Constructional Project

HIGH PERFORMANCE REGENERATIVE RECEIVER

by RAYMOND HAIGH

Provides continuous coverage from 130kHz to 30MHz. Capable of receiving broadcast and amateur stations from around the world.

ORIGINS OF REGENERATION

Almost a hundred years ago, scientists and engineers in Europe and America were trying to develop more sensitive circuits for the reception of radio signals.

C. S. Franklin in England and A. Meissner in Germany were both working on similar lines, but the credit for discovering the benefits of applying positive feedback to a tuned circuit is generally attributed to that great American radio pioneer, E. H. Armstrong. Known as "regeneration", the technique produces a truly dramatic increase in receiver sensitivity and selectivity.

Armstrong filed his patent in October 1913, just two months before his 23rd birthday. At this amazingly young age he had pushed forward the frontiers of technology and made man's dream of long-distance radio reception a reality.

HOW IT WORKS

Tuned circuits, formed by an inductor (coil) and a capacitor, are crucial to the working of radio receivers. By varying one of the components (usually the capacitor), the circuit can be tuned to resonate at a particular frequency.

This combination magnifies a signal to which it is tuned. The degree of magnification is dependant on the quality of the tuned circuit, and this is defined by a figure of merit known as the *Q*-factor. A figure of 100 is common. If a signal of 1mV is applied to a tuned circuit with a "*Q*" of 100, a voltage of 100 x 1mV, or 0·1V will be developed across it.

Armstrong (and others) discovered that, by connecting a triode valve to the tuned circuit and feeding back a tiny portion of the amplified signal to the coil, its *Q* can be dramatically increased. By this means, *Q* factors of several thousand can be achieved before the onset of oscillation, and the wanted signal is greatly amplified.

It is this phenomenon which imparts such a high degree of sensitivity and selectivity to simple regenerative receivers.

POPULARITY

Regenerative radio sets were produced in large numbers throughout the 'twenties. Skill is required to get the best out of radios of this kind: in particular, the regeneration control has to be carefully adjusted when receiving weak signals. Largely because of this, the easily operated superhet (also invented by Armstrong) began to challenge the popularity of the regen' in the 'thirties.

During the Second World War, Germany manufactured regenerative sets for military use, and the British incorporated circuits of this kind into clandestine transceivers. Manufacture for domestic listeners continued almost to the end of the valve era, with Ever-Ready producing a two-valve battery-operated set (their *Model H*) during the ’fifties.

AVOIDING PROBLEMS

Regenerative receivers are easily overloaded by powerful signals. They are also affected by aerial characteristics.

When an aerial system, which is directly connected to the tuned circuit, is resonant at the reception frequency (or a harmonic), it absorbs energy and inhibits regeneration. Known as “suck-out”, the phenomenon manifests itself as dead spots in the tuning range.

Overload and “suck-out”, together with an erratic feedback control, can ruin the performance of regenerative radios. They are avoided in this design.

WAVE TRAP

Powerful local radio transmitters can swamp regenerative receivers (they even cause problems with superhets of advanced design). The answer to this is the inclusion of what is known as a “wave trap”.

An inductor L1 and capacitor C1 form a parallel tuned circuit, which presents a high impedance at resonance, see Fig.1. When the inductor/capacitor combination is set to the frequency of the offending transmitter it blocks it out.

The problem is invariably encountered on Medium Waves, and suitable component values to tackle this problem, should it arise, are scheduled in Table 1.

