IRT FOR THE HEATHKIT 'SB' RANGE OF TRANSCEIVERS

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IRT (incremental receiver tuning) is a feature which is incorporated in many transceiver designs. This useful refinement allows the receiver to be independently tuned a few kHz above and below the transmitted frequency, which eliminates the problems of working stations who listen slightly off-frequency, or have difficulty in accurately netting. IRT is applicable to both SSB and CW working and its use is often a necessity for contest working and DX-chasing. A small offset between transmit and receive frequencies can sometimes make all the difference between making a contact, of getting lost in the on-frequency pile-up.

The purpose of this article is to describe how IRT can be added to the Heathkit SB-100, SB-101 and SB-102 transceivers; the same circuits are applicable to the Heath HW models and to many other makes of transceiver that do not have the IRT facility. As mechanical considerations and panel layouts differ from those of the SB series, the arrangements for fitting the IRT to these other transceivers is not described in detail, but are left to the individual preferences of the users. The principles are the same, and no great difficulties should be experienced in the application of these circuits to any make of transceiver, except perhaps for the newer Heathkit SB-104: this model uses a different type of VFO, to that of the earlier models and this requires alternative circuits to obtain optimum performance. To date, the writer has not been able to persuade any SB-104 owner to experiment with modifications to the VFO, as they are still within the guarantee period and any breaking of the seals on the Heath LMO voids the maker's warranty.

Circuit Considerations

To fit IRT to a transceiver, provision has to be made to vary the received frequency by a few kHz using a separate front panel control. This shift of frequency has to be independent of the transmitted frequency, so a means has to be provided for disconnecting the IRT, or to nullify the shift during the transmit mode. Although the 'shift' and 'nullify' functions are interconnected, for ease of description, they are dealt with separately.

Fig. 1 is a part circuit diagram of the valve LMO used in the SB-100, SB-101 and HW models: there are slight differences between the models, but for our purpose, they can be regarded as identical. The SB-102 uses a solid-state LMO and the same circuit for obtaining the IRT shift may be used; however there is a short-cut that is possible with the SB-102, and this is covered later in this article.

The small shift in frequency is obtained by connecting a voltage controlled variable capacitance diode (*varicap*), in parallel with the tuned circuit (the varicap diode is essentially a variable condenser that is controlled by a DC voltage instead of a rotating mechanical shaft). The capacitance range of these diodes when operated over their rated voltage range can vary from a few pF to over 200 pF depending on the type used. There are many

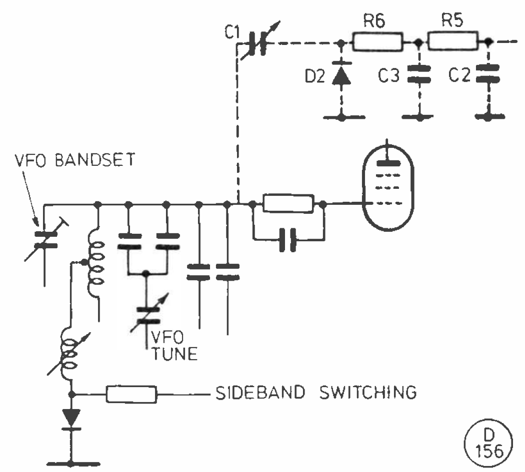

Fig. 1. Part-circuit of the Heath LMO as used in the SB-100, SB-101 and some HW models; shows connection point for IRT components.

different types of varicap diode including those used for VHF and UHF TV tuners, FM and phase modulation, frequency multiplication, mixing and telephone applications. Most types may be used for our purpose, although the higher capacitance types are easier to adjust for optimum IRT range. The writer uses the 1N954, but the Mullard BA-102, BB-105 and BB-110 diodes have been used by other workers.

