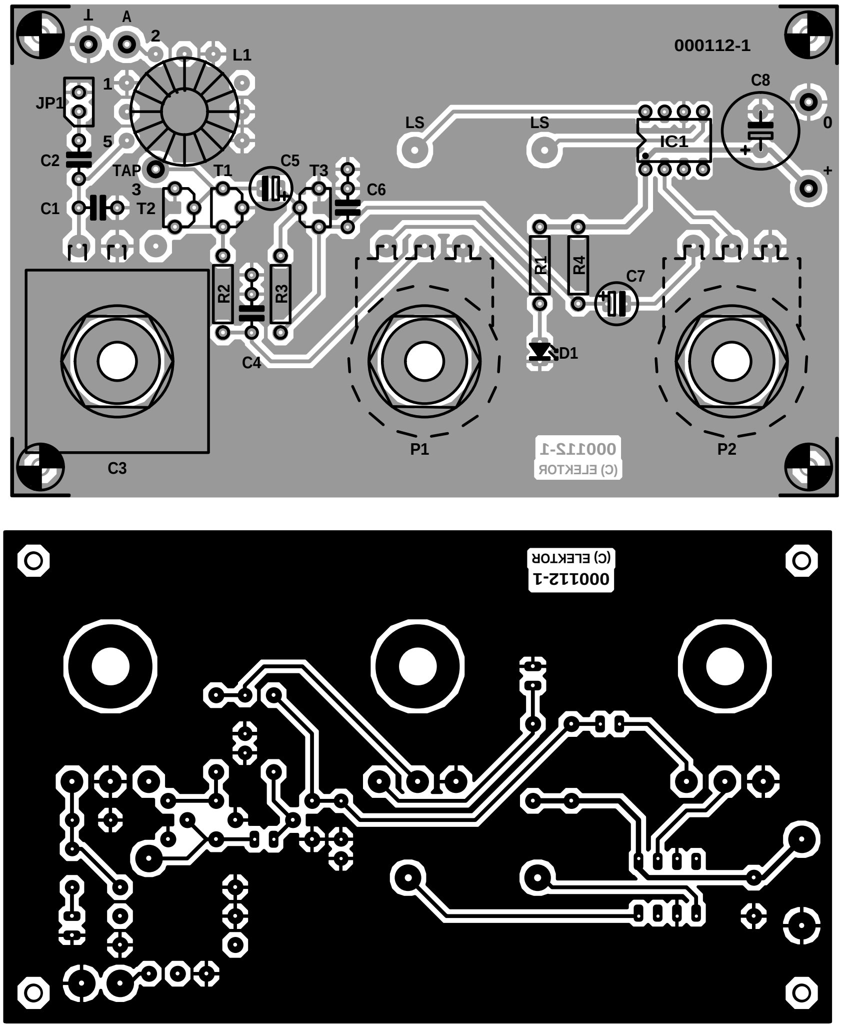


Figure 3. Layout of the single sided PCB.

COMPONENTS LIST

Resistors:
R1 = 2kΩ2
R2,R4 = 10kΩ
R3 = 1MΩ
P1 = 47kΩ linear potentiometer
P2 = 47kΩ logarithmic potentiometer

Capacitors:
C1 = 100pF
C2 = 330pF
C3 = 500pF tuning capacitor
C4 = 100nF
C5 = 1 F 10V radial
C6 = 10nF
C7 = 4 F7 10V radial
C8 = 220 F 10V radial

Semiconductors:
D0 = LED, red (high efficiency)
T1,T2 = BC558B
T3 = BC549C
IC1 = TDA7052 (Philips Semiconductor)