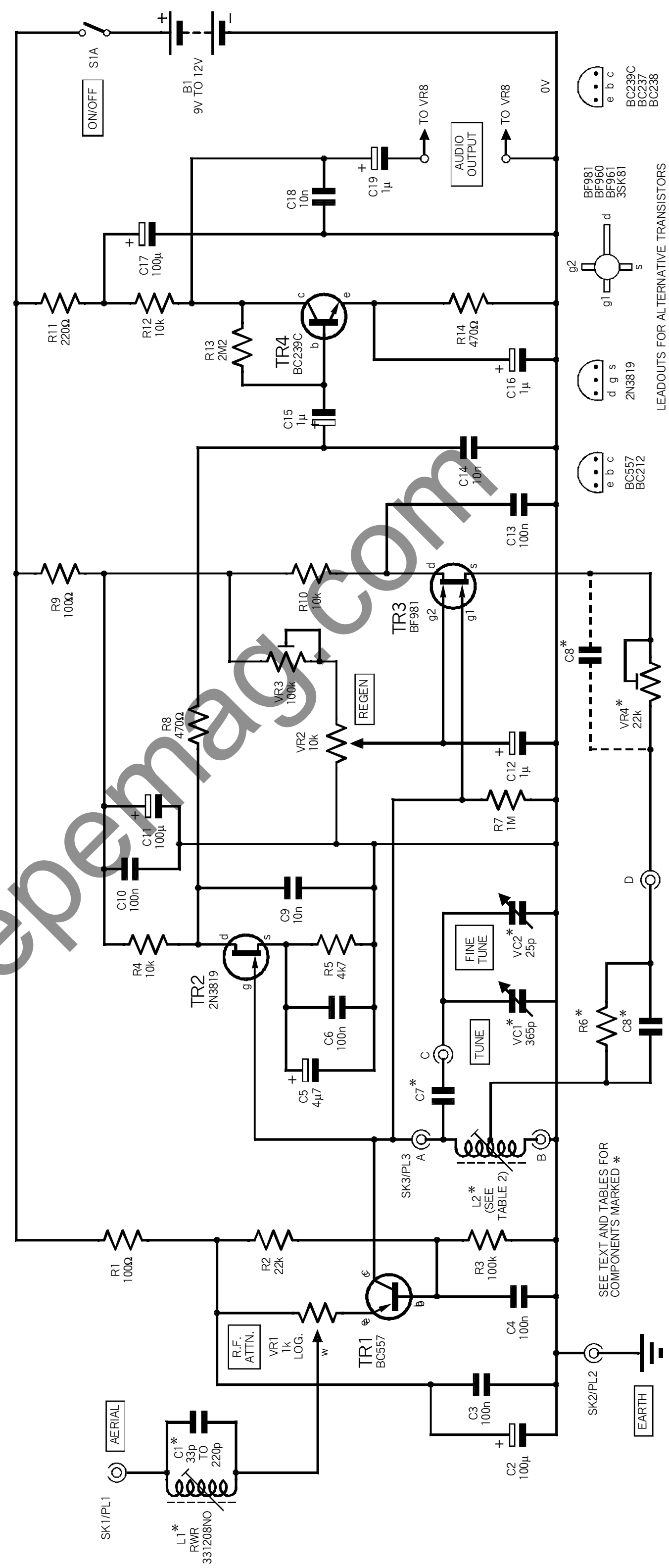

Fig.1. Circuit diagram of the High Performance Regenerative Receiver.

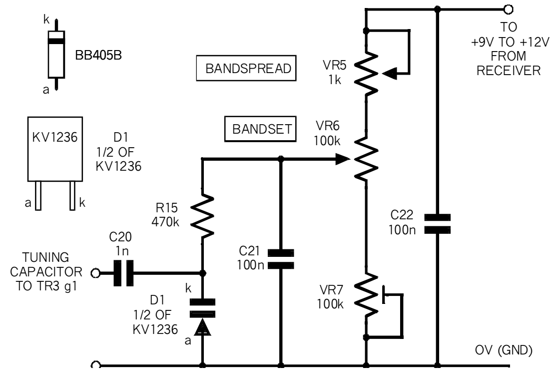

Fig.2. Alternative electronic tuning system. For fine tuning only, delete VR5 and C22, use a BB405B varicap diode, and

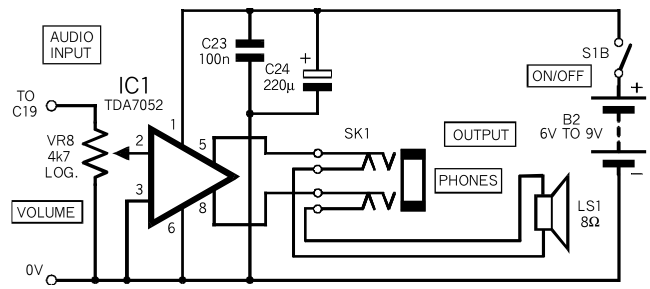

Fig 3. The audio power amplifier stage.

