Simple SSB transceiver

SL600 VERSION

This transceiver, shown in Fig.63, consists of a single conversion superhet receiver with a 9MHz IF and a very efficient audio-derived AGC system, and a filter type SSB generator, also working at 9MHz. Audio AGC in the modulator path gives constant level output. The transmitter and receiver are arranged so that no signal switching is required between transmit and receive, and the RF components are common to both.

The RF input is direct to an Anzac MD-108 (or similar) hot carrier diode ring mixer. This has 50 ohm ports and is also driven by the local oscillator, at about +7dBm (500mV). The output is connected via a 3: 1 step-up transformer to a 9MHz crystal filter. This filter has the 2.4kHz bandwidth required for SSB and a 90dB stopband. Filters with 60dB stopband can be used, but additional filters may be required at low local oscillator frequencies to keep the local oscillator signal out of the IF amplifier (and the overall receiver performance will, of course, be degraded).

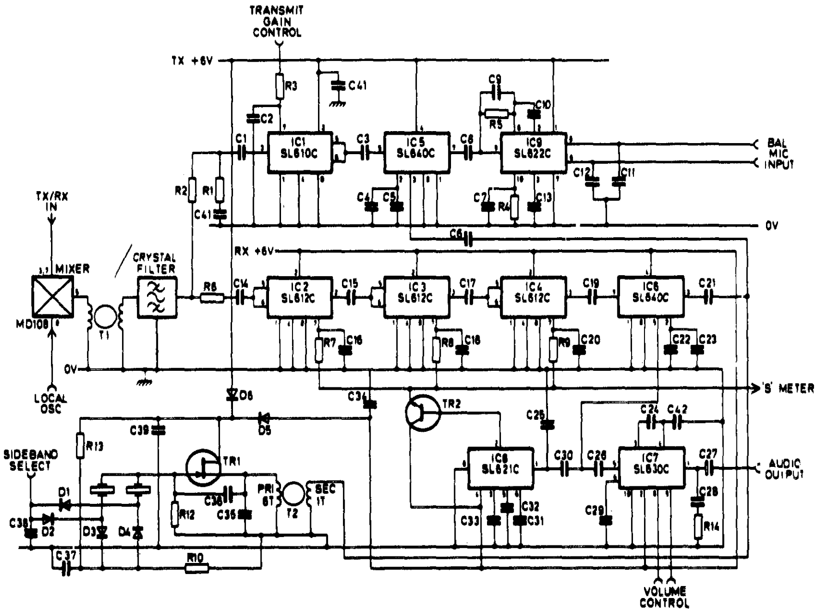


Fig. 63 Simple SSB transceiver circuit diagram

The filter used, an SEI QC1246AX or a KVG XF9-B, has a terminating impedance of 500 ohms, but only within the passband of the filter. At frequencies outside the passband it may be very different, which means that the impedance that the filter presents to the diode ring mixer via the transformer will vary from 50 ohms. Such a mismatch will degrade the cross-modulation and carrier leak performance of the diode ring. However, it was decided on balance, that it was better to tolerate such degradation — which is not excessive — than to complicate the design by incorporating a broadband impedance match (which would probably not be bidirectional and hence would have to be switched between transmit and receive).

The present design allows the same arrangement to operate in opposite directions during receive and transmit without any switching. On the other side of the crystal filter the transmit and receive signal paths diverge but are still not switched.

The Receiver

The incoming RF signal is mixed with the local oscillator in the mixer described above and then passes through an SSB bandwidth 9MHz crystal filter. It is then amplified by three cascaded SL612C IF amplifiers, IC2, 3 and 4. These amplifiers are untuned and since the strip has a maximum gain of 102dB careful attention must be paid both to noise and to stability. The SL612C has a 3dB noise figure which means that the broadband noise at the output of the three-stage strip is about 10mV RMS. This is not sufficient to affect a product detector, which is only concerned with the component within a few kHz of the BFO frequency, but would cause trouble if a diode detector were to be used.

A broadband amplifier with 102dB gain is a likely candidate for stability problems. The three-stage strip used in this receiver is less liable to power supply feedback than most since the SL612C has internal supply decoupling. Nevertheless it must be carefully laid out to minimise earth loops and input/output feedback. The simplest way to do this is to use a double-sided printed circuit board with the components side a continuous ground plane to which all earth connections are made. If this is done the layout on the conductor side of the board is not very critical but if single-sided board is used with the earth conductors on the same side as the other conductors then it does become so. The design of board in Fig. 64 is the most stable layout yet developed for such strips on single-sided board, and it is strongly recommended that it be copied exactly.

There are two other possible causes of instability in this transceiver: inadequate supply switching and inadequate supply decoupling. Since the only on-board transmit/receive switching is by means of power switching it is essential that the transmit supply be not only isolated but earthed during receive, and vice versa. Both supplies should also be well decoupled at RF.

The IF strip has AGC applied to it by an SL621C audio AGC circuit, IC8.AGC is applied via an emitter follower, which has the effect of reducing the AGC range of each SL612C by 0.7V. The overall AGC range could be reduced to less than 90dB were only two SL612Cs to have AGC applied to them. AGC is therefore applied to all three to give 130dB, of which the usable AGC range is about 115dB.

The IF output is applied to an SL640C double-balanced modulator (IC6), used here as a product detector. When AGC is operating, the audio output of the detector is about 10mV RMS. The audio is fed to IC7, an SL630C audio amplifier which has a voltage gain control. The SL630C can supply up to about 60mW to headphones, to a small loudspeaker or to an external amplifier.

The detected audio also goes to the SL621C audio AGC system (IC8). This has an ideal characteristic for SSB reception. It operates from the receiver audio, not from RF, and it has fast attack and fast decay unless a signal disappears altogether — as in speech pauses — when it does not decay at all for a second and then, if the signal has not reappeared, decays quickly. This enables it to track rising or fading signals but prevents it overloading after each brief speech pause. The circuit also incorporates very fast AGC action to suppress brief noise bursts.

An FET oscillator is used to supply carrier to the product detector and to the double-balanced modulator in the transmitter. The voltage applied to the 'sideband select' terminal determines which crystal is used — upper or lower sideband — but the terminal must not be left unconnected: it must either be connected to +6V or to earth. The oscillator is supplied via diodes from both the transmit and receive lines so that it continues to operate on transmit or receive.

The most basic receiver does not have an 'S' meter but if one is required it may be connected to the emitter of the AGC buffer transistor. It should consist of a moving coil meter connected in series with a resistor such that FSD corresponds to 2.5V and three forward biased silicon diodes. This 'S' Meter circuit has a rather compressed scale for signals more than 40dB above the AGC threshold. If a more linear scale is necessary the more complex system described in the multimode transceiver should be used.

This receiver has a sensitivity of 1.0 microvolts for 10dB S/N. This means that at HF with adequate antennas no RF amplifier is required since atmospheric noise will limit system performance. At higher frequencies, or in systems where small antennas are used, RF gain may be necessary to prevent the performance being gain-limited rather than noise limited. Such amplifiers increase gain but degrade intermodulation performance. In general, without the RF amplifier, the receiver will tolerate about 200mV of adjacent channel signal on the mixer without significant intermodulation. This is, of course, a property of the mixer rather than of the rest of the circuit, although the filter characteristics are also involved.

The Transmitter

The transmitter uses the standard filter method of generating SSB. Audio from the microphone is fed to an SL622C microphone amplifier (IC9), which has AGC giving a constant 100mV output over 60dB of input. The AGC ensures an almost constant output from the transmitter, but can be inconvenient in noisy environments when the transmitter will give full modulation on noise in the absence of a speech input. Such noise modulation is avoided by the addition of a single extra resistor (R5, between pins 8 and 9 of the SL622C) which reduces the dynamic range of the AGC.

The constant-level audio from IC9 is applied to the signal input of an SL640C double-balanced modulator (IC5). The output of the FET carrier oscillator is applied to the carrier input of IC5 and a double sideband suppressed carrier signal appears at its output. Carrier suppression is of the order of 40dB.

This DSB signal is amplified in an SL610C (ICI). The AGC pin of ICI is brought out from the board and may be used either to preset the system gain or as an ALC connection. The amplified DSB from IC1 is then passed through the crystal filter, which removes one sideband, leaving SSB. The SSB is mixed to the final transmitter frequency in the diode ring mixer and then goes to a linear amplifier which raises it to the transmitter output level. The output from the diode ring is, of course. lower than the input to the filter and is about 100mV or less into 50 ohms.

The output of IC5 and the input of the first SL612C (IC2) are connected to the same point on the filter via resistors. R6 is merely a buffer resistor but R2 and R1 set the impedance which the filter sees in operation. This varies from 480 ohms on transmit to about 530 ohms on receive, but this small variation does not affect filter performance. The loading effects of a turned-off SL612C during transmission and a turned-off SL610C during reception are similarly insignificant.

The transmitter output (at the diode ring) consists of an SSB signal with carrier below — 55dB and opposite sideband below — 60dB, provided that the carrier oscillator is at the correct frequency. The degree of off-channel spurious signals depends on the crystal filter used: 90dB stopband type gives excellent performance but a cheaper one can sometimes cause trouble.

The Transceiver

The transceiver board needs few extra sub-systems to make a complete transceiver. They are: a power supply, microphone, volume control and loudspeaker and also a filter, local oscillator and linear amplifier. These are connected as shown in Fig. 65.

Much of the performance of the final system will depend upon the standard of design of the local oscillator, pre-selector, RF amplifier (if used) and linear amplifier, but the performance of the transceiver board itself is excellent. The Anzac MD-108 mixer used is capable of the required performance between 10kHz and 500MHz. If other diode rings were used the transceiver might be used over an even wider range. Its power consumption is about 400mW on either transmit or receive.

The most attractive feature of this transceiver, despite its high performance, is its simplicity. It uses only 80 components and contains no tuned circuits or other components requiring adjustment. It was designed for two purposes: (a) to demonstrate the usefulness and versatility of the SL600 Series in SSB applications and (b) as a ready-engineered SSB transceiver suitable for those inexperienced in SSB design. It is capable of giving good performance but can be constructed and commissioned by relatively inexperienced personnel.