Miscellaneous:
JP1 = 2 solder pins with a jumper
PC1-PC6 = solder pins
LS1 = loudspeaker 8Ω 1W
L1 = coil on former (6mm dia., see text)
8-pin IC socket
3 knobs
PCB, order code **000112-1**

ferential resistor and causes regeneration in the tuned circuit. The regeneration circuit can be connected to the ‘hot’ end of the coil or to a tap point. If the tuned circuit has a relatively high damping factor, it is possible that the lowest tap point will have too low an impedance and it will not be possible for the regeneration circuit to compensate for this. The aerial also introduces some damping. A good setup is to use a long aerial connected at a low tapping point. Theoretically, the tuned circuit will be at optimum when the damping impedance is cancelled by the (negative) generator impedance of the circuit. The emitter current through T1 and T2 controls amplification and regeneration in the tuned circuit. The control current is supplied from the wiper of potentiometer P1 through the emitter resister R2. Capacitor C4 ensures that the emitter resister is shorted to earth at high frequencies. The potentiometer is in parallel with the LED D1 and is used to stabilise the voltage.

The coil tap point ‘TAP’ forms the connecting point for the regeneration circuit, which is also coupled to T3 via capacitor C5. T3 amplifies and demodulates the HF signal. C6 together with the output impedance of T3 form a low pass network that filters out the radio frequency components in the signal. The resulting audio signal is coupled to the volume control (P2) by capacitor C7, which also blocks any dc voltage that may be present on the signal. P2 is used to adjust the input signal to amplifier IC1. This amplifier is connected in a bridge configuration and can supply 1 W into the 8 Ω loudspeaker with a supply voltage of 4.5 V.

Coil winding

The coil L1 is the only component in this radio that needs to be made at home.

Before you wind the coil you need a coil former with a diameter of approximately 6 mm. This can be can be made of plastic, paper or card. The coil is wound using 0.3 mm (30 swg) diameter lacquered copper wire, and consists of four equal sections each comprising 5 turns. After winding each section of 5 turns, a small loop is formed in the wire and the loop is tightly twisted to make a tap point. The finished coil is shown in **Figure 2**.Altogether it has 20 windings with three tap points, one connection at the start and one connection at the end. All five connections to the coil must be carefully tinned (after first removing the lacquer). If you find that the connections are a little too long after tinning then it’s a simple job to trim them using sidecutters.

On the circuit board (**Figure 3**) are some pads for mounting the coil. The bottom end of the coil is connected to point 1, this is at ground. The top end of the coil is connected to point 5 so that the coil is on this side of C1 and C2. The “TAP” connection on the PCB links a tap point on the coil with the regeneration circuit. The connection “2” links another tap point on the coil with the aerial (at connection “A”). Both of these PCB connection points should be fitted with solder pins to make it easier to change tap positions on the coil during experimentation.

Fitting the rest of the components is fairly straightforward, the only point to watch out for is to ensure that all connections made in the RF part of the circuit (everything to the left of C7 on the circuit diagram) should be kept as short as possible.

The best type of capacitors to use for C1 and C2 in the tuned circuit is polystyrene film or NPO type ceramic capacitors.

These days it is not so easy to find a good tuning capacitor. Ideally, a good solidly built air-spaced capacitor from an old radio would do the job admirably. Easier to come by but not quite so good would be a tuning capacitor with a film dielectric like the ones that are found in transistor radios. In an emergency, you could use a trimmer capacitor with a spindle glued to the adjustment screw.

The connections between the variable capacitor, PCB, and the coil must be kept as short as possible. If these components are not firmly attached, any movements will alter the coupling between them and lead to unreliable operation. Using a coil former with an adjustable ferrite core for winding L1 gives an additional method of tuning the loop.

Using the coil described above it is recommended to use the two lowest coil connections to attach an aerial and the middle tap or one above for connection to the regeneration circuit. If the regeneration effect is insufficient, even after adjusting P1, it is possible to alter the value of R2. During tests of the prototype using the PCB it was found that the stated value of 10 kΩ for R2 was too high (the sensitivity was too low). The optimal value for R2 was found to be 3.3 kΩ, this gave P1 the best adjustment range. BC550B transistors can be used in place of the BC558B for T1 and T2.