C1 pF	Frequency (kHz) at max inductance (core fully in)	Frequency (kHz) at min inductance (core fully out)
33	1300	1700
47	1100	1400
68	900	1200
120	700	900
220	550	700

CIRCUIT DETAILS

The circuit diagram of the High Performance Regenerative Receiver is shown in Fig.1. Grounded-base transistor, TR1, acts as a radio frequency (RF) amplifier. Whilst its most important function is to isolate the regenerative stage from the aerial, it also provides a useful amount of gain.

Signal input is fed to the emitter (e) of TR1, and potentiometer VR1 acts as an attenuator: an essential feature that prevents overload on strong signals. Bias is fixed by resistors R2 and R3, and C4 is the base (b) bypass capacitor. The RF stage is decoupled from the supply rail by R1, C2, and C3.

The output impedance of a grounded-base stage is high enough for TR1 to be connected directly to the tuned circuit, and the use of a *pnp* device enables its collector (c) to be taken to supply negative via the coil L2.

DETECTOR

Old valve receivers invariably combined the functions of signal detection and regeneration (or *Q* multiplication) in a single stage. With the use of transistors, better results, without recourse to specially designed coils, can be achieved by separating them.

Field effect transistor TR2, biased by resistor R5 into the non-linear region of its characteristic curve, functions as a sensitive, drain-bend detector.

Source decoupling at RF and audio frequencies (AF) is provided by capacitors C5 and C6. The output of TR2 is developed across drain load resistor R4 and C9, R8 and C14 remove residual RF.

Q-FACTOR

Dual-gate MOSFET TR3 provides the modest amount of RF gain required for regeneration or *Q* multiplication. Arranged as a Hartley oscillator, feedback from TR3 source (s) is connected to a tapping on coil L2, via bias components resistor R6 and capacitor C8. *(Hartley oscillators were introduced in detail in the July 1999 installment of our six-part series on oscillators. For more details bounce over to* **www.epemag.com/frmoscii.htm**, *Ed.)*

Preset potentiometer VR4 is included on the printed circuit board (PCB) for use during the setting-up process, after which it is shorted out and replaced by fixed resistor R6. Bypass capacitor C8 assists regeneration when the feedback winding is comparatively small. It is not required on all coil ranges.

Feedback, or regeneration, is controlled by potentiometer VR2, which adjusts the voltage on gate 2 of TR3, thereby varying its gain. Preset VR3 fixes the range of control, capacitor C12 decouples gate 2 and eliminates potentiometer noise, and resistor R10 and capacitor C13 decouple the stage from the supply rail.

When the tuning coil L2 is removed for band changing, the signal gates of TR2 and TR3 are kept at 0V by resistor R7.

TUNED CIRCUIT

The receiver is tuned by inductor (coil) L2 and variable capacitors VC1 and VC2. The

COMPONENTS

Resistors
R1, R9 100 ohms (2 off)
R2 22K
R3 100k
R4, R10, R12 10k (3 off)
R5 47k
R6 various values (see text and Table 2 next month)
R7 1M
R8, R14 470 ohms (2 off)
R11 220 ohms
R13 2M2
*R15 470k
All 0.25W 5% carbon film

Potentiometers
VR1 1k rotary carbon (logarithmic law if obtainable)
VR2 10k rotary carbon, linear
VR3, *VR7 100k enclosed horizontal preset (2 off)
VR4 22k enclosed horizontal preset
*VR5 1k rotary carbon, linear
*VR6 100K rotary carbon, linear
VR8 4k7 rotary carbon, logarithmic

Capacitors
C1 axial polystyrene, See Table 1
C2, C11, C17 100 uF radial electrolytic (3 off)
C3, C4, C6, C10, C13, *C21, *C22, C23 100nF disc ceramic (8 off)