The trimmer (C1) in series with the varicap is essential, as it controls the effective diode capacitance change across the VFO-tuned circuit: for example, the 1N954 diode has a capacitance change of around 100 pF. If this was directly shunted across the VFO-tuned circuit, the IRT range would be far too great and the diode would act as another bandset condenser. If a 10 pF condenser is used in series, the maximum effective capacity added to the VFO-tuned circuit is only about 9 pF; with the 3-30 pF in circuit (at full mesh), the shunt capacity is still only 23 pF. For the SB-101, about 10 pF total capacitance is required to provide an IRT of ± 2 kHz and this can be obtained from almost all of the available varicap diodes and the proper value of series condenser. It should be noted that the change of capacitance from a varicap diode is not a linear function over the range of the control voltage from 0 to maximum. The series resistor (R4) in the earth leg of the control potentiometers applies a standing minimum voltage to the diode and this helps to improve the linearity over the IRT range.

The additional capacity of the varicap and series condenser (C1) shunted across the VFO-tuned circuit will lower the indicated frequency by anything up to 30 kHz. This is not a problem as all the Heath LMO's have a preset parallel bandset condenser which can be adjusted to bring the VFO back to frequency. As the total parallel capacity is not altered, the linearity of the LMO over the complete tuning range is not degraded.

The complete circuit diagram of the IRT facility is shown in Fig. 2. The series trimmer C1 and varicap D2, together with the RF decoupling components C2, C3, R5 and R6, make up the first part of the circuit. These items are located inside the VFO enclosure and comprise the frequency shifting section of the IRT facility. The second part of the circuit relates to the DC supply, the IRT control and the method used to nullify the effect of the IRT shift during transmit. In theory it should be possible to arrange for an 'electrical disconnect' to switch the IRT between receive and transmit functions; however, this is not practical and another method is used to hold the transmit frequency constant, while the IRT is in operation.

Most types of varicap diode will provide enough IRT using a maximum control voltage of between 10-12 volts. In the arrangement used, the DC supply to the varicap is obtained *via* a series resistor R1 from the 150v. supply in the transceiver (for SB-102 *see* below); a 12v. zener diode provides a degree of stabilisation of the control voltage. The 12v. is fed to the varicap through one of two alternative potentiometers (R2 and R3); switching between the potentiometers is *via* a spare set of contacts (*see* below) on the main send-receive relay in the transceiver (R2 is used for transmit and R3 on receive). R3 is the IRT control and is mounted on the front panel; this potentiometer provides a zero frequency shift at the mid-point of rotation and plus/minus the selected IRT at full clockwise or full anti-clockwise rotation. R2 is located at a convenient point on the chassis and is preset to null out the frequency shift caused by the introduction of the varicap and the control parameters.

The SB-102

The LMO used in the SB-102 has integral provision for frequency shift keying, with a separate external connection for this facility. This is not mentioned in the assembly or operating instructions, so it is assumed that Heath had a change of mind, or that there are technical factors that make RTTY or FSK operation unacceptable. The FSK circuit uses a varicap diode, together with the necessary decoupling components, in a similar circuit to that used for IRT. The external connection is located on the rear of the LMO enclosure (labelled FSK) and if connected to the control circuits as used for the other models, a IRT of ± 1 kHz can be obtained. A greater IRT swing can be obtained by increasing the voltage to the FSK connection, but this must be carefully monitored as some SB-102 transceivers have varicap diodes in the circuit which go substantially non-linear with control volts in excess of 15-18 volts. In tests made with several SB-102 units, a IRT of 3 kHz (± 1·5 kHz) seems possible using the FSK connection and 15v. maximum control supply. Some alteration to the value of series resistor (R1) is necessary together with a change of zener diode type to obtain the higher control voltage.