Tuning in

The circuit operates on a supply from 4 to 7 V.

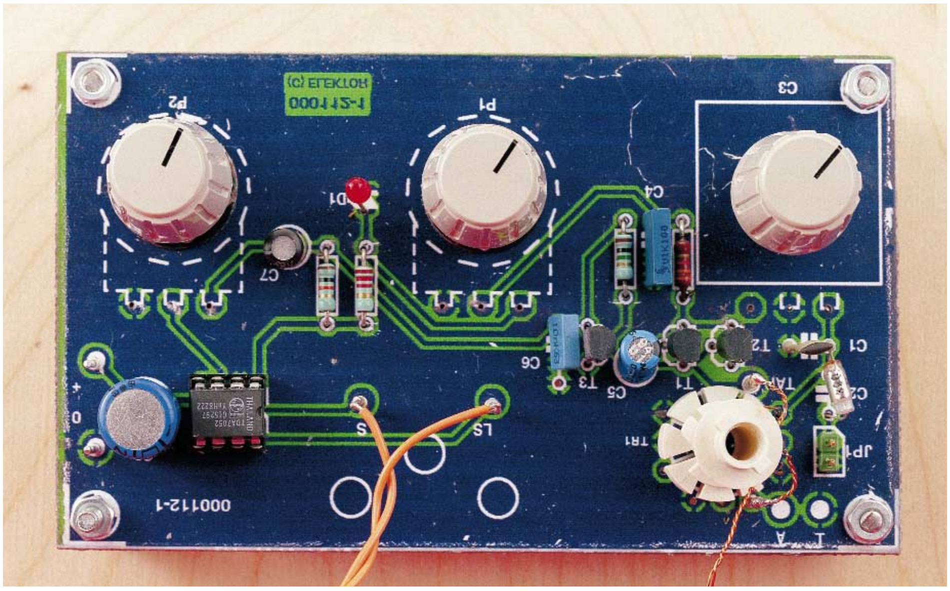
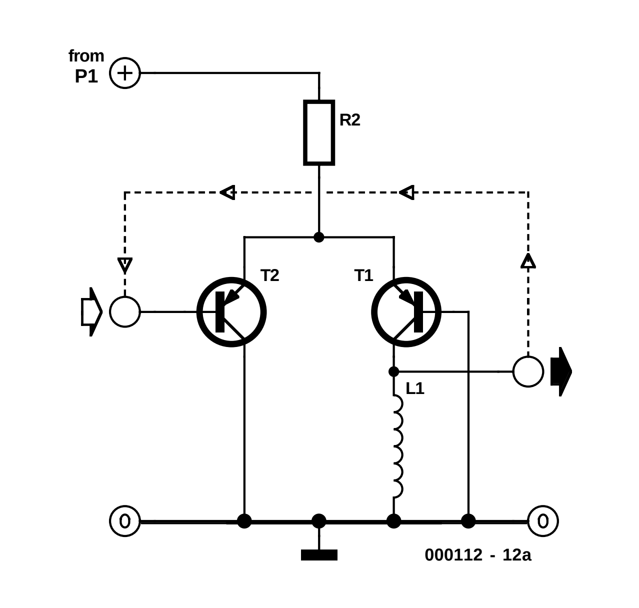
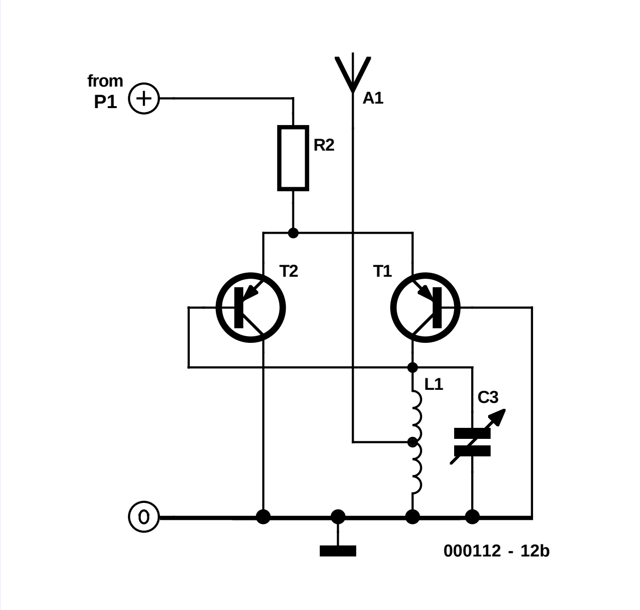