Physical Construction

The board and component layouts are shown in Fig. 64. The board is single-sided and there are two jumper links on it carrying power supplies. As mentioned above the layout on a single-sided board carrying such a high gain broadband IF strip is critical and it should not be changed. All passive component leads should be as short as possible and integrated circuits should not be mounted more than 6mm above the board.

The two transformers T1 and T2 are both wound on small toroids of high frequency ferrite. The exact size and material are not important but the material must be low loss up to at least 45MHz and it is essential that it has a linear B/H characteristic, otherwise it will cause intermodulation at the receiver

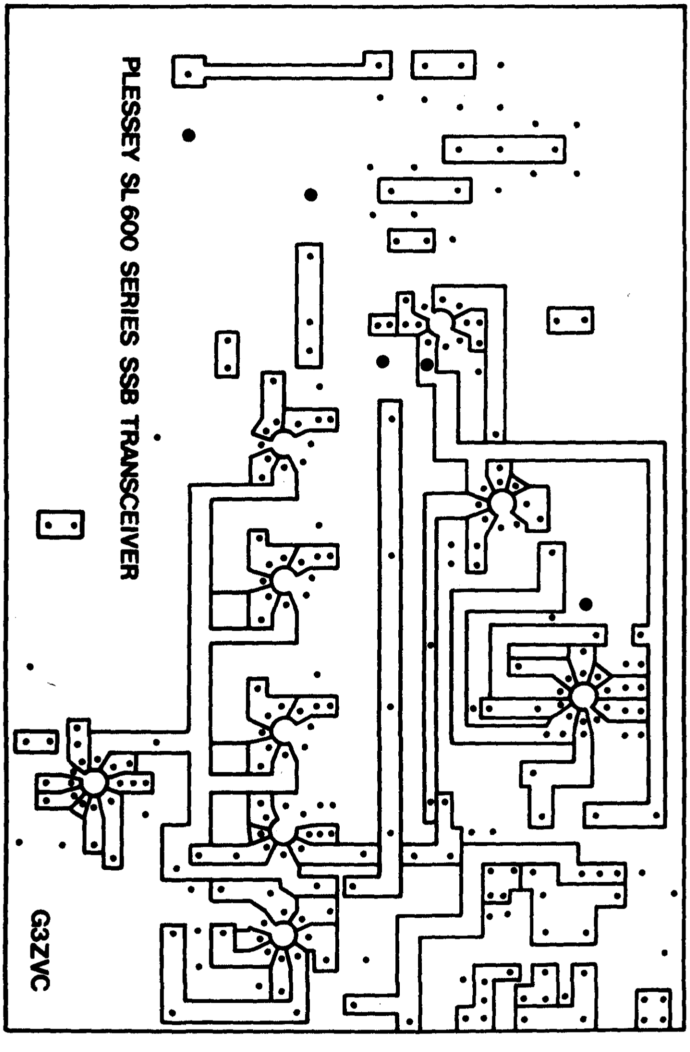


Fig. 64a Copper side of PCB for simple SSB transceiver

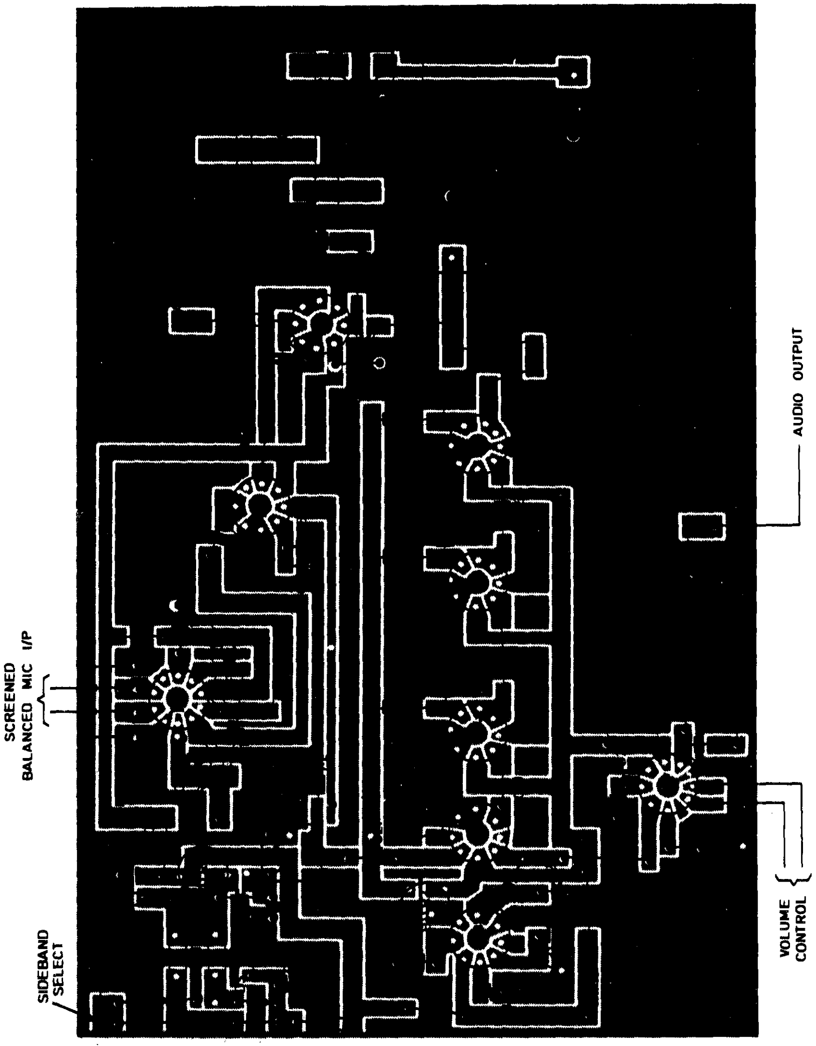


Fig. 64b PCB for simple SSB transceiver

input. T2 is a simple transformer with a six-turn primary and a single turn secondary but T1 is more complex. T1 is made from four 5cm lengths of 26 SWG (0.46mm dia.) enamelled copper wire twisted together. The length of twist is used to wind two turns on the toroid and the ends are separated. Three lengths are then connected in series in the same sense to form the filter winding and the last length is used as the diode ring winding.

There are few other constructional details that need mentioning, but if a receiver without a transmitter is required one may be built by omitting the three transmitting integrated circuits (SL610C, SL622C and the SL640C) between them), R1 to R5 inclusive and C1 to C13 and C40. To preserve the filter impedance match a 500 ohm resistor should be connected from the filter side of R6 to earth.

Component	**Value**	**Rating**	**Type**
R1	100	1/8 W	Hi-Stab.
R2	430	1/8 W	Hi-Stab.
R3	100	1/8 W	Hi-Stab.
R4	680K	1/8 W	Hi-Stab.
R5	1K	1/8 W	Hi-Stab.
R6	50	1/8 W	Hi-Stab.
R7-R9	100	1/8 W	Hi-Stab.
R10	330	1/8 W	Hi-Stab.
R11	10	1/8 W	Hi-Stab.
R12	100K	1/8 W	Hi-Stab.
R13	330	1/8 W	Hi-Stab.
D1-D6			1N4148 Or similar devices
TR1			2N3819
TR2			2N706
T1, T2	See text.		
Mixer	Anzac MD-108		
Crystals	9.0015 MHz & 8.9985 MHz		Parallel (30p) resonant
IC1	SL610C		
IC2-IC4	SL612C		
IC5-IC6	SL640C		
IC7	SL630C		
IC8	SL621C		
IC9	SL622C		
C1-C4	1nF	50V	Weecon (Min Ceramic)
C5	10µF	6.3V	Min. Tantalum
C6	100pF	50	Ceramic
C7	47µF	6.3V	Min. Tantalum
C8	10µF	6.3V	Min. Tantalum
C9	4.7nF	50V	Weecon
C10	2µF	6.3V	Min. Tantalum
C11-C12	1nF	50V	Weecon
C13	100nF	50V	Weecon
C14-C15	100pF	50V	Ceramic
C16	4.7nF	50V	Weecon

Table 4 Components list for the Simple SSB Transceiver (Fig. 63)

Component	Value	Rating	Type
C17	100pF	50V	Ceramic
C18	4.7nF	50V	Weecon
C19	100pF	50V	Ceramic
C20	4.7nF	50V	Weecon
C21	100pF	50V	Ceramic
C22	1nF	50V	Weecon
C23	10µF	6.3V	Min. Tantalum
C24	4.7nF	50V	Weecon
C25	100nF	50V	Weecon
C26	10µF	6.3V	Min. Tantalum
C27	100µF	6.3V	Min. Tantalum
C28	10nF	50V	Weecon
C29	1nF	50V	Weecon
C30	1µF	6.3V	Min. Tantalum
C31	100µF	6.3V	Min. Tantalum
C32	47µF	6.3V	Min. Tantalum
C33	100µF	6.3V	Min. Tantalum
C34	400µF	16V	Min. Al. Elect.
C35-C36	68pF	50V	Ceramic
C37-C38	10nF	50V	Weecon
C39-C41	100nF	50V	Weecon
C42	100pF	50V	Ceramic

