SECTION 6

RECEIVERS RC5/2 AND RC5/3

Introduction

The RC5/2 and RC5/3 are completely transistorised f.m. receivers fitted with carrier-failure relays and intended for rebroadcasting. They may obviously be used also for quality monitoring purposes. They are both designed for operation from a.c. mains, but the RC5/3 includes facilities for automatic change-over to battery operation if the mains fail. These receiver codings do not cover either the local oscillator or the mounting bracket required. Adaptors and side brackets exist to permit the receiver to be flush-mounted or recessed on 19-inch bays. Adaptor plates can also be supplied to permit either type of mounting on 22-inch bays.

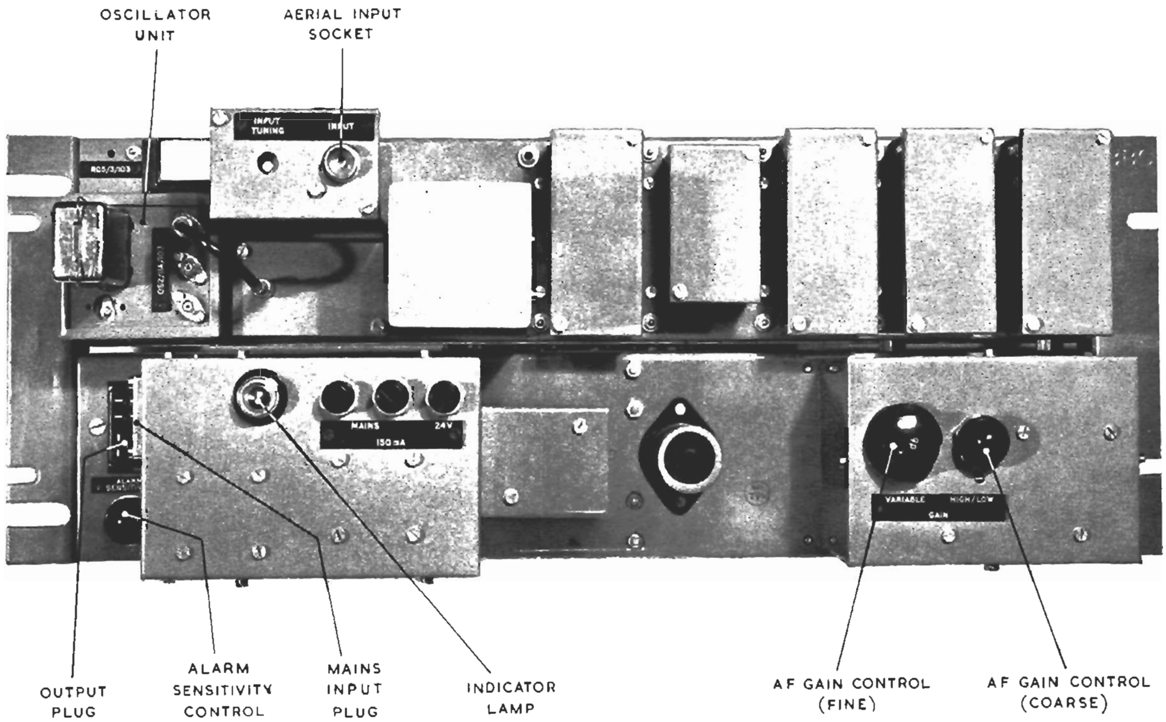


Fig. 6.1. Receiver RC5/3: General View

A general view of an RC5/3 receiver is given in Fig. 6.1. The receiver is constructed on two $3\frac{1}{2}$-inch panels, giving a total depth of 7 inches. One panel contains the r.f. amplifier, frequency changer and i.f. amplifier and limiter and the other contains the discriminator, a.f. amplifier, carrier-failure relays and the supply. This particular division of the circuit was adopted to enable the r.f. and i.f. panel to be used in f.m. translators where the discriminator and a.f. sections are not required. The oscillator is in the form of a unit which can readily be removed from the r.f. chassis and has the general coding OS2/11 or OS2/12. Various versions of the oscillators are available, the differences depending on the frequencies covered and the output arrangements. Earlier receivers are fitted with oscillators Type OS2/11, but in future oscillator Type OS2/12E will be fitted except when a triple oscillator is required, when oscillators Type OS2/11C or D will be used.

The r.f. chassis is of silver-plated copper and all pre-set circuits are adjusted by air-dielectric trimmers. The a.f. amplifier includes two printed wiring cards.

