CHAPTER 28

REFLEX AMPLIFIERS

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SECTION 1 : GENERAL DESCRIPTION

(i) Description (ii) Advantages and disadvantages of reflex receivers.

(i) Description

A reflex amplifier is one which is used to amplify at two frequencies—usually intermediate and audio frequencies.

Reflex radio and audio frequency stages have also been used in very small T.R.F. receivers (see Sect. 5).

Reflex receivers were fairly common in U.S.A. and Australia in the period 1934 to 1937, but suffered from serious distortion and high play-through. These receivers usually had high a-f plate load resistors giving comparatively high a-f gain, low i-f gain and low operating plate voltages and currents. A.V.C. was not applied to the reflex stage which was frequently a sharp-cut-off valve such as the 6B7 or 6B8. A considerable advance was made in Australia by the use of the remote cut-off type 6G8-G with a.v.c., and a further advance was made in the adoption of a comparatively low a-f plate load resistor. The latter enabled nearly full i-f gain to be obtained with normal voltages on the electrodes, thus increasing the maximum plate voltage swing for a limited distortion. The most common application of a reflex amplifier in Australia* at the present time is in a 3/4 valve receiver comprising converter, reflex stage, power amplifier and rectifier. The reflex stage in such a receiver amplifies at intermediate frequency, provides detection and a.v.c. from its diode or diodes, and then amplifies at audio frequency. It may be compared with a straight receiver in which the second valve is used as i-f amplifier and detector, the output from the detector being used to excite the power stage. Using the same valves and components in both cases, the reflex receiver may have a sensitivity up to 10 times that of the straight set.

(ii) Advantages and disadvantages of reflex receivers

Advantages of the reflex receiver

1. Higher sensitivity.

2. Greater flexibility in design, permitting use of negative feedback either with or without tone compensation (bass boosting) for small cabinets.

*Reflex receivers do not appear to be in commercial use in either U.S.A. or Great Britain at the time of writing.

Disadvantages of the reflex receiver

1. Increased cost due to additional components.

2. Increased tendency to overload on strong signals.

3. More complicated design, although once a satisfactory design has been evolved there are no outstanding production difficulties.

4. Somewhat increased distortion at high modulation percentages at medium and high input levels than for a well-designed straight receiver, although both are still in the same class.

5. Play-through—that is the occurrence of a-f output with the volume control at its zero setting. This leads to a further defect known as the " minimum volume effect " whereby minimum volume from the receiver is obtained with the volume control at some setting slightly above zero setting. At the point of minimum volume the signal is very badly distorted since there is a balancing-out of the fundamentals between the normal signal and the out-of-phase play-through signal. Both play-through and the minimum volume effect may be reduced by good design so as not to be objectionable. See Sects. 2, 3 and 4. Perhaps a fairer comparison is between a 3/4* valve reflex receiver and a 4/5 valve straight set. In this case the reflex receiver will be more economical to produce, through the saving of one valve, while there will be a slight saving in space, heat dissipation and current consumption. The 4/5 receiver is capable of being designed to have negligible play-through and may have slightly greater sensitivity.

The design of reflex receivers must necessarily be a compromise, with juggling of inter-acting characteristics. However, by reflexing it is possible to achieve an acceptable performance which would not otherwise be obtainable with the same number of valves. The fact that reflex receivers form a substantial percentage of the Australian market for 3/4 valve sets indicates that their performance is acceptable.

On account of the complicated inter-action which occurs in a reflex receiver, it is impossible to design the reflex stage alone ; the whole receiver must be treated as a single design unit. If any change is subsequently made in any other stage, it is usually necessary to make consequential modifications to the reflex stage for the best results.

So far as sensitivity is concerned, a straight 3/4 receiver using modern valves can give 15 μV broadcast sensitivity†, and 30 μV short-wave sensitivity†, which for most applications is adequate. Nevertheless the higher a-f gain of the reflex receiver removes the problem, which is experienced with straight 3/4 sets, of preventing the a.v.c. from limiting the a-f output before the output valve is fully loaded.