Component Location

The first point to be decided is the location of the IRT control on the front panel. There is a minimum of free space on the SB models, so the best solution is to remove the 'Frequency Control' switch and use the vacated hole to mount the potentiometer. The SB models incorporate a separate crystal oscillator to provide fixed frequency operation for net working or for use on MARS channels. This separate oscillator is switched into circuit in place of the LMO by the 'Frequency Control' front panel control, and as its application has a limited use, it is a very convenient substitution. Some wiring changes

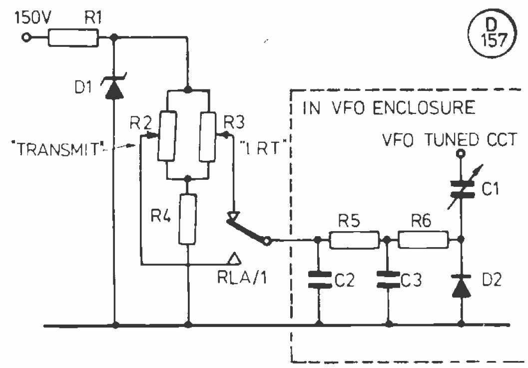

Fig. 2. Complete IRT circuit.

Table of Values

Fig. 2

C1 = Philips 3-30pF concentric trimmer	R1 = 47K 1-watt carbon
C2, C3 = 0·001 μF LV ceramic disc	R2, R3 = Good quality 22K *linear* potentiometers (not wirewound)
D1 = 12v. zener diode	R4 = 2·7K ¼-watt carbon
D2 = varicap diode (*see text*)	RY1 = *see text*

are required to use the transceiver without the switch in circuit, but these are not difficult and details are provided later in this article. Most other transceivers have spare panel space and the IRT control can be located in any convenient position. One possibility that has been used with the Heath HW models is to remove the phone jack socket and re-locate it in a spare hole on the rear apron of the chassis; the IRT control may then be fitted in the hole originally used for the jack socket. The writer does not favour this solution as the jack socket is located very close to the microphone input socket and this requires that a very small knob is used for the IRT control; however, it is a possibility when the transceiver owner does not wish to drill extra panel holes.

The varicap, series trimmer condenser and RF decoupling components are mounted on a small piece of *Veroboard* which is fixed to one of the sides of the VFO enclosure so as to locate the connection to the trimmer close to the tuned circuit inside the enclosure. The most convenient side to remove is the one adjacent to the IF Circuit Board (right-hand-side looking from front). The *Veroboard* can be glued or screwed to the inside of the removed side as required in a position to ensure that the connection from the trimmer to the VFO-tuned circuit is fairly short; the trimmer is connected to the heavy tinned copper wire between the VFO tuning condenser and coil. Two holes are drilled in the side of the enclosure, one to take the lead from the RF decoupling network and the other to permit the adjustment of the trimmer from outside the enclosure.

As mentioned earlier, the 'transmit' potentiometer R2 is mounted in a non-critical position on the chassis. There is a spare hole on the SB-100, SB-101 and SB-102 models adjacent to the power amplifier enclosure and in the same section of the chassis as other preset potentiometers (bias, headphone volume etc.). If the 'transmit' potentiometer is mounted in this hole, it will be necessary to use a small-diameter component to prevent it fouling the other presets. The writer preferred a larger sized potentiometer and mounted it on the top of the chassis by means of a small 'U' bracket fixed to the metal plate to the right-hand-side (from front) of the power amplifier enclosure. The zener diode and series resistor are mounted on another small piece of *Veroboard* fixed alongside the 'transmit' potentiometer.

The multipole transmit-receive relay in the Heath models has a set of spare change-over contacts intended to switch external equipment, such as a linear amplifier or transverters. If this is not in use, then the contacts may be used to switch the IRT potentiometers. If the relay is already fully committed, then the contacts used in conjunction with the 'Frequency Control' circuit may be used. Some users may prefer to do this, even if the spare contacts are not being used, as it allows for future additions. The necessary wiring changes are described below.

Transceiver Modifications

Assuming that the IRT control is to be mounted in place of the 'Frequency Control' switch, it is necessary to unsolder the various connections and remove the switch from the front panel. Fig 3 shows the switch wiring diagram and the circuit of the associated relay connections. It should be noted that the switch and relay contacts are numbered in the overall transceiver circuit diagram in the handbooks applicable to each of the Heath SB models. The numbers and colour codes in Fig. 3 are those relative to the SB-101 and these may differ from the designations for the SB-100 and SB-102. Before attempting any modifications, the master circuit diagram should be checked to ensure that the correct contacts are identified, particularly in relation to the relay connections. It should also be noted that the series 100 ohm resistor and associated decoupling condenser (100 pF) in the RF feed to the first transmitter mixer V5A, and the 56 ohm shunt resistor in the RF output from the LMO, are mounted on the switch wafer; these components should be unsoldered from the switch when it is removed from the front panel.