Capacitors (continued)
C5 4u7 radial electrolytic
C7 axial polystyrene, see text and Table 2 (next month)
C8 ceramic, see Table 2 (next month)
C9, C14, C18 10n disc ceramic (3 off)
C12, C15, C16, C19 1u radial electrolytic (4 off)
*C20 1n (1000p) or 50p polystyrene (see Fig.2)
C24 220uF radial electrolytic
VC1 365p Jackson O-type air-spaced tuning capacitor (see text)
VC2 25p Jackson C804-type air-spaced tuning capacitor (see text)
All capacitors 12V working or greater

Semiconductors
*D1 KV1236, KV1235, or BB405B varicap diode (see text)
TR1 BC557 *pnp* silicon transistor
TR2 2N3819 *n*-channel field effect transistor
TR3 BF981 *n*-channel dual-gate MOSFET
TR4 BC239C *npn* silicon transistor
IC1 TDA7052 low voltage 1W power amplifier

See also the SHOP TALK Page!

Miscellaneous
L1 RWR331208NO inductor (TOKO), only required if "wave trap" is needed (see text)
L2 tuning band coils (TOKO), (8 off) see text and Table 2 (next month)
PL1 to PL8 9-pin D-type plugs for L2 (8 off) see Table 2 for other components
S1 d.p.d.t. toggle switch
SK1, SK2 screw terminal post (Aerial and Earth)
SK3 9-pin D-type socket (for plug-in tuning coils)
SK4 switched stereo jack socket
B1 9V to 12V battery pack
B2 6V to 9V battery pack

Printed circuit boards available from the *EPE Online Store*, codes 7000254 (receiver), 7000255 (Electronic Tuning), and 7000256 (Amplifier); 9-pin D-type plugs (8 off for tuning coils); aluminum or diecast box; 8-pin DIL socket; plastic control knobs (4 small, 1 large); reduction drive for tuning capacitor; multistrand connecting wire; card for tuning dial; nuts, bolts, washers, and stand-offs; solder pins, solder, etc.

Note: All components marked with an asterisk (*) are for the optional electronic tuning system.

Approx. Cost Guidance Only *(Excluding batteries and tuning capacitors)* **$56**

larger of the two capacitors, VC1, acts as a coarse (Bandset) tuning control. The smaller one, VC2, provides fine (Bandspread) tuning. These components are discussed later. Fixed capacitor C7 limits the maximum value of VC1 on the shortwave ranges. The reduced swing makes tuning less critical and consistent regeneration easier to achieve.

Details of the coverage obtained with a range of Toko coils, together with the associated values of C7, R6, and C8, are given in Table 2 (next month).

AUDIO AMPLIFIER

The base (b) and emitter (e) bias of audio amplifier, TR4, are fixed by resistors R13 and R14. Signal output is developed across collector (c) load resistor R12; and R11 and C17 decouple the stage from the supply.

The low value of emitter bypass capacitor C16 results in gain-reducing negative feedback at the lower audio frequencies. This improves clarity. Coupling and DC blocking capacitors C15 and C19 have a low value for the same reason.

Response to the higher audio frequencies is curtailed by capacitor C18. Constructors who find the tone too “bright” should increase the value of this component to 47nF or 100nF.

ELECTRONIC TUNING

The use of a separate *Q*-multiplier stage (TR3) makes the receiver tolerant of electronic tuning. (The somewhat modest *Q* of high capacitance varicap diodes inhibits the operation of most regenerative sets).

A suitable, add-on, electronic tuning circuit is given in Fig.2. Potentiometer VR6 controls the reverse bias on varicap diode D1 and varies its junction capacitance. This forms the coarse, or Bandset, tuning control.

Potentiometer VR5 permits a small adjustment of the bias voltage, and acts as the fine, or Bandspread, control. Preset VR7 fixes the lowest level the bias voltage can fall to, thereby determining the maximum value of the tuning capacitance. (Diode junction capacitance increases as the reverse bias is reduced.)

The varicap diode D1 is coupled into the main circuit via DC blocking capacitor C20 and resistor R15 isolates the signal path from the potentiometer chain. Potentiometer noise is prevented by capacitors C21 and C22.

High value varicap diodes have a relatively large minimum capacitance, and an additional coil may be needed in order to secure continuous coverage. Furthermore, performance above 20MHz or so is not quite as satisfactory as that afforded by a traditional variable capacitor.