General Description

The receiver is a superheterodyne type using the standard intermediate frequency of 10·7 Mc/s. The circuits of the mixer, i.f. stages and limiter are similar to those of a receiver developed in Research Department.*

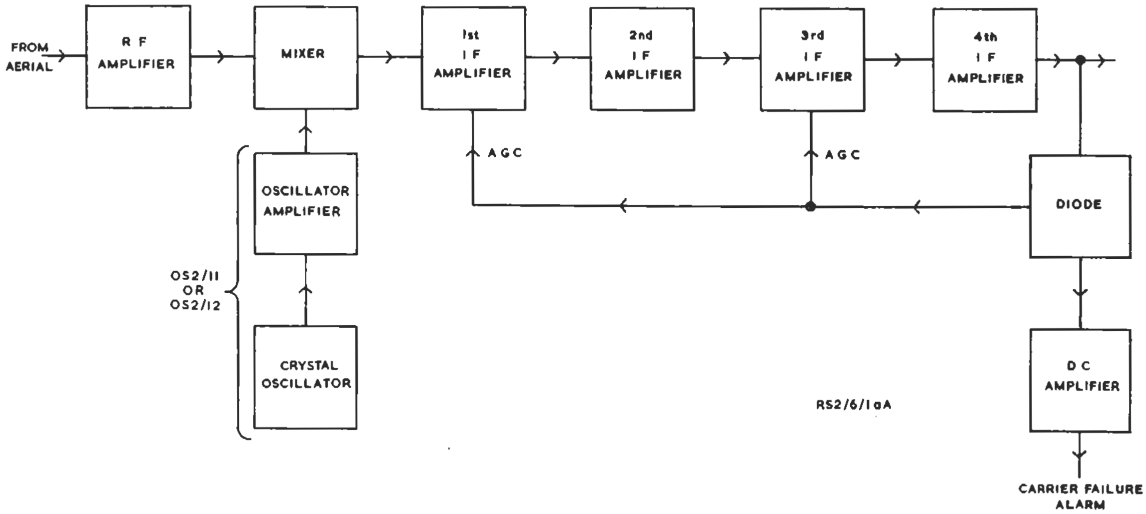
A block diagram of the receiver is given in Fig. 6.2. As shown there is a single r.f. stage and 5 i.f. stages. The diode mixer is fed from the oscillator via an oscillator-amplifier included in the OS2/11 or OS2/12. A diode at the output of the fourth i.f. amplifier supplies a.g.c. bias to the first and third i.f. amplifiers and also operates the carrier-failure relays via a d.c. amplifier. One set of back contacts of the carrier-failure relays is generally used to short-circuit the audio output, thus muting the receiver in the event of any failure. This is effected by means of straps in the bay wiring at the back of the cable-ended socket which engages with the receiver output plug. The remaining relay contacts may be used for other purposes, such as operating carrier-failure alarms.

The discriminator feeds two stages of a.f. amplification via a sensitivity control and variable negative feedback applied to these stages gives fine control of audio output level. A phase-splitter following these stages drives a push-pull output stage incorporating negative feedback.

Circuit Description (Figs. 15 and 16)

R.F. Stage

The r.f. stage is a common-emitter amplifier using a 2N502 transistor VT1. The co-axial r.f. input and the input to the base of the transistor are tapped down the inductors L1 and L2, the position of the tapping points being chosen to give good selectivity rather than maximum power transfer to the transistor. Particular emphasis is laid on selectivity throughout the design of the receiver because it must be capable of satisfactory operation near f.m. transmitters with carrier frequencies not greatly displaced from the received frequency. The mean collector current of VT1 is stabilised by the potential divider R1 R2, which impresses a particular steady potential on the base, and by the emitter resistor R4 which determines the emitter (and hence the collector) current.



Mixer Stage

Mixing is achieved by the two diodes MR1 and MR2. These are connected between the centre-tapped windings of L4 L5 and are driven in push-pull at the oscillator frequency, the primary winding of L4 being tuned to give maximum oscillator injection. The signal frequency input to the mixer is applied to the centre point of L4 secondary winding to minimise transfer of oscillator output to the r.f. stage and thus to the aerial. This precaution is necessary because transistors readily convey signals from their output to their input circuits. The wanted difference-frequency output from the mixer is selected by the i.f. input filter.

Oscillator OS2/11

The oscillator OS2/11A shown in the circuit diagram, Fig. 16, comprises a crystal-controlled oscillator stage VT1 and an r.f. amplifier VT2

*See Research Report T.078, 'An Experimental Transistor Receiver for V.H.F. Sound Broadcast Reception,' and R. Harvey, 'Transistor V.H.F./F.M. Receiver,' *Wireless World*, August, September and October 1960.

feeding three co-axial output sockets, only one of which is used in this receiver.

The oscillator has a tuned collector circuit L3 which is coupled by a winding on L3 to the emitter to give the positive feedback necessary for oscillation. Included in series with the coupling winding is the crystal XL1 which, in conjunction with C3, enables the frequency of oscillation to be adjusted to and maintained at the required value. The base of VT1 is effectively earthed by C1 and C5 to facilitate the application of a.g.c. and clearly therefore the emitter circuit cannot be earthed also. An undecoupled resistor R4 is hence included in series with the emitter bias components R5 C6. resistors R4 and R5. The pre-set component RV1 is adjusted to give the desired oscillation amplitude across the crystal.

The input to the r.f. amplifier VT2 is obtained from a winding on the transformer L3, and the mean collector current is stabilised by the potential divider R6 R7 and the emitter resistor R8. The circuit includes a transformer L5 with three windings each feeding a co-axial output socket. The transformer is tuned by C10 (and the output capacitance of VT2), resonance at the oscillator frequency being secured by adjustment of the primary inductance of L5.