The various leads to the switch have to be linked together and the two resistors and the condenser reconnected in the feed from the LMO to the mixers. The modified wiring is shown in Fig. 4, and again the colours refer to the SB-101. The connections to the relay are no longer required and these leads can be removed from pins 1, 5 and 9 and taped into the wiring harness for possible future use.

The complete IRT facility (Fig. 2) can now be wired into circuit using either the spare set of relay contacts or the set that were used with the crystal oscillator. Apart from the frequency shifting components in the VFO enclosure and the linked coaxial wiring between the LMO output and the mixers, none of the other wiring is critical and the connections between the LMO to the relay, the potentiometers and the DC supply may be run in the existing cable-forms.

Setting-up

The alignment procedure is relatively simple and consists of adjusting the frequency swing of the IRT control, recalibrating the main VFO dial and adjusting the transmitter potentiometer to null out the offset introduced by the IRT components. A digital frequency counter makes these adjustments very easy, but this is not essential and the circuits can be aligned using the internal crystal calibrator together with a separate receiver that will cover either 5-5·5 MHz or 3·5-3·6 MHz.

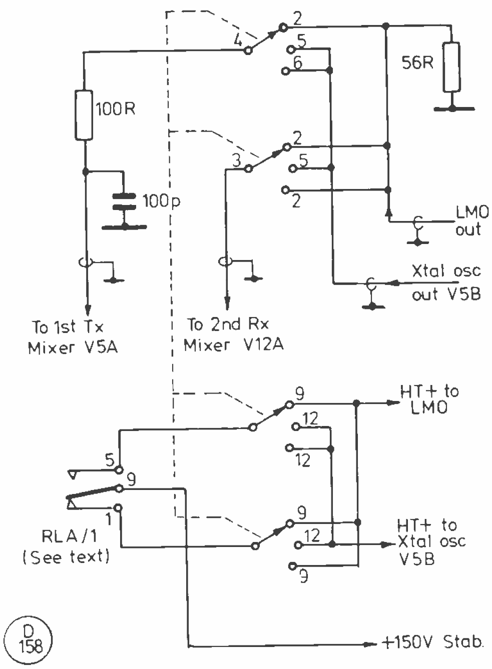

Fig. 3. Wiring to 'Frequency Control' switch before modification (numbers and colour coding refer to original Heathkit circuit designations for the SB-101).

If a counter is available, it should be connected to the VFO output *via* a small series condenser (5-10 pF). If not, then the transceiver has to be coupled to the external receiver by connecting a coaxial link lead between the 'Rec Ant' socket on the rear apron of the transceiver and the aerial socket of the receiver. The 'Antenna Switch' on the rear of the transceiver should be set to 'Rec' so as to isolate the transceiver aerial input to the receiver section from the transmitter output; a dummy load should be connected to the transceiver 'RF Output' socket. No other test equipment is required and the extra receiver is only needed if a frequency counter is available.

With the transceiver tuned to 3600 kHz, the crystal calibrator in circuit and the IRT control at mid-point, the VFO calibration can be roughly set on frequency. Owing to the extra capacity of the varicap and its associated components, the calibration will have moved low frequency and the zero-beat point corresponding to 3600 kHz may be as much as 25-30 kHz LF. The VFO calibration is corrected by adjustment of the VFO parallel band-set condenser (at the rear of the LMO enclosure)to regain zero-beat with the calibrator at exactly 3600 kHz. *WARNING:* do not adjust the coil slug on the top surface of the LMO enclosure, as this will alter the shift between upper and lower sidebands and will degrade the linearity over the LMO range.