These disadvantages do not apply when the electronic tuning circuit is used with a VHF diode solely to provide fine tuning (VR5 is omitted and the top end of VR6 is connected directly to the positive supply rail). This arrangement has the advantage of low cost and conveys a freedom to locate the DC operated Bandspread control in a position remote from the tuned circuit. The prototype Receiver, shown in the photographs, incorporates this arrangement.

POWER AMPLIFIER

The circuit diagram of the additional, single chip, audio power amplifier stage is given in Fig.3. This amplifier has its own 6V to 9V power supply to avoid any possible interaction with the receiver section. Designed around a TDA7052 low voltage power amp IC, the only external components are capacitors C23 and C24 which ensure the stability of the device. Potentiometer VR8 acts as the volume, or AF gain, control.

The power amplifier IC1 is short-circuit protected, requires no heatsink and can deliver a clean 1W of audio into an 8 ohm speaker with a 6V supply. It is also claimed that there are no switch-on or switch-off clicks with this device.

POWER SUPPLIES

Current drain is extremely modest, being only 2mA for the radio section and 50mA for the power amplifier when it is delivering a good speaker volume (5mA when 'phones are used).

Battery supplies are, therefore, eminently suitable, and any possibility of hum and interference from the mains is avoided (regenerative receivers are very susceptible to this and require a carefully designed supply unit when they are mains powered).

The power amplifier current swings between 6mA and 60mA or more when it is being driven hard. The resulting supply voltage fluctuations would disturb the operation of the *Q*-multiplier, despite heavy decoupling.

Separate battery supplies for the Receiver and Power Amplifier sections are, therefore, strongly recommended. They are essential when electronic tuning is adopted. A double-pole toggle switch, S1a and S1b, connects the two separate battery packs into circuit.

COMPONENTS

Before we commence construction, a few words now on choice of components may help. Readers are also directed to our **Shoptalk** page for details of possible suppliers for some off those "hard to find" items.

The chassis of the prototype was fabricated from aluminum and a wooden case with hinged lid holding the loudspeaker made to house the receiver. The lid can be raised and held up by a hinged wire frame (shown above) when in use.

Coils

All of the inductors used in this Receiver are from the Toko range. Their frequency coverage is shown in Table 1 and Table 2 (next month) together with suitable tuning capacitor values.

Coils can also be hand wound. As a very rough guide, when 20mm to 25mm diameter formers are used, feedback tappings should be about 10 turns up from the "earthy" end on Long waves, 5 turns on Medium waves, and 2 or 3 turns on Shortwaves.

Transistors

Transistor types are not critical. The *Q*-multiplier circuit works well with a range of dual-gate MOSFETS, including the 40673 and the MFE201. The 3N201 was not tried, but it should prove satisfactory.

A 2N2905 *pnp* transistor worked well in the RF stage, and a 2N5827 or a 2N5828 should be suitable for TR4.

The alternative devices mentioned here have different case styles to those depicted in Fig.1, and the lead-outs must be checked.

Tuning Capacitors

A Jackson 365pF O-type air-spaced tuning capacitor is the preferred component for bandset control VC1, and a 25pF Jackson C804 type is ideal for VC2, the Bandspread control. If this latter value produces a bandspread tuning rate which is too fast, connect a 10pF or 5pF polystyrene capacitor in series with it to reduce its swing.

Inexpensive, polythene dielectric variables, of the kind used in transistor portables, can also be used. Some of these have comparatively low values, and both sections may need connecting in parallel to obtain the required tuning range. (A swing of at least a 10pF to 200pF is needed to give continuous coverage from 150kHz to 30MHz with the coils listed in Table 2). The 25pF FM tuning section of one of these capacitors can act as the bandspread control VC2.

If salvaged tuning capacitors are used, make sure that they are clean and dry, that the rotor contacts are satisfactory, and that the vanes are not shorting.

Varicap diodes are retailed by a number of suppliers and should not be too hard to find. Any 450pF varicap designed for 9V bias, should be suitable for full electronic tuning.

NEXT MONTH

In Part 2 next month we'll go over the constructional details for this project.

Go to next section