Four types of oscillator unit OS2/11 exist. Units designated OS2/11A and OS2/11B have single crystals oscillating respectively below and above the signal frequency with a small variable capacitor providing fine tuning. Units designated OS2/11C and OS2/11D have three crystals, all combined in a single B7G valve-type envelope, and the variable capacitor is replaced by a 3-way switch which selects the crystals to give reception of the Home, Light and Third programmes. In units coded C the crystals oscillate below the signal frequency and in units coded D above signal frequency.

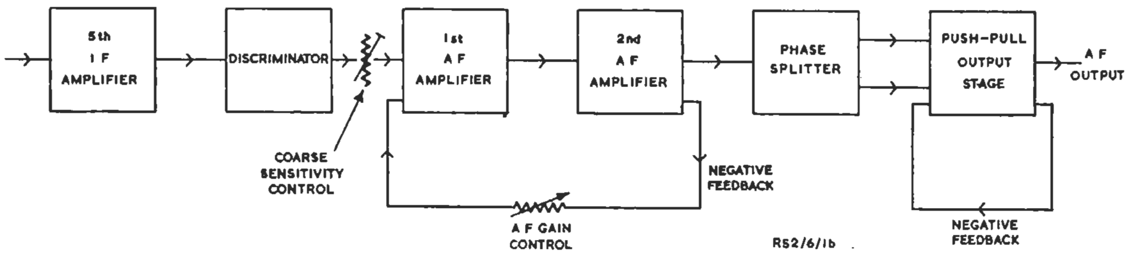


Fig. 6.2. Receivers RC5/2 and RC5/3: Block Diagram

The crystal is a type designed for good frequency stability over a wide temperature range, and although it is mounted in an oven the heater windings are not used. The oven is however heated in other applications of the oscillator, e.g., in translators.

The output amplitude of the oscillator is stabilised by an a.g.c. circuit. The r.f. signal at the collector is applied by C4 to the voltage-doubler rectifiers MR1 MR2. The rectifier output appears across the load resistor R3 and any r.f. ripple is removed by L2 and C5. The resulting smoothed output is applied as a positive-going control bias to the base of VT1, thus reducing any tendency for the oscillator output to depart from the desired amplitude.

The mean collector current of VT1 is determined by the potential divider R1 RV1 R2 which applies a voltage to the base (via R3) and the emitter

Oscillator OS2/12E

The oscillator OS2/12E, shown in Fig. 17, consists of a crystal controlled oscillator stage VT1, together with two buffer stages VT2 and VT3, the latter feeding the coaxial output socket.

The oscillatory circuit is derived from a basic

Colpitts type, with collector to emitter feedback through the series resonant crystal XL1. The circuit employed allows one side of the crystal to be earthed, a practical convenience; this arrangement involves an earth at the mid point of C3 and C4, and resistor R4 is therefore included to prevent a short-circuit on C3 and to allow voltages across C3 to be fed back to VT1 base via C1. Since VT1 operates in the common base mode, R2 is necessary to enable these feedback potentials to be applied to the base. R6 and C2 are decoupling components.

The crystal operates on the fifth harmonic, being forced into the correct mode by the tank circuit comprising L1, C3 and C4. The two components C5 and C6 together form a phasing capacitor for pulling the crystal to the correct frequency.

Inductor L2 tunes out the self capacitance of the crystal. The inductor is not placed directly across the crystal, because this would invite unwanted series resonance with C5 and C6 at some point in the tuning range of the receiver, i.e., 78 to 95 Mc/s.

As in the OS2/11, the crystal is mounted in an oven, but since its stability is inherently good the heater and control circuits are not used.

The Zener diode, ZD1, stabilises the operating point of VT1 base, the biasing current being obtained via R1.

Coupling from the oscillator stage VT1 to the first buffer stage VT2 is via the small capacitor C7 to the base of VT2. This latter transistor is connected as a common-emitter amplifier of low gain with negative feedback from R10.

VT2 is coupled to the output transistor VT3 via C11. VT3 operates as a common-base amplifier having low input impedance and high output impedance which avoids damping the output circuit and provides good isolation of the output from the input. A π output circuit C13, L3, C15 is used to match to the load, correct matching being obtained by variation of the ratio of L3 to C13. C14 is an isolating capacitor, R17 is a damping resistor, and the choke L4 provides a low resistance path for the collector current. The normal output impedance is 75 ohms, but small variations of load can be taken up by adjustment of C13 alone. C13 is accessible externally.

I.F. Input Filter

This filter is a combination of two rejector and three acceptor tuned circuits, designed to give a bandwidth of $\pm$150 kc/s with rejection points at $\pm$600 kc/s. This is another measure adopted in this receiver to provide additional selectivity.