The advantages to be obtained at audio frequencies from reflexing a 3/4 valve receiver are considerable. A straight 3/4 valve set without an a-f stage almost invariably suffers from " bubbling " at high a-f outputs on strong signals, and to prevent this the low frequencies are reduced as much as possible without making the reproduction too thin. With the additional stage of a-f amplification provided by reflexing, the regenerative effect which causes bubbling becomes degenerative, and the bass can be boosted to any desired extent without bubbling being experienced.

In addition it is not possible in straight 3/4 valve sets to use negative feedback for any purpose other than mild frequency correction because any reduction in the mid-frequency gain of the output stage makes i-f overloading probable before the output valve is driven to full output. With reflexing an appreciable amount of the added a-f gain can be used for any desired form of negative feedback.

Reflex superhet. receivers may be divided into two principal groups, those employing plate reflexing (see Sect. 3), and those employing screen reflexing (see Sect. 4).

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*A 3/4 valve receiver is one having three amplifying valves and a rectifier.
†For 50 milliwatts output.

SECTION 2 : SOME CHARACTERISTICS OF REFLEX SUPERHET. RECEIVERS

(i) Play through (residual volume effect) (ii) Over-loading (iii) Automatic volume control (iv) Reduction in percentage modulation (v) Negative feedback (vi) Operating conditions of reflex stage.

(i) Play-through (residual volume effect)

This effect has been briefly described in Sect. 1. Play-through in a reflex receiver is due to the rectification caused by the curvature of the valve dynamic characteristics. Play-through increases as the input signal is increased, and may be measured with a large signal input—preferably with a high modulation percentage and with the volume control at zero. During design it may be found that play-through increases rapidly when the signal input to the reflex stage passes some critical level. In such a case the a.v.c. system must be designed to prevent signals of this magnitude from appearing at the grid of the reflex stage. Since play-through is a function of rectification and therefore of the curvature of the characteristic, it is a variable depending on the bias. By plotting play-through for varying bias voltage on the reflex stage with a constant input signal to the reflex stage, it is possible to determine the range of a.v.c. voltages which may be applied to the stage without resulting in serious play-through. This may entail using only a small fraction of the developed a.v.c. voltage on the reflex stage.

(ii) Overloading

It is practicable to design a reflex receiver to handle input voltages up to 1 volt without serious distortion (of the order of 10% at 100% modulation).

(iii) Automatic volume control

The a.v.c. system should be designed so that high peak i-f plus a-f voltages are not built-up in the plate circuit of the reflex stage. There are three principal a.v.c. systems in use :

1. Full a.v.c. applied to both converter and reflex stages.

2. Fractional a.v.c. applied to both stages, although the two fractions may be different.

3. Full a.v.c. is applied to the converter and fractional a.v.c. to the reflex stage.

The choice of converter valve has considerable bearing on the a.v.c. design. The use of a converter with a not-too-remote cut-off (e.g. 6BE6) assists in the reduction of play-through by limiting the maximum signal voltage applied to the grid of the reflex stage.

If the fraction of the a.v.c. applied to the reflex stage is reduced too much, or omitted entirely, the reflex stage may run into grid current and cause " bubbling " with the volume control at maximum because the rectified a-f signal returned to the grid from the plate of the reflex stage may exceed the bias on the valve. If the fraction of a.v.c. applied to the reflex stage is increased too much, the a.v.c. characteristic will tend to reach a maximum output and then to fall with increasing input voltages. The worst effect of excessive control is the inability of a receiver to give full a-f output on strong stations even with the volume control at maximum. Also, in such a case the effect of tuning to a powerful signal is to produce less output when the receiver is tuned directly to the carrier than when it is tuned to one side, so that there are two adjacent tuning positions of maximum volume. A further effect of too large a fraction of a.v.c. voltage is the increase in play-through referred to above.