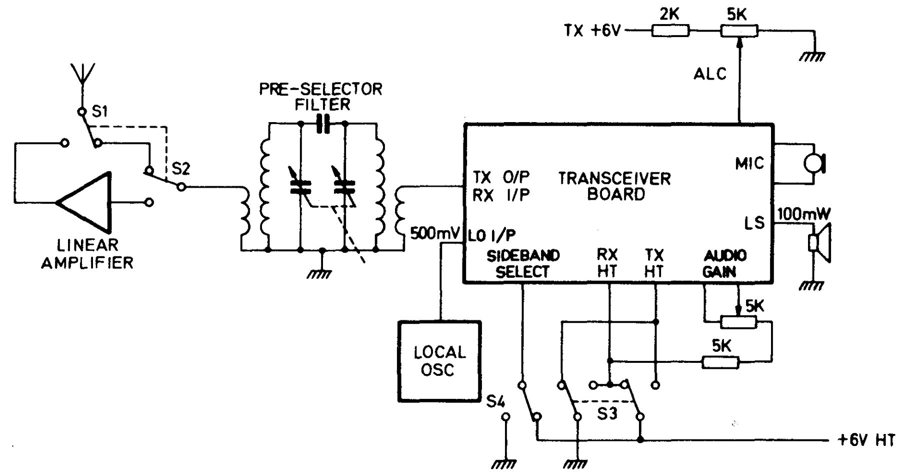
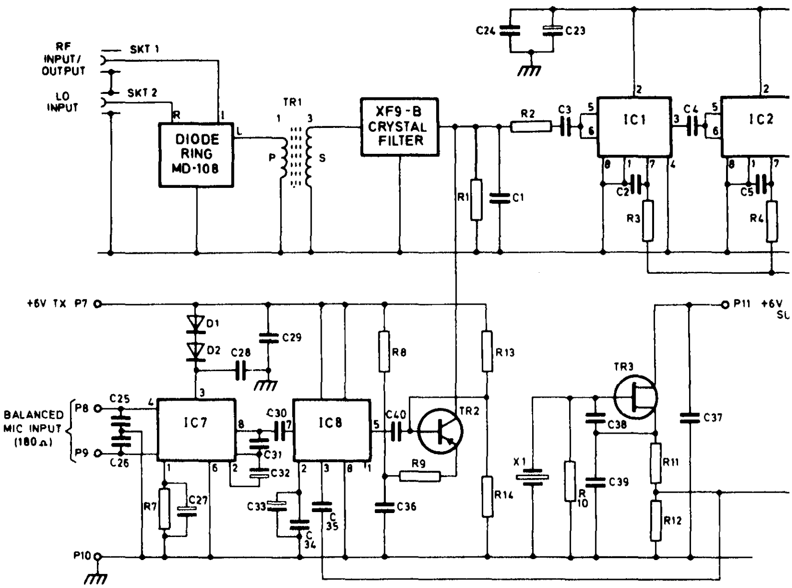


Fig. 65 Block diagram of complete SSB transceiver

SL1600 VERSION OF THE SSB TRANSCEIVER

Figs. 66 and 67 show the circuit diagram and board layout respectively of a version of the SSB transceiver which has been designed to use the SL1600 devices. In addition to the use of the SL1600 series circuits a single PNP transistor is used in place of the SL610 in the transmitter and has only one BFO crystal on the board.



Resistor values are in ohms, capacitor values in microfarads unless otherwise stated.

IC1	SL1612C
IC2	SL1612C
IC3	SL1612C
IC4	SL1640C
IC5	SL1621C
IC6	SL1630C
IC7	SL1622C
IC8	SL1640C
TR1	Si NPN - 2N706, BC108 etc.
TR2	High frequency Si PND - 2N3906 etc.
TR3	High frequency N-channel FET - 2N3819, BF244B etc.
D1 D2	Almost any small Si diode - 1N914 etc.

Diode ring - ANZAC MD-108

Filter - KVG Xf9-B

X1	30pF parallel resonant 8998 5kHz in HC18 or HC25
T1	P 2 turns 2 hole S 5 turns ferrite bead
R1	470
R2	47
R3	120
R4	120
R5	120
R6	10
R7	470k
R8	100
R9	100
R10	100k
R11	1k
R12	Select to give 200mV rms at pin 4 of IC4
R13	2.7k
R14	8.2k

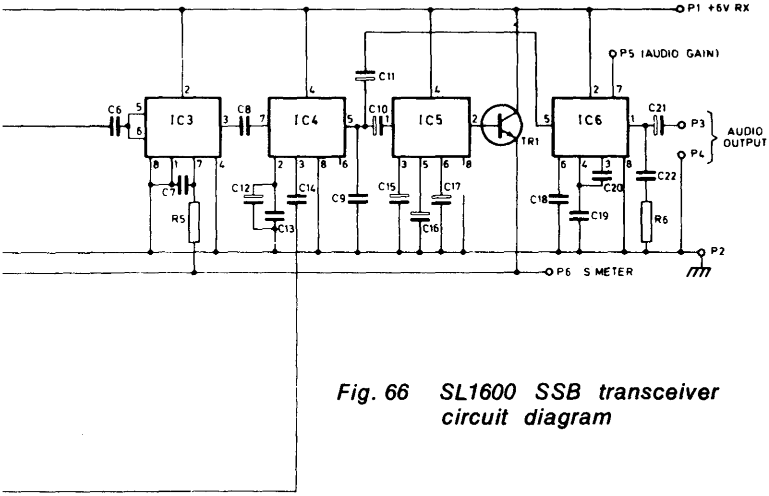


Fig. 66 SL1600 SSB transceiver circuit diagram

16V receive supply
Ground
Audio output
Audio ground
Audio gain control
'S' meter (if used)
+6V transmit supply
} Balanced microphone input (180 ohms)
0 Ground
1 +6V common supply

resistors 5 per cent $\frac{1}{4}$W

capacitors miniature ceramic ;ept ones marked TANT which are ad tantalum.

22pF	C31	5000pF
0.01	C32	2 TANT
1000pF	C33	10 TANT
1000pF	C34	0.1
0.01	C35	1000pF
1000pF	C36	0.1

C7	0.01
C8	1000pF
C9	0.1
C10	1 TANT
C11	1 TANT
C12	10 TANT
C13	0.1
C14	1000pF
C15	100 TANT
C16	47 TANT
C17	100 TANT
C18	1000pF
C19	100pF
C20	5000pF
C21	100 TANT
C22	0.01pF
C23	100 TANT
C24	0.1pF
C25	1000pF
C26	1000pF
C27	47 TANT
C28	0.1
C29	0.1pF
C30	1 TANT

C37	0.1
C38	56pF
C39	56pF
C40	0.1

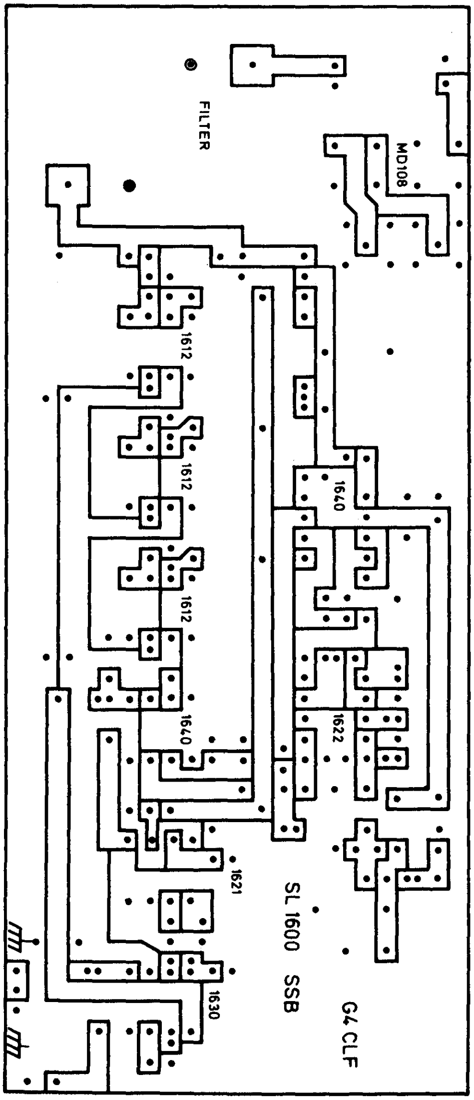
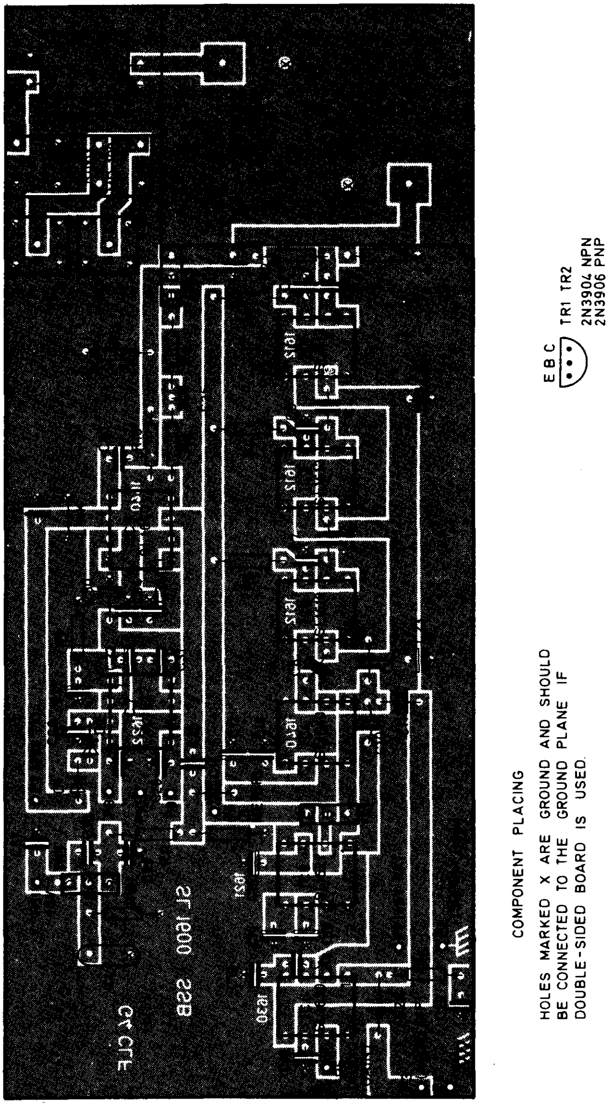


Fig. 67a SL1600 SSB transceiver printed circuit layout. Scale 2:1



COMPONENT PLACING

HOLES MARKED X ARE GROUND AND SHOULD BE CONNECTED TO THE GROUND PLANE IF DOUBLE-SIDED BOARD IS USED.

Fig. 67b SL1600 SSB transceiver component locations. Scale 1:1. Holes marked X are ground and should be connected to the ground plane if double sided board is used

Like the simple SSB transceiver this multimode transceiver consists of a single printed circuit board and requires the addition of a local oscillator, preselector, power amplifier, microphone, loudspeaker and volume control, as well as power supplies and possibly an RF amplifier, to make a complete transceiver.

The board, the block diagram of which is shown in Fig. 68, contains nearly all the signal processing of the transceiver, including a noise blanker, VOX, dual time constant AGC, an 'S' meter/squelch control and RF compression during transmission. Since most sub-systems work independently the board may be built without such refinements and used — either temporarily as a stage in construction and evaluation, or permanently if particular functions are not required. Thus the board may be used to build many different receivers or transceivers.