First I.F. Amplifier

The first i.f. amplifier is an OC170 transistor connected as a common-emitter amplifier. The collector supply is applied to a tapping point on the collector inductor L10 to permit neutralising via the capacitor C15. A.G.C. is applied via the decoupling components R5 C16 and an undecoupled 22-ohm resistor R65 is included in the emitter circuit to reduce variations in transistor input resistance and capacitance due to a.g.c. action.

Second I.F. Stage

The second i.f. amplifier VT3 is an OC170 common-emitter stage stabilised by the potential divider R64 R8 and the emitter resistor R9. The coupling from the previous stage includes a band-pass filter L10 L11 coupled by the small series capacitor C24. VT3 is, of course, connected across only part of L11, the position of the tapping point being chosen to give the desired working value of *Q*. VT3 is neutralised by the capacitor C25.

Third I.F. Stage

The third i.f. amplifier VT4 is an OC170 common-emitter stage controlled from the a.g.c. line and fed via C30 from the single-tuned i.f. inductor L12. The amplifier includes a 22-ohm emitter resistor R66 and the circuit resembles that of the first i.f. amplifier.

Fourth I.F. Stage

The fourth i.f. amplifier VT5 is an OC170 common-emitter stage fed from VT4 via a double-tuned i.f. transformer similar to that used between VT2 and VT3. VT5 is stabilised by the potential divider R15 R16 and emitter resistor R17 and is neutralised by the capacitor C40.

Fifth I.F. Stage

The fifth i.f. amplifier VT6 is an OC170 common-emitter stage stabilised by the potential divider R21 R22 and the emitter resister R23. It is fed via the capacitor C46 from a coupling winding on the i.f. tuned circuit L15.

Automatic Gain Control

Under certain conditions, when severely overloaded, transistor tuned stages can develop negative input resistances. This is avoided in the present receiver by applying a.g.c. to the first and third i.f. stages. The control voltage is obtained by rectifying the i.f. signal at the secondary winding of L15 by means of the diode MR3; this circuit has the incidental merit of reducing to some extent any amplitude-modulated component present in the i.f. signal across L15.

The a.g.c. voltage is generated across the diode load circuit R19 C47. R19 and C47 are not returned to the earth line but to a source of stabilised voltage 4·25 volts negative with respect to earth. The potential is obtained from R20 and the Zener diode ZD1, the type of diode being chosen to give the required value of stabilised voltage. Thus the potential on the a.g.c. line *C* is —4·25 volts (with respect to earth) in the absence of an input to the receiver and goes positive to an extent dependent on the magnitude of the r.f. input to the receiver. This voltage is returned to the bases of the first and third i.f. transistors, to reduce their emitter currents and their gain.

The stabilised voltage across the Zener diode ZD1 is fed to the carrier alarm circuit via *D*.

Limiter

The receiver includes a Seeley-Foster discriminator, which has no inherent a.m. rejection, and therefore a separate limiter stage is incorporated. This includes the diode MR5 which is fed from the secondary winding of inductor L16. The diode is returned to the potential divider R25 R26, which applies a reverse bias of approximately 1·5 volts. Thus the diode conducts on all signals whose peak value exceeds 1·5 volts and the input to the discriminator is effectively stabilised at this value.

Discriminator

The Seeley-Foster discriminator is fed from the limiter via a small variable capacitor C56 which provides the required high source impedance. The discriminator circuit is somewhat unconventional and indeed at first sight might be mistaken for a ratio detector. This particular arrangement was chosen to give a low output impedance suitable for transformer coupling to the a.f. amplifier. Two shunt-fed diodes MR6 and MR7 have load resistors R27, R28 and R29 so arranged that R29 carries current from both diodes in opposite directions. The a.f. output is thus developed across R29 (with a value of 15 kilohms only, although each diode has an effective load resistance exceeding 100 kilohms). R30 and C64 provide de-emphasis.

Carrier Failure Relays

The base of transistor VT14 is connected to the a.g.c. line *C* via the 100-kilohm resistor R58 and the emitter is fed via the potential divider RV1 from the —4·5 volt line *D*. RV1 is so adjusted that when the carrier is present (making *C* positive with respect to *D*) VT14 is cut off. There is then no collector current due to VT14 in the 100-kilohm resistor R71. However this resistor also supplies the base bias to VT16, an npn transistor, and with VT14 cut off the base of VT16 is at the same potential as the emitter; VT16 therefore also cuts off. This removes the current input to the base of VT17, cutting off its collector current; with no current in R59 due to VT17, the base of VT15 goes negative with respect to the emitter and VT15 conducts, causing the relays RLA and RLB to operate.

If the carrier input to the receiver disappears, the a.g.c. line *C* takes up the same potential as *D*. The emitter of VT14 is then positive with respect to its base and VT14 conducts. Its collector current, in passing through R71 causes the potential of VT16 base to go positive with respect to the emitter and VT16 conducts. Under these conditions, the low resistance of the base/emitter junction of VT16 appears across R71 and is in effect, the load for VT14. VT16 is now conducting and, as its collector current is also the base current for VT17, this transistor also conducts, the current being limited by R72. With VT17 conductive, R73 is effectively connected to ground via the base/emitter junction of VT17 and forms with R59 a potential divider across the supply. This potential divider carries VT15 base voltage towards the positive line, passing the emitter voltage which is locked to —12 volts. VT15 then cuts off, de-energising RLA and RLB. By adjustment of RV1 the relays can be set to operate for any amplitude of receiver input signal up to 1 mV. The relays will also be de-energised if for any reason the receiver fails.