As a criterion of good a.v.c. design, the volume control should be approaching its maximum position for maximum undistorted a-f output at any signal level. The minimum volume effect may be reduced by using a tone control which gives severe treble attenuation.

(iv) Reduction in percentage modulation

With a large signal input and with the volume control at maximum, a reduction in the percentage of modulation occurs due to the curvature of the characteristics. Under laboratory conditions this can be quite considerable, for example 30% modulation may be reduced to 10%, but it is usually unimportant with ordinary listening because it only occurs under conditions which would also cause overloading of the power stage. However, where a Scroggie-type of a.v.c. characteristic indicates serious a-f overloading with the volume control at maximum, the actual overloading with a strong input signal may be appreciably less than that indicated, owing to the reduction in percentage modulation.

(v) Negative feedback

If full a.v.c. is applied to the reflex valve, a strong signal will then reduce the a-f gain, which in turn will reduce the a-f feedback, if any. Under these conditions feedback is available on weak signals where it is not needed, but it is very much reduced on strong signals where it is most needed. As a consequence, negative feedback is only practicable with a small fraction of the a.v.c. voltage on the reflex stage.

Negative feedback, in addition to its use for the reduction of distortion and for tone compensation, also assists very considerably in the reduction of play-through (e.g. Fig. 28.3).

(vi) Operating conditions of reflex stage

The reflex stage should be biased, with a very small signal, to give maximum gain unless this bias is insufficient to prevent the valve from drawing grid current due to a-f signals in excess of the bias voltage being applied to the control grid at input signals such that the a.v.c. has not yet become fully effective.

Adequate r-f filtering of the demodulated signal is necessary before returning it to the grid of the same valve again, to avoid regeneration or actual i-f oscillation.

SECTION 3 : DESIGN OF PLATE REFLEX SUPERHET. RECEIVERS

(i) General considerations (ii) Full a.v.c. applied to both stages (iii) Fractional a.v.c. applied to both stages (iv) Full a.v.c. on converter, fractional a.v.c. on reflex stage.

(i) General considerations

The majority of reflex receivers are in this class. Plate reflexing is less critical in relation to valve operating point and less critical so far as design is concerned. However, under some conditions, screen reflexing will give less play-through. With high i-f gain in any receiver it is difficult to eliminate regeneration entirely without some filtering, but in a plate reflex receiver i-f decoupling is an inherent feature due to the plate circuit components, and no other i-f filtering is necessary.

(ii) Full a.v.c. applied to both stages

With suitable valve types, this very simple system is capable of handling an input of 1 volt (30% modulated) with distortion as low as can be obtained from any other a.v.c. arrangement. Current designs of reflex receivers employing this a.v.c. arrangement have fairly high play-through but this may be due to factors other than the a.v.c. system.

(iii) Fractional a.v.c. applied to both stages

A typical example is Fig. 28.1 in which a large fraction of the a.v.c. voltage is applied to the converter stage and a small fraction to the reflex stage. As a result of reduced a.v.c. voltage on the reflex stage, the play-through is considerably reduced.

(iv) Full a.v.c. on converter, fractional a.v.c. on reflex stage

An example of a receiver in this class is Fig. 28.2 in which one ninth of the a.v.c. voltage is applied to the reflex stage. The receiver has a sensitivity of 40 μV (for 50 mW output), the comparatively low sensitivity being due principally to the use of low Q i-f transformers. It is capable of handling an input up to 1 volt with complete stability under all conditions, and has several interesting features. The plate load