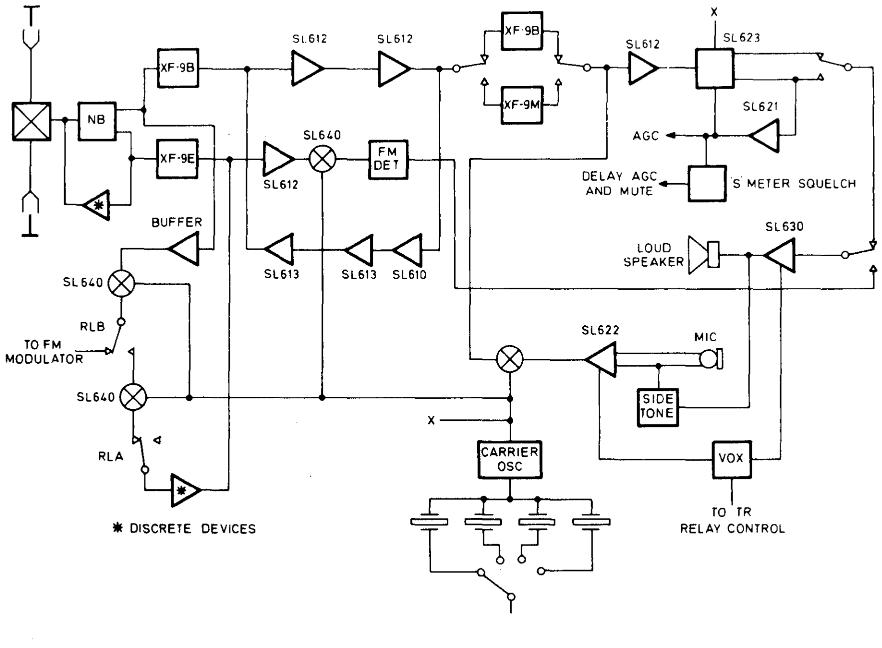


Fig. 68 Multimode transceiver block diagram

RECEIVER DESIGN CONSIDERATIONS

The major problem of receiver design is that of strong signal handling during weak signal reception. There is no single cure for it but designs of high performance receivers usually have as little RF gain as possible, followed by a mixer with good strong signal performance followed at once by a crystal filter. The crystal filter removes the majority of unwanted signals and the rest of the receiver is unlikely to be troubled by them.

The crystal filters do not follow the mixer directly in this receiver, for two reasons: first, to improve the impedance match between the mixer and the filter, and secondly to permit the use of a noise blanker to suppress impulse interference.

A suitable mixer for high performance receivers must have low noise, as little conversion loss as possible, and be able to handle strong unwanted signals without intermodulation. In this transceiver (as a reasonable compromise between cost and performance) a hot carrier diode ring mixer, the MD-108 has again been chosen. Such ring mixers perform best when they are terminated in 50 ohm resistive loads at all ports, but the input impedance of crystal filters, besides being generally higher than 50 ohms, is reactive at frequencies away from the filter passband.

In the Simple SSB Transceiver a transformer matching system was used between the mixer and the filter and the reactive mismatch was ignored. In this system a buffer amplifier, which is in fact also part of the noise blanker, is used to terminate both the mixer and the filter correctly.

A major reason for the failure of receivers to produce weak AM and SSB signals is man-made noise, typically ignition interference, at the antenna. This noise is frequently in the form of very narrow pulses of very high amplitude which can cause the crystal filter to ring at its resonant frequency. Once the filter has been thus stimulated it will stretch the pulse so that it cannot be distinguished from the wanted signal, which it swamps. Only by stopping the ignition pulse before it reaches the filter can this interference be suppressed. The noise blanker must therefore be somewhere in the receiver before the crystal filter and the best place is between the mixer and the filter.

After the crystal filters the receiver design is quite conventional. There are two filters, each feeding its own IF strip. One has a 12kHz passband and feeds the FM IF system, which is a double conversion system with a 455kHz second IF and a quadrature detector. This receiver was designed before the introduction of the SL665, which would allow the use of a single 9MHz IF.

The other filter has a 2.4kHz passband and its output goes to the CW/SBB/AM IF strip. This strip has a broadband gain of about 70dB followed by another crystal filter, which is of 2.4kHz bandwidth for AM and SSB and 500Hz for CW. There is then another IF amplifier stage followed by two detectors. For SSB and CW there is a product detector and for AM there is an envelope detector.

On AM the envelope detector provides carrier AGC to the system but on CW and SSB an audio derived AGC system is used. Squelch and 'S' meter signals are derived from the AGC line.

The decision to use a 2.4kHz filter for AM, removing one sideband, was taken on cost grounds, as was the decision to use only one 500Hz CW filter halfway down the IF strip, whereas two such filters, one at the input to the strip, would certainly improve strong signal rejection in the CW mode. Ideally there should be four filters at the input (with bandwidths of 12, 6, 2.4 and 0.5kHz respectively for NBFM, AM SSB and CW) and a further three filters halfway down the AM/SBB/CW IF strip to reduce IF noise to a minimum. This would entail an extra three expensive crystal filters compared with the present system — for only a marginal increase in system performance.

The use of two filters halfway down the IF strip is well justified, however. The CW filter in this position removes both unwanted CW signals in the 2.4 kHz passband and also much of the broadband noise which can cause difficulty in copying very weak signals. The 2.4kHz filter is essential to remove the broadband noise between 100kHz and 30MHz generated by the first two IF stages which, if allowed into the AM diode detector, would greatly degrade its performance.

The improvement due to this filter on the SSB product detector is much less, since product detectors produce supersonic outputs from broadband noise and these can be filtered without loss of wanted signal. There is nevertheless a 3dB improvement in S/N ratio in systems where IF noise is the limiting factor on system performance.

TRANSMITTER DESIGN CONSIDERATIONS

The transmitter has to generate all the modes that the receiver has to receive. This is not particularly difficult, but several complexities have been introduced to minimise spurious outputs and broadband noise while making the transmitter as effective as possible.

The modulation envelope of SSB does not resemble the audio producing it and normal audio speech processing techniques do not greatly improve the S/N ratio at the receiver. RF clipping, however, reduces the peak/mean power ratio of the signal and hence improves its mean power and readability.

It is also convenient to use the RF clipper for NBFM and AM, these signals being demodulated from clipped SSB back to audio and the audio signal applied to the NBFM or AM modulators. This technique gives up to 12dB apparent signal to noise ratio improvement and the resulting received audio, while obviously 'processed', is not unpleasant.

The audio input to the transmitter passes through an audio preamplifier with AGC to ensure a roughly constant modulation signal regardless of microphone or audio level. It is converted to DSB in a double-balanced modulator and filtered to SSB which is then applied to a limiting amplifier which removes all amplitude variations. This clipped signal is, of course, rich in both harmonics and intermodulation products and must be filtered in a 2.4kHz bandwidth filter to remove them. The quality of this filter determines the spectral purity of the resulting clipped SSB and is more important than the first filter producing the sideband.

The 2.4kHz bandwidth filter reintroduces amplitude variations into the signal which must be amplified by a linear amplifier. The signal is then either further amplified and mixed to the final transmitter frequency or demodulated to yield processed audio which can be applied to the AM or FM modulators.

The FM system uses this audio to modulate the external VFO while the transceiver board supplies a steady 9MHz output to the transmitter mixer. The AM modulator – which also supplies this unmodulated carrier during FM transmission – consists of a double-balanced modulator with deliberate carrier leak. All transmitted signals pass through a 12kHz filter as they leave the board – this costs nothing since the filter is already present in the FM receiver, and removes any broadband noise which the buffer amplifiers may have introduced.

The CW transmitter uses the complete SSB system except that a keyed tone is used as the audio input and the 500Hz filter is used instead of the 2.4kHz filter in the SSB generator. This allows only a single frequency to go to the RF clipper, rather than the several frequencies caused by harmonics from the tone generator, which would result from the use of the 2.4kHz filter.

Like the simple SSB transceiver the majority of the transmit/receive switching is performed by switching power supplies and not signal lines. The power switching itself, however, is performed by a relay which can be driven either from a transmit/receive switch or by the VOX system. Mode switching, however, is performed by relays, so that when the transmitter and receiver are in different modes some relays change state between transmission and reception.

TRANSCEIVER SYSTEMS

To use the transceiver board it is built into a system very similar to that used for the Simple SSB Transceiver illustrated in Fig. 65. A small difference is that if FM transmission is required provision must be made for the processed audio from the board to modulate the VFO. Otherwise the two systems are identical – except that rather more power supplies and function switching are required with the multimode transceiver.

Sub-systems may be omitted if a simple transceiver, or just a receiver, is required. Similarly, the board may be built and operated as an SSB receiver, then expanded to an SSB transceiver without RF clipping, then RF clipping added, etc., as required.

CIRCUIT DETAILS

The circuit diagram of the complete transceiver board is shown in Fig. 69. The whole circuit will be described but where sub-systems are built entirely of SL600 devices conventionally used no explanation of circuit configuration will be given. If this is required the reader is referred to Section 1.

The sub-systems into which the board has been divided are described below.

The Mixer

The Anzac MD-108 mixer was chosen for its performance coupled with its low price, but any hot carrier diode ring modulator with 50 ohm ports and adequate strong signal performance (the MD-108 will handle over 200mV RMS adjacent channel signal) combined with low noise and under 7dB conversion loss could be used euqally well. The MD-108 has two ports with 5–500MHz bandwidth and one with DC to 500MHz bandwidth. If the transceiver is used with signals or VFO of under 5MHz it is important to ensure that this signal is applied to the correct port.

It might be thought that the receiver performance on strong signals would be improved by using a better diode ring, able to handle larger signals. This is not in fact so: if the mixer is improved the noise blanker and filter become the limiting factors in the strong signal performance. A mixer with better high or low frequency performance may, however, be substituted if required.