The relays release as a result of VT14 taking current through R71, and the leakage current of VT14 must be so low that it cannot cause the relays to release even at the highest ambient temperatures. This is ensured by using a silicon transistor for VT14, this type having particularly low leakage currents.

A.F. Gain Stages

VT7 collector is directly coupled to VT8 base and considerable negative feedback is applied from VT8 emitter circuit to VT7 base. The d.c. component of this feedback reduces the zero-frequency gain of VT7 and VT8 to a very low value, thus stabilising the mean component of the collector currents against temperature variations.

Most of the d.c. feedback is provided by R37, R39 and R40, but these resistors are decoupled by the large capacitors C67 and C70 to prevent signal-frequency feedback. Signal-frequency feedback occurs only via the undecoupled resistor R41 and the variable attenuator AT1. The effective resistance of this network can be varied by means of AT1 to provide fine gain adjustment.

Phase Splitter Stage

The output at VT8 collector is applied via C69 to the base of VT9, the mean emitter current of which is stabilised by the potential divider R42, R43 and the emitter resistor R45. VT9 is a phase-splitter, one half of the output stage being fed from its collector circuit and the other half from the emitter circuit. A similar circuit is used in valve amplifiers to feed push-pull stages, and in such circuits equal-value anode and cathode resistors must be used to supply equal signal voltages to the two halves of the following stage. The requirements of a phase-splitter to supply a transistor push-pull stage are somewhat different; here we need to feed equal *currents* to the following stage and to obtain this each half of the push-pull stage should be fed from an equal source resistance. The source resistance for VT10 is equal to the parallel resistance of R44 (3·9 kilohms), R49 (10 kilohms) and R50 (4·7 kilohms); the output resistance of VT9 collector circuit is too large to have a significant affect on the source resistance. The source resistance for VT11 is similarly the parallel resistance of R48 (4·7 kilohms), R47 (10 kilohms) and a resistance composed of R46 and the output (emitter) resistance of VT9. For equality of source resistances it follows that R46 and VT9 output resistance should total 3·9 kilohms. VT9 has a source resistance of the order of 10 kilohms and its output resistance is approximately 300 ohms. Thus R46 should have a value of 3·9 kilohms less 300 ohms, i.e., 3·6 kilohms.

A.F. Output Stage

Each side of the push-pull output stage consists of two transistors direct-coupled in the so-called Darlington or super-alpha circuit. In this circuit arrangement the emitter of the driver transistor (e.g., VT10) is directly connected to the base of the following transistor (VT12), and the two collectors are also bonded. This is a convenient way of connecting two transistors in cascade, no coupling components being required. The combination can be regarded as a single transistor with a very high current amplification factor (approximately equal to the product of the individual amplification factors) and a high input resistance (probably of the order of 20 kilohms).

Voltage negative feedback is applied to the emitters of VT12 and VT13 by windings on the output transformer. R51 is an emitter resistor which in conjunction with the potential divider R49 R50 determines the steady current in VT10 and VT12. Similarly R47, R48 and R52 determine the steady current in VT11 and VT13.

Power Supply Circuit: RC5/2

This is conventional and includes a full-wave bridge rectifier comprising MR8 to MR11 and a π-section smoothing circuit L19 C75A C75B. The d.c. output is fed to the receiver r.f. chassis through the Zener diode ZD2. The current through the diode generates a voltage across it which is practically independent of the current, and is used to reduce variations in the r.f. chassis supply voltage with changes in load.

Power Supply Circuit: RC5/3

The power supply circuit of the RC5/3 is illustrated in Fig. 16 and differs from that of the RC5/2 in having an additional facility for automatic change-over to a battery supply in the event of a failure of the mains supply.

This facility is provided by relay RLC which is connected across the smoothed d.c. output of the mains power supply circuit. When the mains supply is available RLC is energised and contact RLC1 connects the smoothed output of the supply circuit to the receiver. If the mains supply fails RLC is de-energised and contact RLC1 connects the receiver to the 24-volt battery.

A Zener diode ZD3 and a 330-ohm resistor are included in series with the relay winding. During normal operation of the receiver from the mains the voltage across ZD3 is well above its reference voltage and the diode is of low resistance. The current in the circuit is then limited by the resistor to a value suitable for energising the relay. If the mains fail however the voltage delivered by the mains supply unit to the relay winding circuit falls. When the voltage across ZD3 reaches the reference voltage, the diode resistance becomes suddenly very high and the current in the circuit collapses abruptly, de-energising the relay and giving a more rapid change over to battery operation than if no diode were present.

Performance

The overall frequency response of the receiver is within ±2 dB of a 50-μsec de-emphasis curve (given in Fig. 3) from 40 c/s to 20 kc/s.