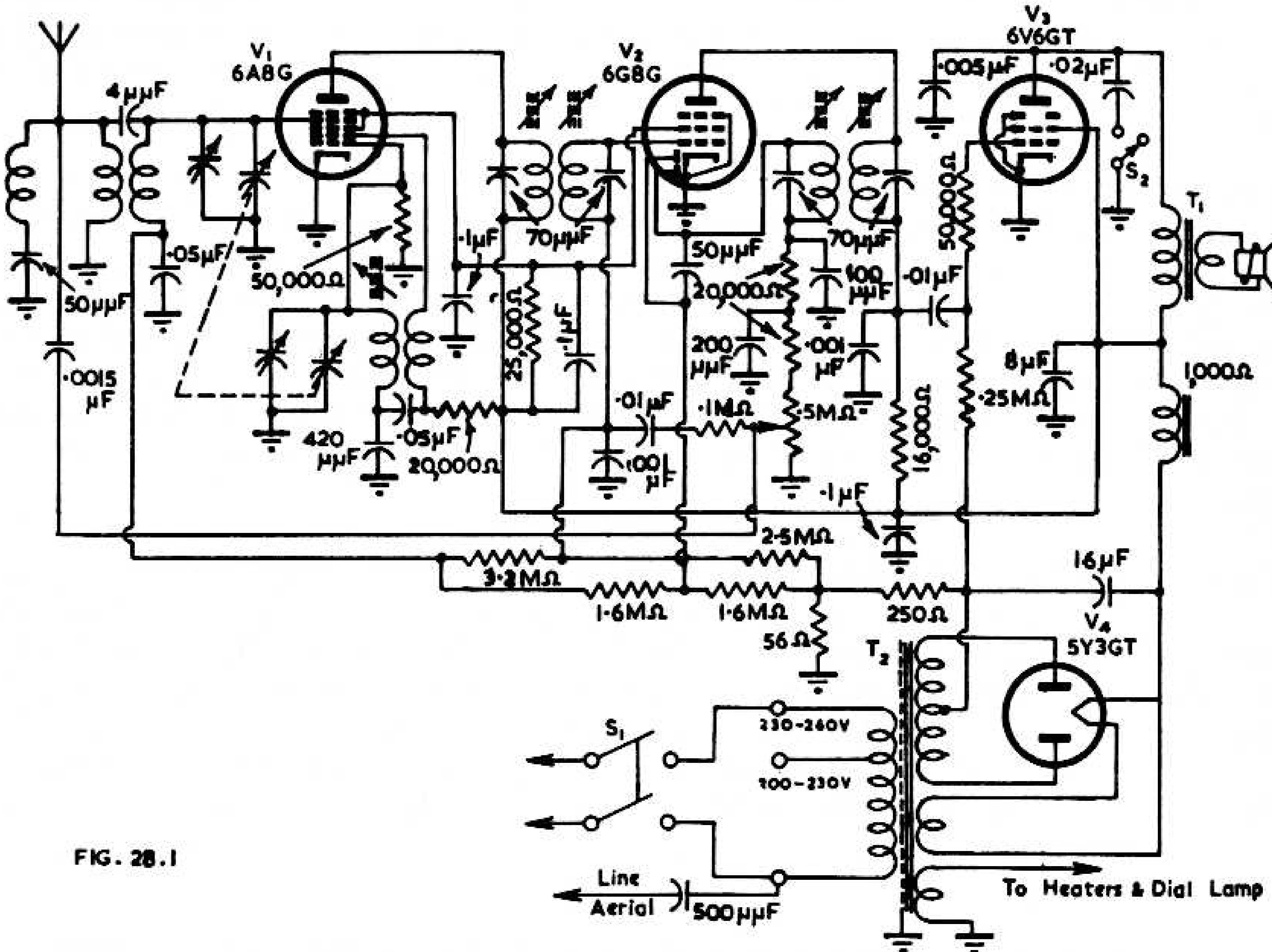

Fig. 28.1. *Reflex superhet. receiver with plate reflexing and fractional a.v.c. on both controlled stages* (*A.W.A. Radiola Model* 517-*M*).