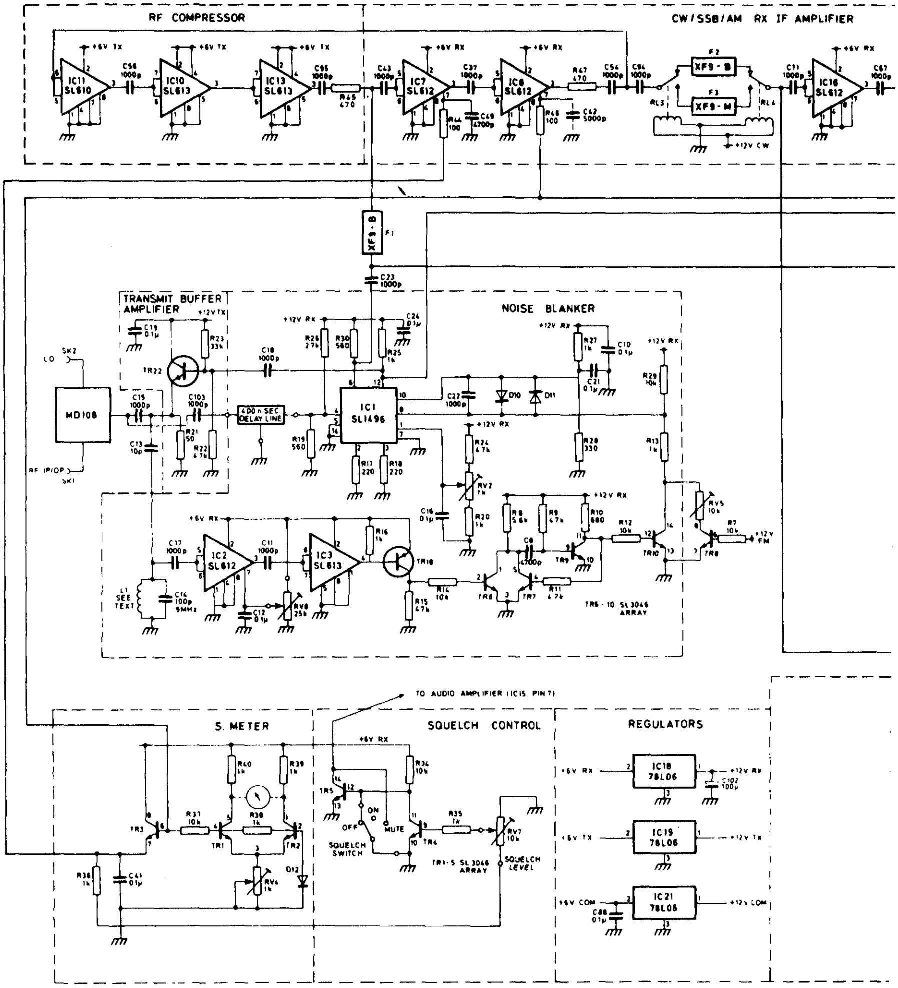
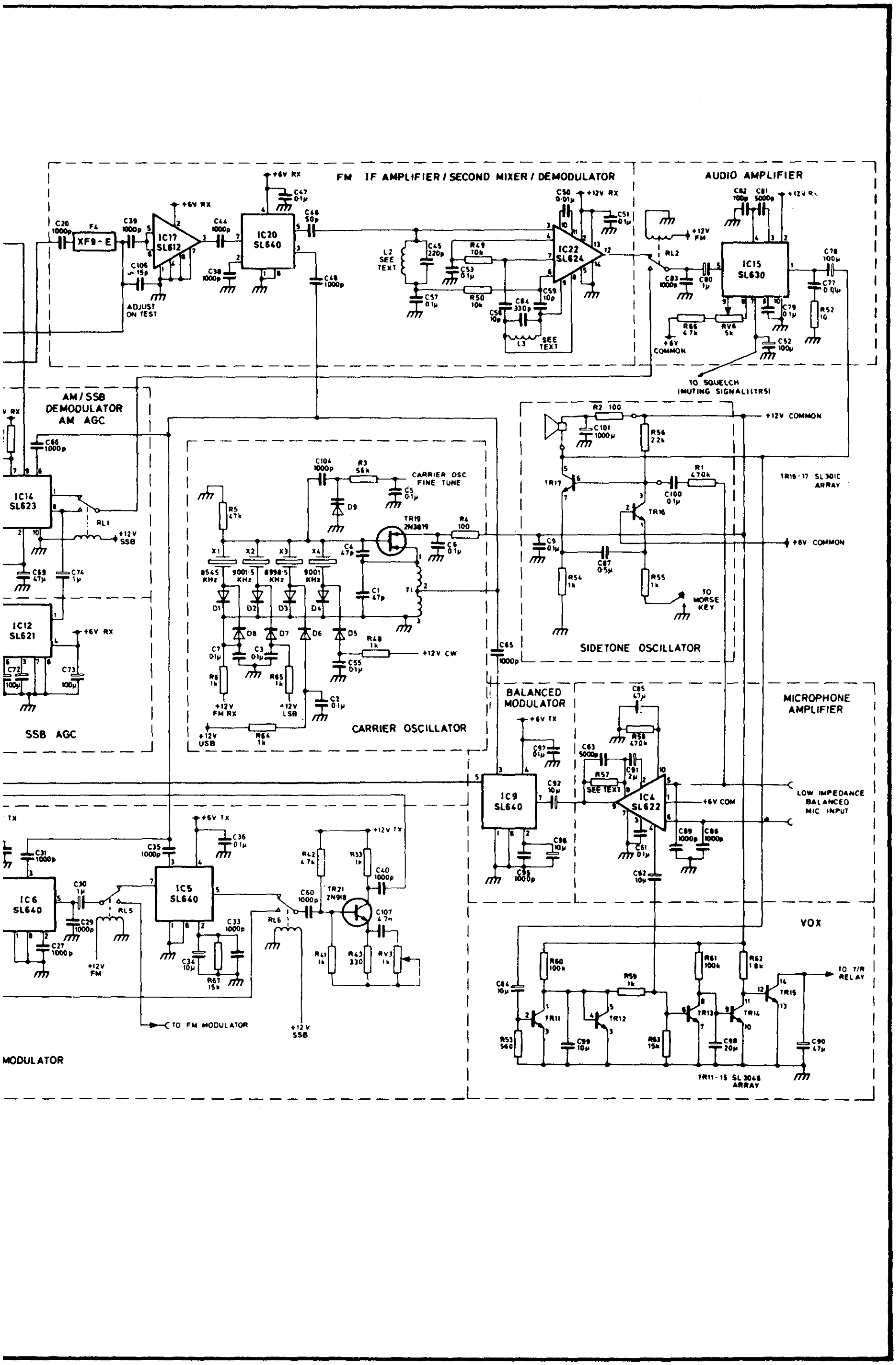


Fig. 69 Multimode transceiver circuit diagram

Island Labs


FM IF AMPLIFIER / SECOND MIXER / DEMODULATOR
AUDIO AMPLIFIER
AM / SSB DEMODULATOR AM AGC
SSB AGC
CARRIER OSCILLATOR
SIDETONE OSCILLATOR
BALANCED MODULATOR
MICROPHONE AMPLIFIER
VOX
MODULATOR
IC17 SL612
IC20 SL640
IC22 SL624
IC15 SL630
IC14 SL623
IC12 SL621
IC9 SL640
IC4 SL622
IC6 SL640
IC5 SL640
F4 XF9-E
ADJUST ON TEST
L2 SEE TEXT
L3 SEE TEXT
TR19 2N3819
TR21 2N918
TR16-17 SL301C ARRAY
TR11-15 SL3046 ARRAY
X1 8545 KHz
X2 9001·5 KHz
X3 8998·5 KHz
X4 9001 KHz
CARRIER OSC FINE TUNE
TO SQUELCH (MUTING SIGNAL) (TR5)
+12V COMMON
+6V COMMON
TO MORSE KEY
LOW IMPEDANCE BALANCED MIC INPUT
TO T/R RELAY
TO FM MODULATOR
+12V CW
+12V FM RX
+12V LSB
+12V USB
+12V SSB
+6V RX
+6V TX
+12V TX
+12V RX
RL1
RL2
RL5
RL6
SEE TEXT

The Noise Blanker

Probably as much work went into the development of this noise blanker as into the rest of the receiver. It has excellent performance and causes very little degradation of the receiver strong signal characteristics.

A noise blanker is a receiver which receives noise pulses, amplifies and shapes them, and uses them to turn off the main receiver while noise is present. As noise is not evenly distributed throughout the frequency spectrum the noise blanker receiver should be operated in the same frequency band as the main receiver.

This in turn suggests that the noise receiver and the main receiver be common and that the blanking pulse be applied late in the main receiver. However if a noise pulse is applied to a crystal filter it is stretched from its original length of a few microseconds to as much as several milliseconds. Blanking must therefore be applied before the crystal filters.

The noise blanker must therefore stop a noise pulse before it can reach the crystal filter from the mixer. Furthermore if a blanking pulse has sharp (large dV/dt) edges these will themselves act as noise pulses, negating the effect of blanking the received noise.

There are therefore two conflicting requirements: the noise blanker must act very quickly to prevent the leading edge of a noise spike from reaching the crystal filter, and it must apply a blanking pulse with a slow rise time to the noise gate to prevent the blanking pulse from acting as a noise pulse. The only way these requirements can be met is to delay the signal between the mixer and the filter in a linear delay line and to place the noise gate between the delay line and the crystal filter.

Various forms of blanking gate were tried during the development of the noise blanker – including diode modulators and single and balanced FETs – but none of them gave better performance than an SL1496 double-balanced modulator. The circuit diagram of an SL1496 is shown in Fig. 70 and a diagram of the noise gate in Fig. 71. Transistors designated TR followed by a lower case letter subscript are those internal to the SL1496. Transistor designations using numerals are employed for all other devices.

In this application pins 5 and 14 of the SL1496 (IC1) are connected together and the emitters of TRa and TRb are thus open-circuited. They are then connected externally to the rest of the circuit. When there is no blanking pulse TR10 is turned off and TRc and TRf are turned hard on. With TRc hard on TRa acts as an amplifier to signals on its base and its output goes, via TRc to the XF9-B crystal filter. Since TRd and TRe are off no signal is applied to the XF9-E filter.

When a blanking pulse is applied to TR10 it is turned on and TRc and TRf turn off (slowly because of the resistor in TR10 collector and the 1 nF capacitor between inputs 8 and 10 of the SL1496) and TRd and TRe turn on. The signal path is now to F4 and the F1 is isolated – noise cannot pass to the CW/SSB/AM IF strip.