For an input modulated by a single frequency to a deviation of ±75 kc/s and an output of +12 dB into 600 ohms any individual harmonic distortion in the audio output is less than 0·33 per cent (−50 dB). The total harmonic distortion is less than 0·5 per cent (−46 dB).

For an input of 30 μV the signal/noise ratio is better than 40 dB, for 100 μV input it is better than 46 dB and for 1 mV input it is better than 48 dB.

Installation, and Adjustment of A.F. Output Volume

1. Set the primary tappings on the mains transformer to the local mains voltage, and power the receiver.
2. Connect the aerial feeder to the receiver.
3. Set the crystal selector switch (if any) to select the desired transmission.
4. Connect the 600-ohm input of a PPM/6 to the receiver output (pins 1 and 2 on the 8-pole plug) and adjust the two gain controls to give zero level output when the transmitter is radiating line-up tone before programme transmission. Both gain controls have approximately 10-dB range but the coarse control has only two positions (labelled *high* and *low*) and the fine control has 10 steps.
   Alternatively, a PPM/2 or a TPM/3 can be used for this measurement, provided that a 600-ohm resistor is connected across the receiver output sockets.

Adjustment of Carrier Failure Relays

Connect the output of a signal generator to the receiver input, and adjust the generator to give an unmodulated output at the carrier frequency to which the receiver is tuned. Connect an Avometer (switched to its resistance-measuring range) between tags 2 and 3 of relay RLA. Connect a second Avometer, similarly switched, between tags 2 and 3 of relay RLB. Adjust the carrier failure alarm control RV1 for minimum sensitivity and measure the receiver input at which the two relays just operate (indicated by readings on both Avometers): the input should exceed 2 mV.

Now reduce the receiver input until both relays just release; the reduction of the input should be less than 8 dB (corresponding to an input ratio of 2·5 : 1).

Set the signal generator to 1 μV output and adjust RV1 for maximum sensitivity. RLA and RLB should both operate. Adjust RV1 until both relays just release. Increase the receiver input until both relays just operate again. The signal generator should now indicate a receiver input of less than 40 μV. Check that when the receiver input is reduced by 8 dB (to 16 μV) the relays again release.

Finally set RV1 so that the relays just release with a receiver input of 40 μV. Connect an Avometer between point *Z* and chassis and confirm that operation and release of RLA and RLB does not significantly affect the Avometer reading.

Maintenance

The power supply and a.f. amplifier of the receiver should be maintained at the site but, if a fault develops elsewhere in the receiver, Equipment Department should be contacted (preferably by telephone) and a request should be made for a replacement spare receiver of the correct type and channel, it being important to ensure that the spare receiver includes the correct type of oscillator unit and is fitted with the correct type of mounting brackets. This receiver should be installed and the faulty receiver sent to Equipment Department for attention. When the original receiver is returned, the replacement spare should be sent back to Equipment Department.