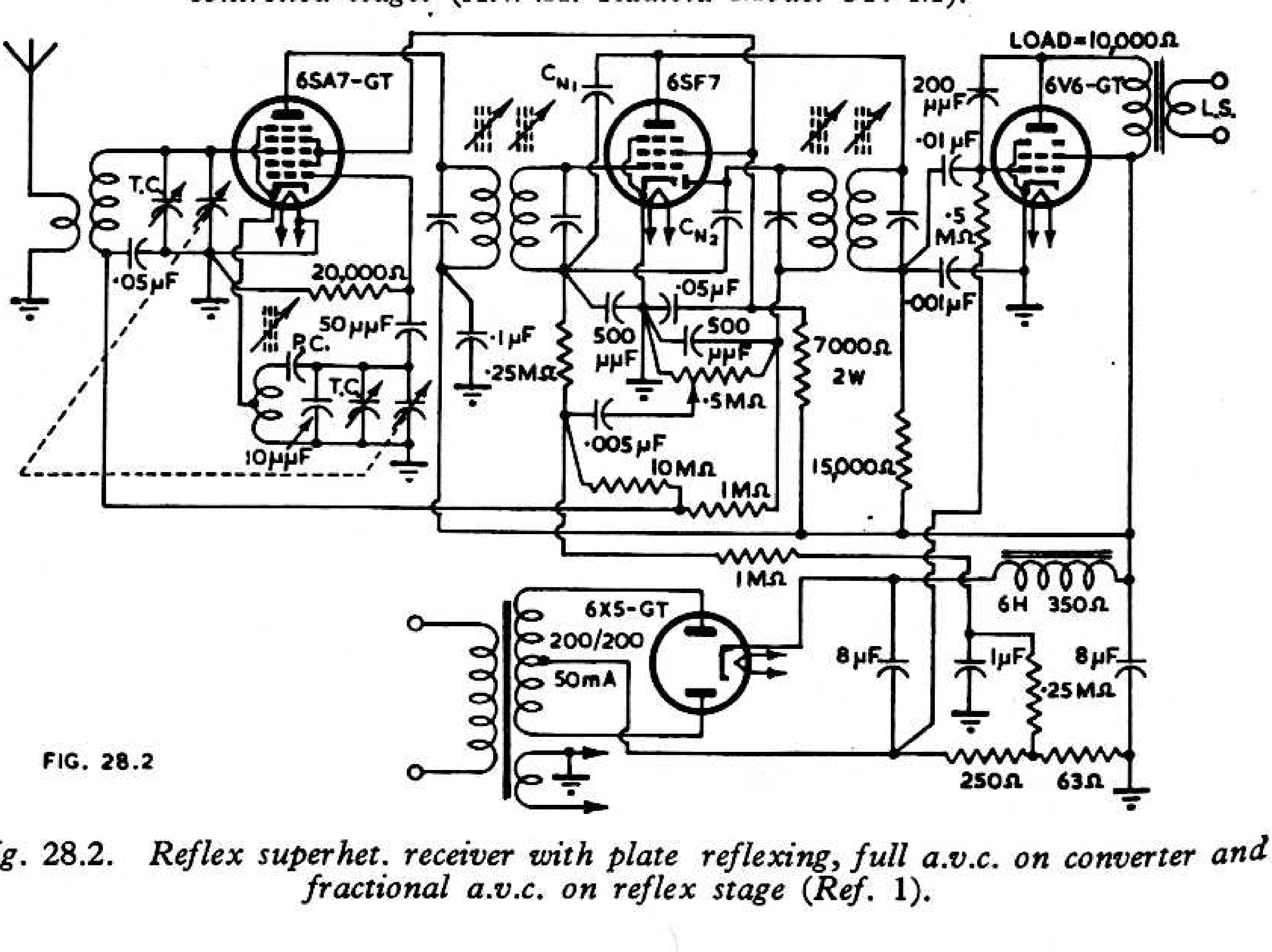

Fig. 28.2. *Reflex superhet. receiver with plate reflexing, full a.v.c. on converter and fractional a.v.c. on reflex stage* (*Ref.* 1).

resistor was selected to provide optimum operation together with minimum hum ; a certain amount of hum neutralization is possible between the reflex (a-f) and power amplifier stages. Feedback in the reflex stage is neutralized by the very small fixed capacitances C_{N1} and C_{N2}, while a small degree of negative feedback is provided on the output stage.