The noise blanker is not effective during FM reception and is not used. Instead TR8 is turned on and this balances the modulator so that TRc, TRd, TRe and TRf are turned on and signals go to both IF strips. This is necessary because the squelch is derived from the CW/SSB/AM strip in all modes, including FM.

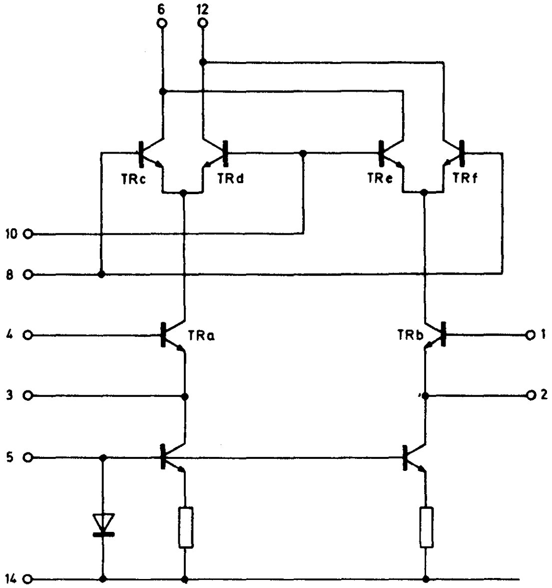


Fig. 70 SL1496C circuit diagram

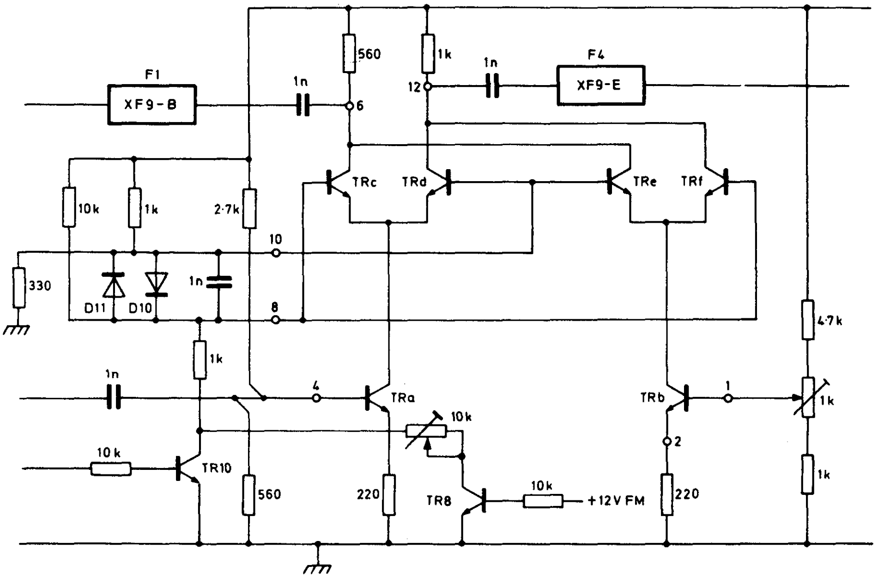


Fig. 71 The noise gate

The diodes between pins 8 and 10 of the SL1496 ensure that the switching drive is at the correct level and the preset current source TR8 keeps the DC current in the filter loads constant as the system switches from the unblanked to the blanked condition.

The whole system is shown in Fig. 72. The noise receiver has its input via a tuned circuit to prevent local oscillator leak from the mixer triggering the system. The noise IF amplifier consists of an SL612C (IC2) and an SL613C (IC3) which acts as a detector. Gain control is applied to IC2 to set the blanking level.

Pulse outputs from the detector in IC3 are buffered by a PNP transistor TR18 to a simple monostable (TR6, TR7 and TR9) with a 10 microsecond pulse. This pulse operates the noise gate. A 400 ns delay line between the mixer and the noise gate ensures that the system is blanked before the pulse that triggers the monostable arrives at the noise gate.

Lastly, a feature of the system is that it acts as a matching amplifier between the 50 ohm mixer and the 500 ohm filters.

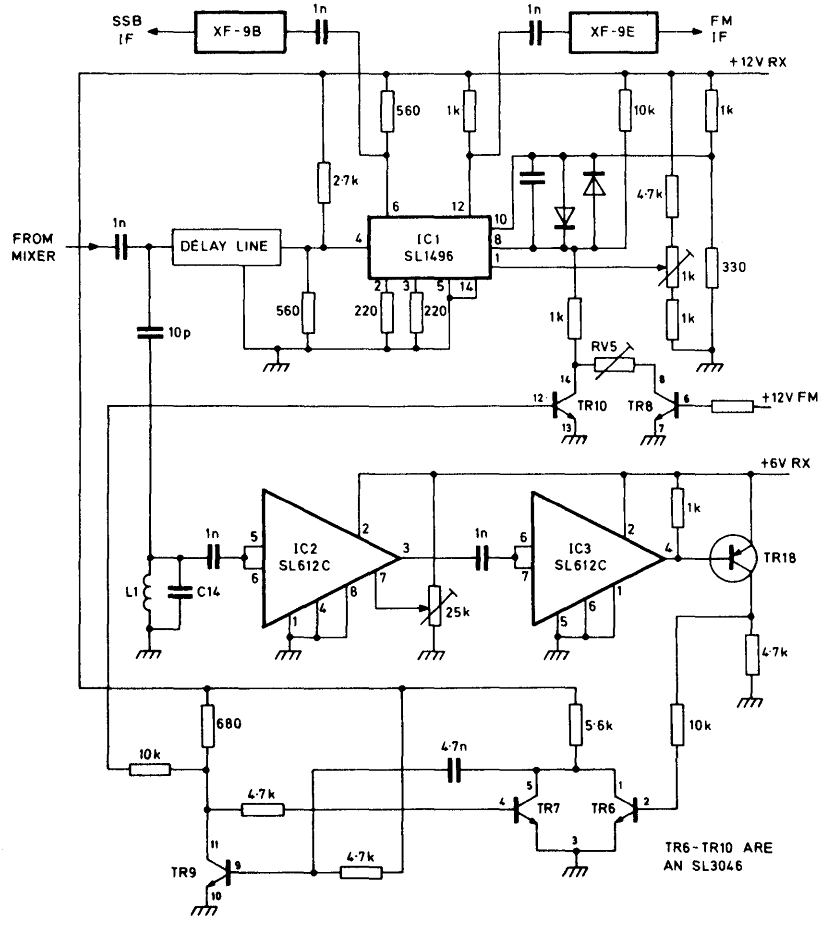


Fig. 72 The noise blanker

The AGC 'S' Meter and Squelch Circuit

As mentioned above the SL623C (IC14) operates as a carrier AGC system during AM reception. It also operates in the same mode during FM reception but does not apply AGC to the FM IF, the AGC line being used only for squelch and to drive the 'S' meter. When the carrier oscillator is turned on, the product detector in IC14 operates and a signal is applied to an SL621C (IC12) connected to its output. The SL621C is more sensitive than the SL623C and so it takes over as AGC source to provide an audio derived AGC system for CW and SSB reception. Since the output impedance of both the SL621C and the SL623C AGC systems are high when they have no input they are both connected to the AGC line and do not load each other.

If fast AGC is required during tuning in the SSB and CW modes, the IC12 may be turned off and control restored to the IC14. This will result in higher outputs but faster decay when tuning from a strong signal. Some professional receivers using SL621C circuits have facilities for dumping AGC from the timing capacitors but it was felt unnecessary to this design.

The AGC line from these two devices drives the second SL612C (IC8) in the CW/SSB/AM IF strip directly and also goes to the squelch and 'S' meter circuitry shown in Fig. 73. TR3 acts as a buffer to drive the squelch circuitry, and also as a diode drop (0.7V) to delay the AGC to IC7. The output of TR3 is filtered by 1 kilohm and 100 nF and applied to a potentiometer ('Squelch Level') and thence to the base of TR4, which acts as an inverter. The inverter output drives TR5 which mutes the SL630C audio amplifier (IC15), by connecting pin 7 of IC15 to earth. A three-position switch which earths either TR4 collector (to disable the Squelch) or TR5 collector (to mute the receiver) is included. Its centre position neither mutes the receiver nor disables the squelch. If a mute position is not required, a single pole on/off switch may be used.

As the AGC characteristic of SL600s is somewhat non-linear, a simple voltmeter on the AGC line does not make a good 'S' meter since it tends to be too sensitive to signal changes near the AGC threshold and not sensitivie enough to large signals. The long-tailed pair TR1 and TR2 with the diode D12 form a compensating circuit. All five transistors in this block of circuitry are on a single chip, the SL3046, in a 14-lead DIL package. This saves board space and gives a good match between TR1 and TR2.

The FM IF Strip and Detector

Double conversion is used in the FM receiver because of the difficulty of providing adequate 'Q' at 9MHz for an NBFM quadrature detector. The 9MHz output from the 12kHz-wide XF9-E filter F4 is amplified by an SL612C (IC17) and is then mixed to 455kHz in an SL640C (IC20). A single tuned circuit is used to remove the image and the signal is then passed to an SL624C working as a limiting amplifier/quadrature detector. This receiver was developed before the SL665 became available – otherwise a single 9MHz filter would have been used and the SL624C replaced by an SL665C.

The CW SSB AM IF Strip

The IF strip is quite conventional. The output of the XF9-B 2.4kHz filter F1 is applied to two cascaded SL612C amplifiers. The output of the second SL612C (IC8) goes either to a 2.4kHz XF9-A or to a 500Hz XF9-M filter, (F3), depending on whether the receiver is in SSB/AM or in CW mode. The filters are switched by two small relays. After the filter there is another SL612C (IC12) and an SL623C detector (IC14). Without a carrier oscillator IC14 acts as an envelope detector for AM and generates carrier-derived AGC in this mode. When the carrier oscillator is applied IC14 acts as a product detector for SSB and CW and an SL621C (IC12) at the product detector output takes over the AGC. The audio output line must be switched between the two detectors.