The next adjustment is to set the total frequency shift of the IRT circuit. This is done by checking the frequency swing at both ends of the potentiometer travel using the counter, or by retuning the VFO to obtain zero-beat and reading off the two frequencies from the VFO dial. If more than 4-5 kHz coverage is obtained, it will be necessary to reduce the capacity of the varicap series trimmer C1. If more variation is required, the trimmer capacity will need to be increased. The writer favours a total IRT variation of ± 2·5 kHz max., but the actual coverage is left to the individual choice of the user.

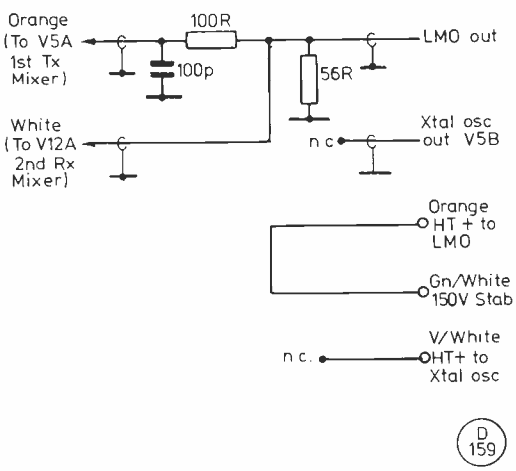

Fig. 4. Modified wiring after removal of 'Frequency Control' switch and connections Nos. 1, 5 and 9 to relay disconnected.

There will be some mutual interaction between the IRT range and the VFO calibration, so it may be necessary to re-calibrate the VFO after each adjustment. Once the IRT range has been fixed, it will hold over the complete range of the transceiver and the frequency shift will be identical for each band. A small label made from card and lettered using dry transfer, decals or engraved strip from a labelling machine may be fitted to show the mid-point (zero IRT), and the LF and HF shifts. The original Heathkit knob as used for the 'Frequency Control' switch is fitted with a pointer and is ideal for the IRT control.

The final adjustment is to zero the transmit offset. With the IRT control at mid-point and the received signal from the calibrator at zero-beat, the VFO frequency should be again checked using the counter or the external receiver; with the transceiver coupled to the receiver as previously described, no difficulty should be experienced in hearing the 5400 kHz (approx.) signal, or the transceiver calibrator signal on the external receiver. If the 3600 kHz frequency is being monitored instead of the VFO output, the external receiver should be tuned exactly to zero-beat with the calibrator signal from the transceiver. The transmitter is operated at low power in the 'Tune' mode with the 'CW Level' control backed off. If too much transmitter power is used, the counter may read the signal frequency rather than the VFO output; it will also be difficult to obtain a clean signal on the external receiver. It is likely that the VFO frequency will change by a few kHz between the 'receive' and 'transmit' modes and the chassis-mounted 'transmit' potentiometer has to be adjusted to compensate for the change. The transceiver can be switched between 'Tune' and 'CW' (key-up) to check that the VFO frequencies are identical. When the 'transmit' potentiometer has been set so as to null out the offset of frequency, the alignment procedure is complete and the external receiver or counter may be disconnected. The 'Antenna Switch' should be returned to 'Com' and the transceiver is ready for normal use with the added advantage of IRT.

In Conclusion

This particular IRT circuit was originally devised by the writer in 1953 for use with a Collins KWM-1 transceiver to overcome the problems of receiving SSB stations that were using homebrew and converted equipment with built-in offsets. It has now been used with over 30 different transceivers, ranging from the KWM-1, KWM-2, various Swan models and the Heathkit SB and HW models. Although different mechanical arrangements have been used, including a few 'outboard' versions with a separate external relay, no difficulty has been reported by any of the transceiver users who have made the modifications. Several *de-luxe* versions have been fitted with an additional switch to permit both IRT and incremental transmitter tuning (ITT); this requires that the two potentiometers are reversed using a double-pole change-over switch. Others have provided a separate switch to disconnect the IRT facility when it is not in use. The writer has not found these extra facilities to be helpful and provided the IRT control is always returned to the mid-point, there will be no offset between 'receive' and 'transmit' frequencies.