Considerably improved performance is obtainable by the use of type 6AR7-GT in the reflex stage, together with high Q i-f transformers. This avoids the necessity for neutralization and gives higher gain. Still higher gain is obtainable with a high-slope output valve, although the play-through is increased thereby. This circuit arrangement has considerable merits and there are prospects that, by suitable choice of valve types and a.v.c. design, the play-through may be reduced to a low level.

A possible alternative form of the circuit would be to use type 6BE6 converter, 6BA6 reflex amplifier and a duo-diode-output pentode.

SECTION 4 : DESIGN OF SCREEN REFLEX SUPERHET. RECEIVERS

(i) Screen reflex receivers (ii) Comparison between plate and screen reflexing.

(i) Screen reflex receivers

In a screen reflex receiver the screen of the reflex stage is by-passed to earth for intermediate frequencies only, and the screen is coupled to the grid of the power stage for audio frequencies. For the same number of components and the same economy, screen reflexing permits the use of separate screen dropping resistors for the converter and reflex stages, thus giving greater flexibility in design and less interaction. The play-through is less than with plate reflexing and may be made quite small with the application of negative feedback. It is necessary for the diode-screen capacitance to be low, and in this respect the Australian type 6AR7-GT is satisfactory. The screen dropping resistor and grid bias must be designed for optimum i-f gain ; in the 6AR7-GT this also provides satisfactory a-f gain. Screen reflexing requires good hum filtering.

With screen reflexing, careful design is necessary for optimum results to be obtained. An example of a well designed screen reflex receiver is Fig. 28.3. This has been designed for high sensitivity with reasonably low distortion and low play-