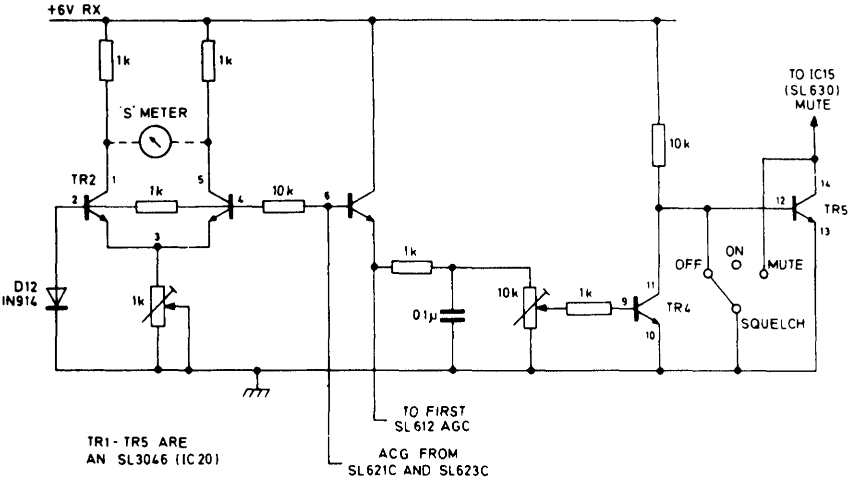


Fig. 73a AGC "S" meter and squelch circuit

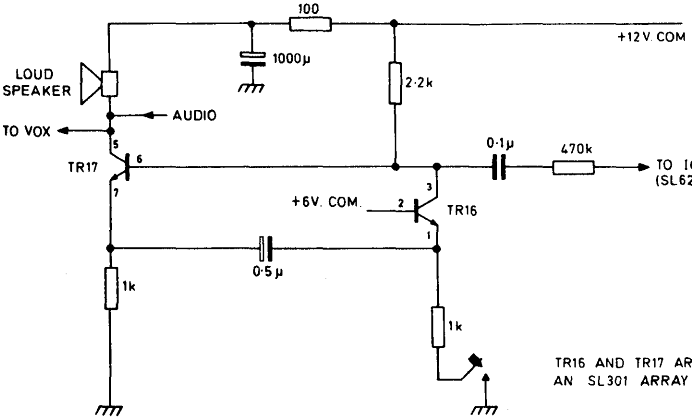


Fig. 73b Sidetone oscillator

The Carrier Oscillator

The carrier oscillator has four different frequencies: 8545kHz for the second mixer in the FM IF system, 8998.5kHz for USB, 9001.5KHz for LSB and 9001 kHz for CW. The circuit is a conventional FET Colpitts oscillator (TR19) and uses diode switching to select one of four crystals.

The output of the oscillator is about 1 volt RMS and is therefore reduced in a potentiometer to the 200mV RMS required by SL640Cs. This potentiometer acts as a virtually constant load to the oscillator and an output buffer is not required.

If the crystals used do not oscillate at their nominal frequency, either the two 47pF capacitors between gate and source and source and ground may be changed in value while remaining equal. Alternatively, where only one or two crystals need trimming, provision is made for crystal trimming by a varicap and a potentiometer for each sideband crystal.

The Audio Amplifier and Sidetone Oscillator

The SL630C audio amplifier (IC15) is driven from a +12V line. It is capable of providing up to 200mW to a small loudspeaker but if a greater output is necessary an additional audio amplifier should be provided. The output of the SL630C is also applied to the VOX circuitry, TR11 to TR15. Gain is controlled by a voltage applied to pin 8 of IC15.

Since the output impedance of the SL630C is quite high when it is turned off, and likewise that of the sidetone oscillator, the loudspeaker is connected directly to both. The sidetone oscillator shown in Fig. 73, is an emitter-coupled multivibrator keyed in the emitter of TR16. A signal is taken from the collector of TR17 and applied to the transmitter audio input.

The sidetone frequency is 1kHz and the system relies on the CW filter to produce a single tone output from the transmitter. If the 500Hz CW filter is omitted the frequency should be raised to about 1750Hz to place the second harmonic well down the SSB filter characteristic. In amateur transceivers an accurate 1750Hz may have an additional use as a repeater access tone.

The Microphone Amplifier and SSB Generator

The audio from the microphone (or the CW from the sidetone oscillator) is amplified by an SL622C (IC4). The SL622C contains its own AGC circuitry with fast attack and slow decay so that its output is around 100mV RMS for over 60dB range of input. There is also a sidetone output which is not affected by the AGC and is used to operate the VOX. R57 sets the microphone AGC threshold and dynamic range. If R57 is open circuit, the threshold is 100 microvolts and the dynamic range is 60dB; if it is 1 kilohm the values are 1mV and 40dB, and if it is 330 ohms they are 3mV and 30dB. C63 should be increased to 0.05 microfarad if R57 is 1 kilohms and to 0.15 microfarad if it is 330 ohms.

The output from the SL622C is applied to the signal input of an SL640C double-balanced modulator (IC9) whose carrier input is 8.9985 MHz or 9.0015 MHz from the carrier oscillator. The output is DSB which is applied to the 2.4kHz bandwidth 9MHz filter (F2) and one sideband removed to produce SSB (USB if 8.9985 MHz is used, LSB if 9.0015).

The RF Compressor

The SSB produced in the system above is normal SSB. Its peak/mean power ratio is fairly large, even though its mean power level is quite constant as a result of the audio AGC. It is therefore amplified in a three-stage amplifier consisting of an SL610C (IC11) followed by two SL613Cs (IC10 and IC13). The SL610C is merely to provide gain but the SL613Cs are high performance limiting amplifiers with symmetrical limiting. The signal emerging from this limiting amplifier preserves its phase information but has had practically all amplitude variation removed from it.

Such a clipped signal is rich in both harmonics and intermodulation products, so it is immediately filtered in another 2.4kHz bandwidth filter (F1) which removes both, but reintroduces some amplitude variation.

The above system is used to process all signals which are to be transmitted, in whatever mode the transmitter is operating. However if a CW signal is being sent, the first 2.4kHz filter (F2) is replaced with a 500Hz filter (F3) to ensure that a single tone is applied to the clipper. After the second filter, however, different modes are processed in different ways.

Single-sideband and CW signals are amplified in a two stage linear amplifier, applied to a 12kHz filter to remove noise and sent to the mixer via the transmit buffer.

When the transmitter is operating in AM or FM mode the clipped SSB is demodulated in an SL640C product detector (IC6) to yield clipped audio, which is then applied to the AM or FM modulators. The SSB clipping produces audio with a slightly artificial sound which, however, is not unpleasant under strong signal conditions, and is particularly easy to copy through noise.

The AM modulator is another SL640C (IC5) with carrier leak deliberately introduced so that the output is AM rather than suppressed carrier DSB. This modulator is used both in the AM and FM modes, but in the FM mode no signal is applied to the signal input and the output is an unmodulated carrier. In either case the output is amplified, filtered in the 12kHz filter (F4), and sent to the transmitter via the transmit buffer and the mixer.

In FM mode the circuit transmits an unmodulated carrier. Frequency modulation is performed off the board by using the processed audio to modulate the transceiver VFO during transmission.

The carrier on AM and FM is not, as one might expect, 9MHz. There is only one carrier oscillator on the board and it is used during transmission to produce clipped SSB. It is therefore working at 9001.5kHz or 8998.5kHz, depending on the position of the sideband selector. The AM or FM carrier is at the same frequency.

The Buffer Amplifiers

The buffer amplifiers used between the various parts of the transmitter are simple transistor or FET circuits. The first designs of the transceiver used integrated circuits to perform these functions but this led to unnecessary complexity and cost with no corresponding increase in performance.

The VOX (Voice Operated Transmit Relay)

A VOX circuit is one which switches a transceiver from receive to transmit when it detects speech at the microphone. The obvious problem with such circuits is to prevent them from reacting to signals from the loud speaker.

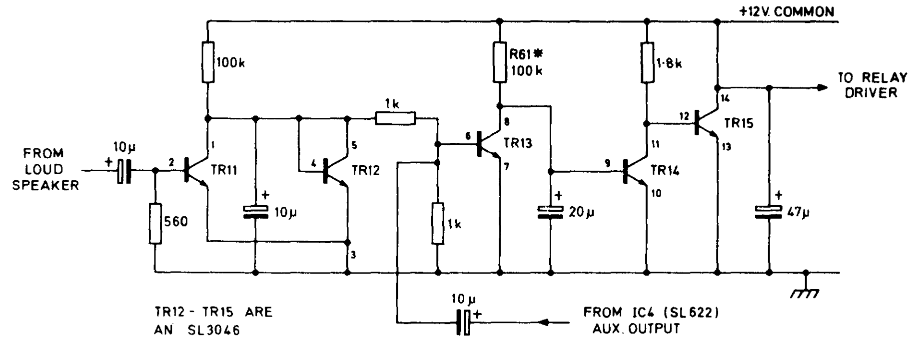


Fig. 74 VOX circuit

The simplest way to do this is to feed the loudspeaker signals to the VOX circuit so that only microphone signals which are not also present in the loudspeaker circuit affect its operation. This is quite difficult and is often liable to cause spurious switching unless the system is carefully adjusted by the operator to compensate for the microphone and the acoustics of the surroundings.

The system used in this transceiver is slightly different. The signal from the microphone is gated by the internal signal to the loudspeaker so that no input to the microphone will affect the VOX while there is a signal to the loudspeaker. The only drawback to this system is that the VOX cannot operate during the reception of non-syllabic noise. Such conditions are, however, unusual.

The circuit is shown in Fig. 74 and uses another SL3046 five transistor monolithic array. Positive half-cycles from the microphone amplifier SL622C (which is powered during reception) turn on TR13 unless prevented by the presence of a loudspeaker signal on TR11. The time constant of the gate circuit is such that VOX action can occur in the spaces between words in normal speech.

TR13 turns on TR15 via TR14. An integrator consisting of R61 and C98 controls the time which elapses between the cessation of speech and the reversion to reception. For breakthrough CW operation (when the operator listens between the dots and dashes of his own transmission) the time constant may be reduced. If the relay is a low power one it may be connected between TR15 collector and +12V, otherwise a PNP driver should be used with an input resistor in its base circuitry.

Power Supplies and Switching

The transceiver board uses three +12V supplies. One is present during reception, one during transmission, and one is common. There are three +6V integrated circuit regulators on the board, one for each +12V line, to supply the appropriate SL600s. This type of regulation greatly reduces crosstalk via the supplies.