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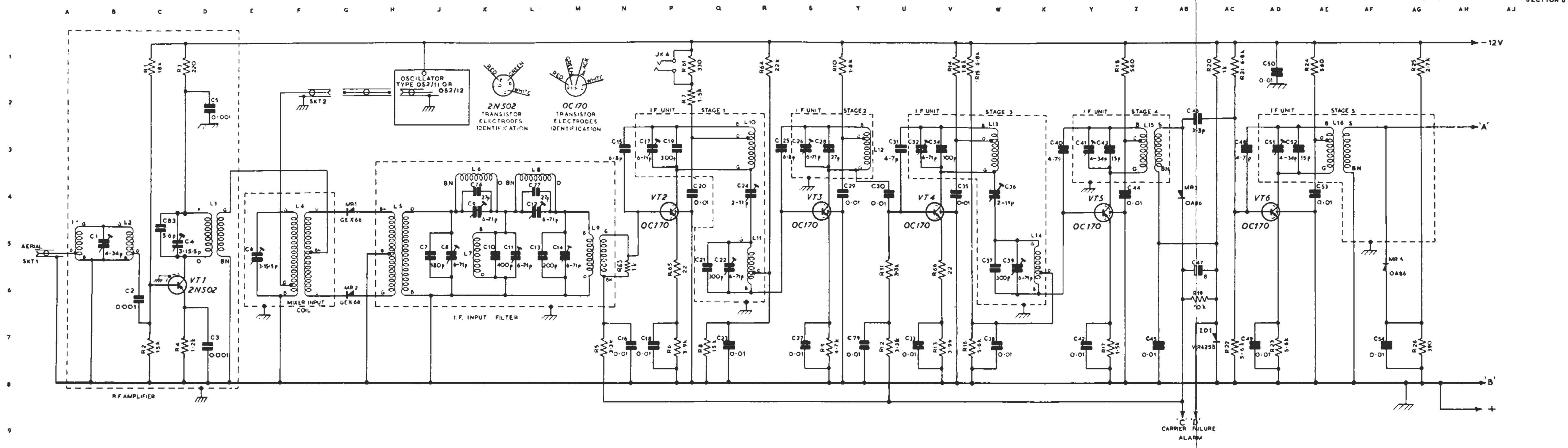
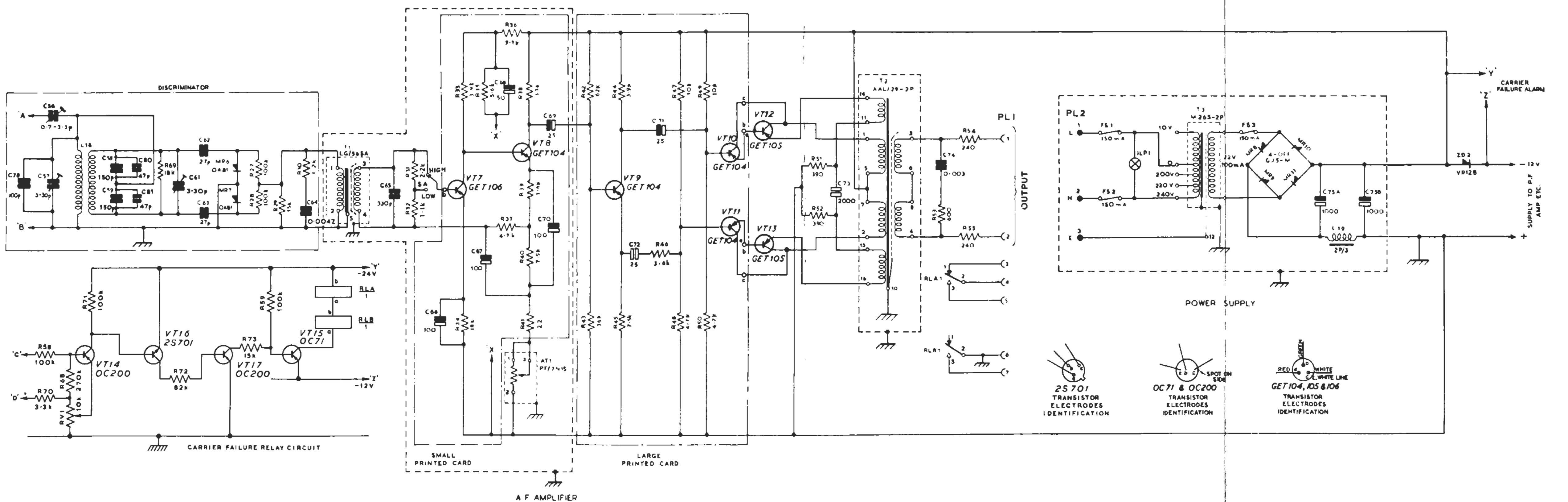