Figure 4. PCB with components fitted. The grid of holes can be used to try out different coils.

The Regeneration circuit



T1 and T2 in the regeneration circuit form a two stage RF amplifier configured as a long tailed pair, a configuration that is often used in integrated RF amplifiers. In **Diagram A** the basic principles of design are shown. At first sight T1 and T2 appear to form a differential amplifier but on closer inspection you will notice that the collector of T2 is connected to ground along with the base of T1. From this we can see that T2 is used as a common-collector configuration while T1 is used in the common-base configuration, both transistors share the same emitter resister. To an input signal applied to the base of T2 the transistor acts as an impedance converter (emitter follower), the input signal appears at the emitter of T2 unamplified but in phase with the input signal and with a lower source impedance. This signal at the base-emitter junction of T1 now controls the collector current of T1 (also in phase). The ratio of low emitter impedance to high collector impedance (L1) of T1 gives this configuration its voltage amplification, in which the output signal at the collector of T1 is always in phase with the input. Linking the output of the amplifier back to the input (dotted line) causes the negative feedback to behave as a positive feedback. **Diagram B** shows the regeneration circuit as it is used in the Audion-based receiver. Positive feedback occurs at the connection of the collector of T1 and the base of T2. Both are connected to the coil that forms a resonant circuit with the tuning capacitor. The aerial is also connected to the tuned circuit through a tap on the coil. Received signals are amplified and positive feedback at the input to the regeneration circuit is used to boost the tuned circuit



The normal frequency range of the radio goes from 6 MHz to 9 MHz, the actual range depends on the value of capacitors in parallel with the variable capacitor and the number of windings in the pick-up coil. Capacitor C2 can be linked into this circuit to extend the frequency range down to the 80 m amateur band where there are good possibilities of picking up SSB and CW transmissions.

Tuning the radio is best done with both hands, one hand on the tuning capacitor to find the station and the other on the feedback control (middle knob), adjusting the regeneration for best signal strength. With too much feedback (P1 turned clockwise) the regeneration circuit will suddenly start oscillating. This condition is useful to enable the reception of SSB and CW stations. For AM reception however, P1 is adjusted so that the level of regeneration is not quite enough to cause oscillation of the circuit. You will know oscillations have begun when you hear a roaring sound from the speaker and the received signal disappears. Roaring or whistling sounds may also be caused by external sources of interference, for wexample, fluorescent lamps, in this case the roaring will not be quite so loud and the received radio signal will still be audible.

When the feedback is optimally adjusted this circuit offers good sensitivity and selectivity. Some problems which afflict other types of receiver design, for example, blocking due to large input signals and intermodulation problems do not occur with this design because the regenerator only amplifies the desired frequency.

In practice, the clarity and sensitivity of this simple circuit can put some commercial super-PLL General Coverage receivers in the shade. To provide an aerial you will need a length of wire at least 50 cm long but 3 m would be better. The design of this radio will allow reception of many stations in the 49 m and 41 m band, even the 40 m Amateur band (CW) and SSB transmissions on the 80 m band (with the jumper in place to switch in C2) are possible. One refinement that can be made to the design is to use a geared motion tuning capacitor in place of C3. The circuit can also be modified to incorporate switched coil sections in L1 to make this into an All-Band or receiver.

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