Mode switching is accomplished by applying +12V to the relevant one of the three mode lines: CW, FM, or SSB. The two unwanted lines are earthed.

Construction

The transceiver board is constructed of double-sided printed circuit material and earth connections are made on both sides of the board – plated through holes would remove this necessity but were not used in the prototype for reasons of cost and ease of modification. As the board is very small for the complexity of circuitry it carries some of the relay connections were wired. The board diagram is Fig. 75a and the component location is given in Fig. 75b.

It would be almost impossible to make such a system stable on single-sided board but systems derived from this one and built on double-sided board should not present any particular layout problems.

Table 5 Components for the multimode transceiver (Fig. 69)

INTEGRATED CIRCUITS	
IC1	SL1496
IC2	SL612C
IC3	SL613C
IC4	SL622C
IC5	SL640C
IC6	SL640C
IC7	SL612C
IC8	SL612C
IC9	SL640C
IC10	SL613C
IC11	SL610C
IC12	SL621C
IC13	SL613C
IC14	SL623C
IC15	SL630C
IC16	SL612C
IC17	SL612C
IC18	78L06
IC19	78L06
IC20	SL640C
IC21	78L06
IC22	SL624

RESISTORS (ohms)	
R1	470(NOB)
R2	100(NOB)
R3	56K
R4	100
R5	47K
R6	1K
R7	10K
R8	5.6K
R9	4.7K
R10	680
R11	4.7K
R12	10K
R13	1K
R14	10K
R15	4.7K
R16	1K
R17	220
R18	220
R19	560
R20	1K
R21	50
R22	4.7K
R23	33K
R24	4.7K
R25	1K
R26	2.7K
R27	1K
R28	330
R29	10K
R30	560
R31	10K
R32	560
R33	1K
R34	10K
R35	1K
R36	1K
R37	10K
R38	1K
R39	1K
R40	1K
R41	1K
R42	4.7K
R43	330
R44	100
R45	470
R46	100
R47	470
R48	1K
R49	10K
R50	10K
R51	82
R52	10
R53	560
R54	1K
R55	1K
R56	2.2K
R57	See text
R58	470K
R59	1K
R60	100K
R61	100K
R62	1.8K
R63	15K
R64*	1K
R65*	1K
R66	4.7K(NOB)
R67†	15K

* Vertical on board
† May need selection

VARIABLE RESISTORS	
RV1	10K
RV2	1K
RV3	1K
RV4	1K
RV5	10K
RV6	5K Lin.(NOB)
RV7	10K Lin.(NOB)
RV8	25K Lin.(NOB)

CAPACITORS	
C1	47p
C2	0.1μF
C3	0.1μF
C4	47pF
C5	0.1μF
C6	0.1μF
C7	0.1μF
C8	4700pF
C9	0.1μF
C10	0.1μF
C11	1000pF
C12	0.1μF
C13	10pF
C14	100pF
C15	1000pF
C16	0.1μF
C17	1000pF
C18	1000pF
C19	0.1μF
C20	1000pF
C21	0.1μF
C22	1000pF
C23	1000pF
C24	0.1μF
C25	1000pF
C26	0.1μF
C27	1000pF
C28	1000pF
C29	1000pF
C30	1μF(T)
C31	1000pF
C32	0.1μF
C33	1000pF
C34	10μF(T)
C35	1000pF
C36	0.1μF
C37	1000pF
C38	1000pF
C39	1000pF
C40	1000pF
C41	0.1μF
C42	4700pF
C43	1000pF
C44	1000pF
C45	220pF
C46	50pF
C47	0.1μF
C48	1000pF
C49	4700pF
C50	0.01μF
C51	0.1μF
C52	100μF(T)
C53	0.1μF
C54	1000pF
C55	0.1μF
C56	1000pF
C57	0.1μF
C58	10pF
C59	10pF
C60	1000pF
C61	0.1μF
C62	10μF(T)
C63	4700pF
C64	330pF
C65	1000pF
C66	1000pF
C67	1000pF
C68	1μF(T)
C69	47μF(T)
C70	0.1μF
C71	1000pF
C72	100μF(T)
C73	100μF(T)
C74	1μF(T)
C75	100μF(T)
C76	47μF(T)
C77	0.01μF(T)
C78	100μF(T)
C79	0.1μF
C80	1μF(T)
C81	4700pF
C82	100pF
C83	1000pF
C84	10μF(T)
C85	47μF(T)
C86	1000pF
C87	0.5μF(T)

Table 5 (continued)

C88	0.1µF
C89	1000pF
C90	100µF(T)
C91	2.2µF(T)
C92	10µF(T)
C93	1000pF
C94	1000pF
C95	1000pF
C96	10µF(T)
C97	0.1µF
C98	20µF(T)
C99	10µF(T)
C100	0·1µF(NOB)
C101	1000µF(NOB)
C102	100µF(T)
C103	1000pF
C104	1000pF
C105	10µF(T)
C106	15pF(SOT)
C107	4.7nF

NOB = Not on board
All ¼W film types
Tolerance 5%

SOT = Select on test

All capacitors except C101 (which is aluminium electrolytic) are either bead tantalum (marked T) or miniature ceramic; tolerance 20%

TI	6:1 Toroidal RF transformer

L1	3.1µH Nominal, slug tuned screened RF coil.
L2	550µH Nominal, slug tuned screened RF coil.
L3	370µH Nominal, slug tuned screened RF coil.

F1	XF9-B	KVG crystal filters
F2	XF9-B	
F3	XF9-M	
F4	XF9-E	

X1	8545KH	
X2	9001.5KHz	Parallel (30p) resonant
X3	8998.5KHz	HC18 or HC25 crystals
X4	9001Khz	

RL1–6 National R5-12V miniature relays

Diode ring – Anzac MD108

TRANSISTORS

TR1–5	SL3046C
TR6–10	SL3046C
TR11–15	SL3046C
TR16–17	SL301C Dual transistor
TR18	2N3906 or similar PNP
TR19	2N3819 or similar N-FET
TR20	2N3819 or similar N-FET
TR21	2N918 or similar fast NPN
TR22	2N706 or similar NPN

D1–8	1N914 or similar low capacity Si switching diode
D9	MV1 1
D10–11	MBD101
D12	1N914

Delay line
Belfuse 0420-0400-05, or any delay line with 500 ohm ports, 300 to 800ns delay and less than 8dB insertion loss at 9MHz.

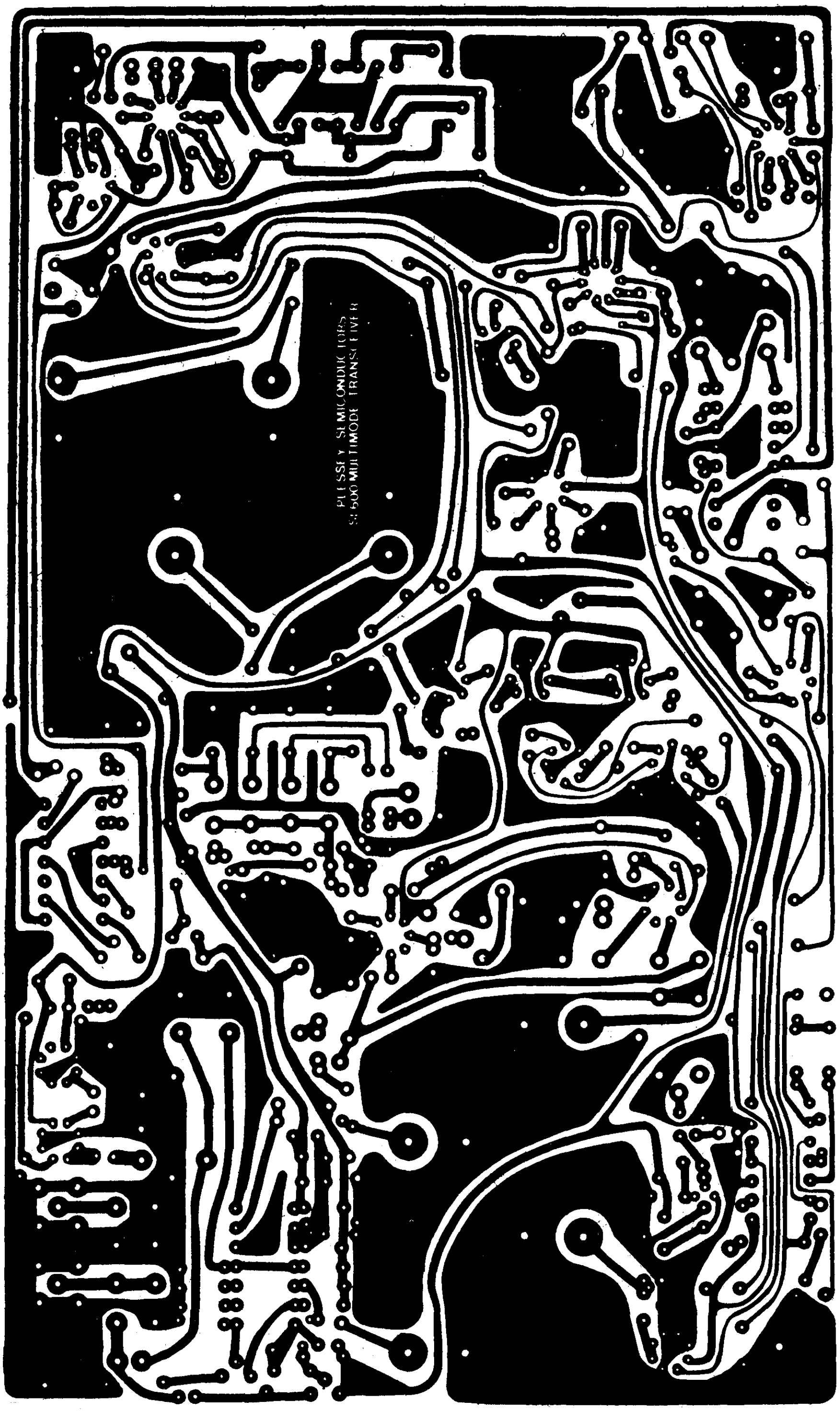


Fig. 75a Multimode transceiver PCB

Fig. 75b Multimode transceiver component layout