RECEIVERS RC5/2 & RC5/3: R F & I F AMPLIFIER CIRCUIT



RECEIVER RC5/2: DISCRIMINATOR A F AMPLIFIER & POWER SUPPLY CIRCUIT

FIG 16
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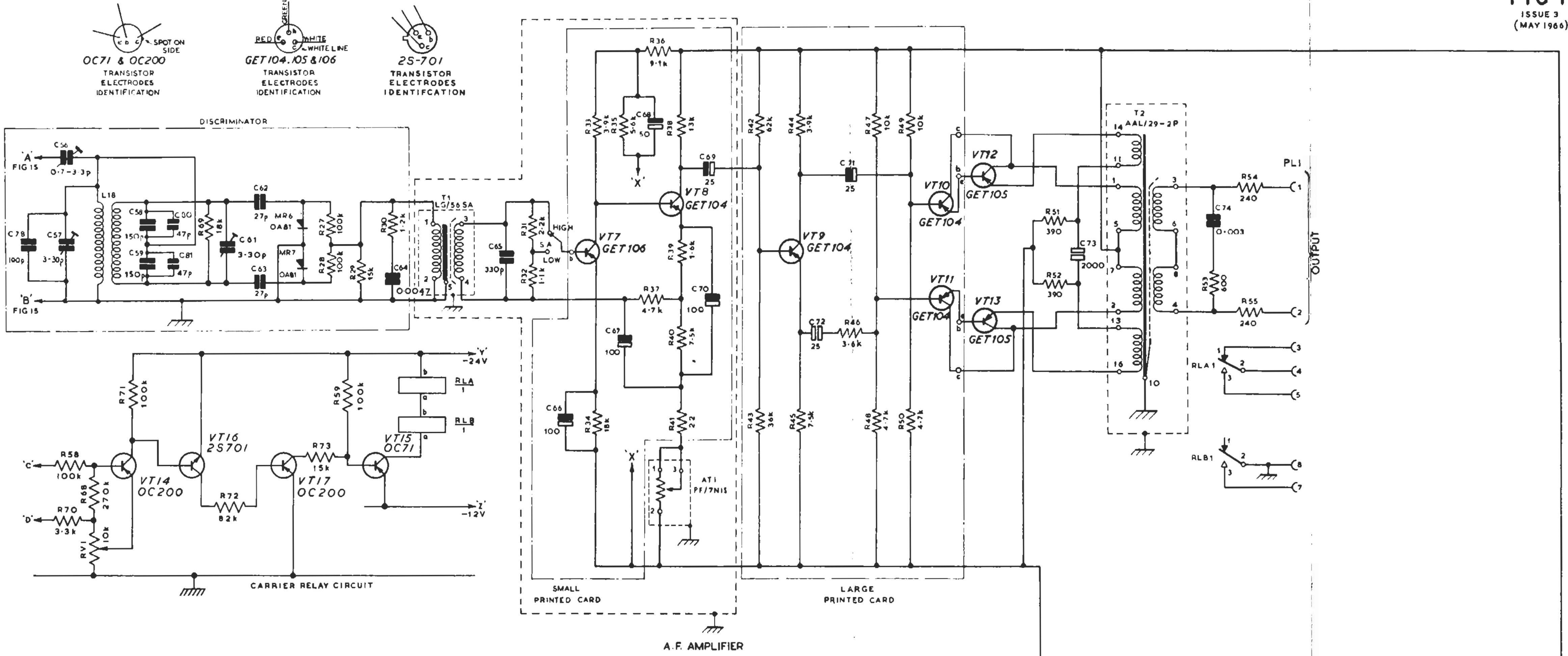
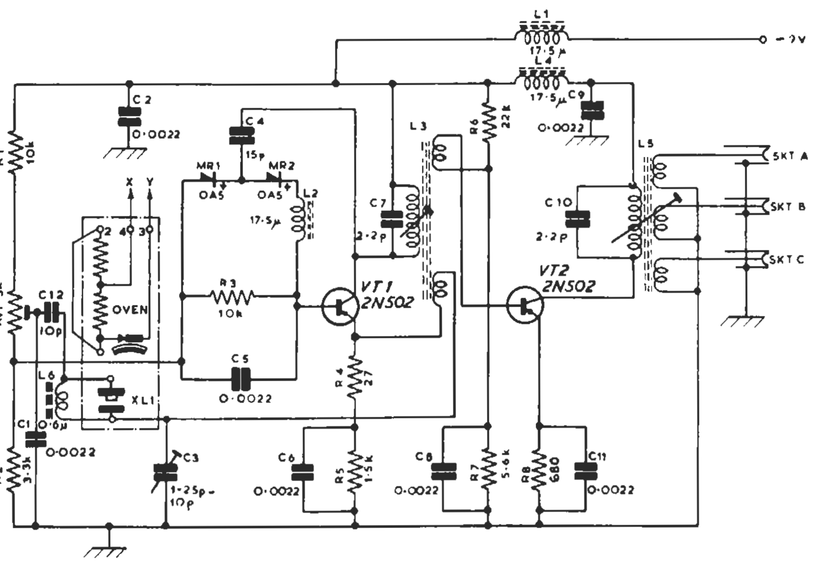
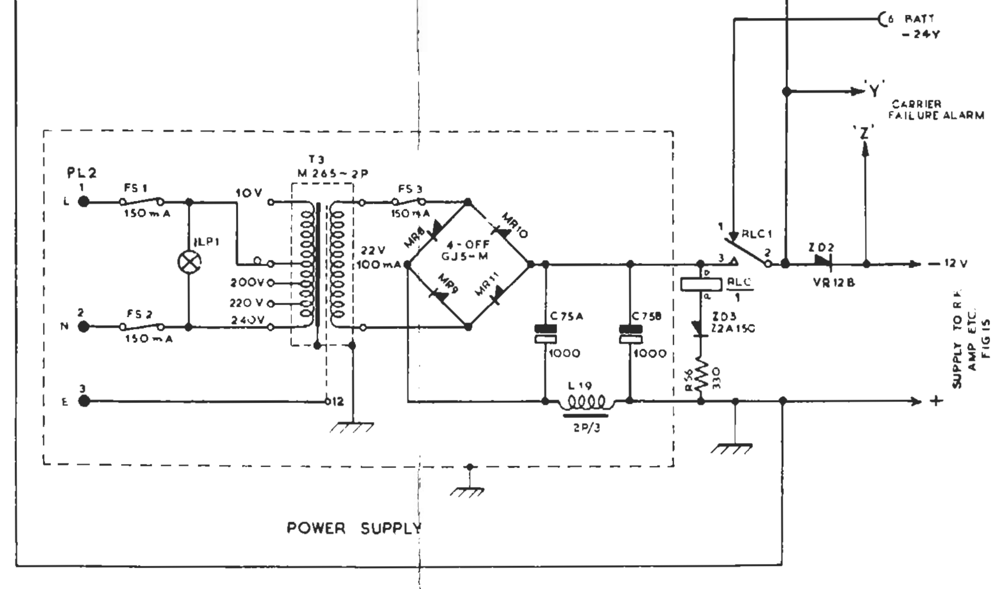


RECEIVER RC5/3: DISCRIMINATOR & A F AMPLIFIER CIRCUIT



OSCILLATOR OS2/11A CIRCUIT



RECEIVER RC5/3: POWER SUPPLY CIRCUIT