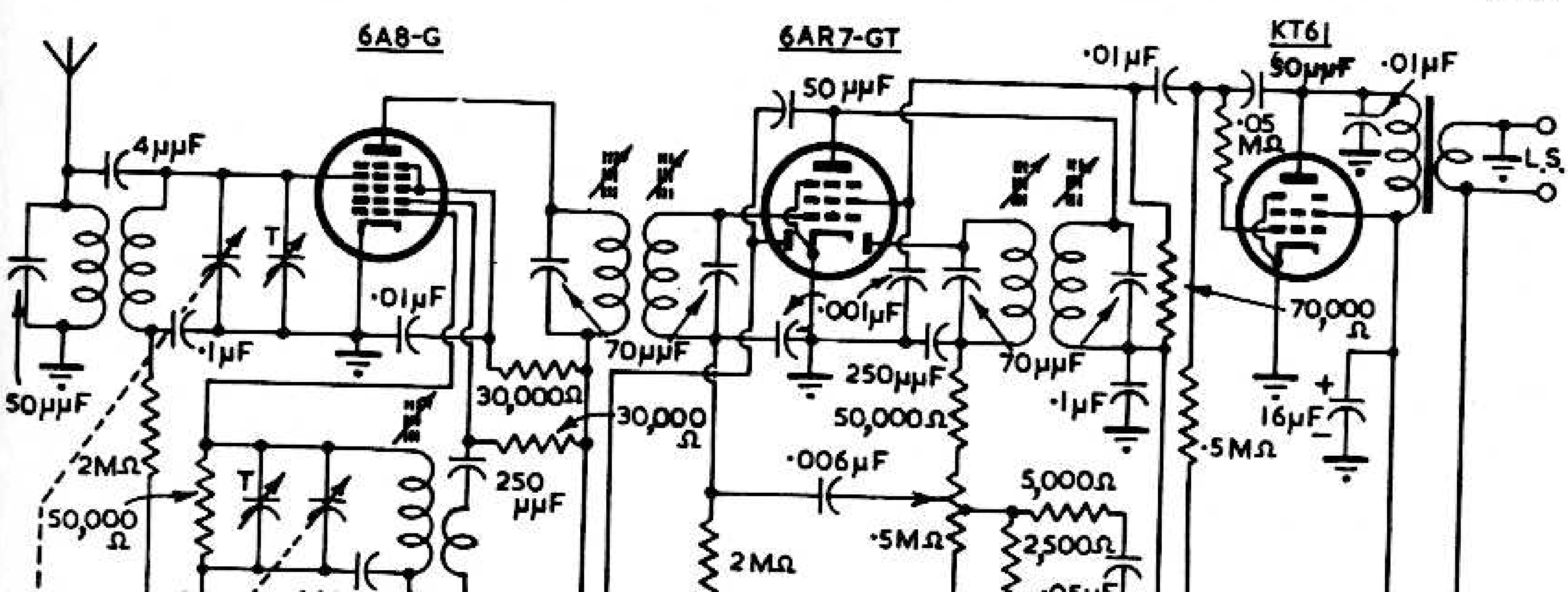

Fig. 28.3. Reflex superhet. receiver with screen reflexing (Ref. 4).

through. The aerial sensitivity is approximately 5 μV for 50 mW output, and the signal to noise ratio is 10 to 13.5 db at 5 μV input. The distortion is 6.9% with an input of 1 volt, 30% modulated, but 12% with an input of 0.5 volt, 100% modulated. An output of 0.5 watt is obtained with 20 μV input, 30% modulated. With an input of 1 millivolt to the aerial terminal, 30% modulated at 400 c/s, an output of 2 watts is obtained with 10% overall distortion.

Feedback is applied by returning the lower end of the volume control to the voice coil. Maximum bass boosting is provided when the volume control is at the tap, which is adjusted for the lowest listening level. The high frequency peak and bass boosting are reduced as the volume control setting is increased towards maximum. The response above 5000 c/s is cut sharply by a combination of shunt capacitances together with negative feedback. The overall result is an automatic high frequency tone control which gives a " mellow " tone with weak signals and a normal radio tone on strong stations. The gain reduction due to feedback is 14 db with 1 mV signal input and with the volume control at its minimum position. The gain reduction decreases as the volume control is advanced.

The conventional i-f filter in a reflex circuit is a series resistor from the volume control slider, connected to a by-pass capacitor at the cold end of the first i-f transformer secondary. These two components give phase shift at some high frequency with the volume control at its minimum setting, additional to the phase shifts already in the circuit and may thus cause oscillation when heavy feedback is applied with the volume control at zero. However if the resistor is wired in series with the hot end of the volume control, as in Fig. 28.3, with the volume control at its zero setting there is no series resistor in the feedback path, phase shift is reduced and high frequency peaks (or oscillation) are avoided.

Resistance-capacitance filtering is used here for economy. The plate supply voltage is 185 volts. One ninth of the a.v.c. voltage is applied to the reflex stage. The play-through is as low as in some commercial receivers that do not use reflexing.

(ii) Comparison between plate and screen reflexing

Plate reflexing is capable of higher a-f gain than screen reflexing, since the latter is limited by the " triode mu " of the reflex valve. For this reason, types 6AR7-GT and 6BA6 with grid-to-screen mu factors of 18 and 20 respectively are quite suitable for use in screen reflex receivers. However, plate reflexing gives more play-through than screen reflexing for similar conditions in both cases.

Type 6AR7-GT as a screen reflex amplifier allows a higher gain in the output stage than a lower gain valve (e.g. 6G8-G) with plate reflexing, for the same play-through performance in both cases, and similar converter conditions.

SECTION 5 : DESIGN OF T.R.F. REFLEX RECEIVERS

In such a receiver the r-f amplifier is reflexed and used also as an a-f amplifier. The only application at the time of writing is to 2/3 valve receivers having a diode-pentode as a reflexed r-f, a-f amplifier and diode detector, followed by a power pentode (e.g. 6AR7, KT61). A sensitivity of the order of 1000 μV (for 50 mW output) is practicable. A limited degree of regeneration assists gain and selectivity.

SECTION 6 : REFERENCES TO REFLEX AMPLIFIERS AND REFLEX RECEIVERS

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