EQUIPMENT REVIEW

The Yaesu Musen FT101ZD hf transceiver

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Introduction

Ever since the original version appeared during 1970, the FT101 series of hf transceivers has been one of the most popular available. The latest in this series are the FT101Z (analogue frequency readout) and the FT101ZD (digital frequency readout). Comparing these latest versions with the earlier versions shows how far this series of transceivers has evolved—they have very little in common. The earlier versions (FT101, FT101B etc) used a double-conversion design with intermediate frequencies of 5,520–6,020kHz and 3,180kHz. The FT101Z and FT101ZD are essentially single-conversion designs with an i.f. of 8,988kHz and a greatly extended number of facilities. The mechanical construction is also totally different. The earlier versions used plug-in boards and edge connectors extensively with interconnections routed via the main chassis. The latest transceiver uses mainly fixed boards with plug and socket interconnections.

The FT101Z and FT101ZD cover all WARC 1979 allocated hf bands and give nominally 100W output power. Valve driver and pa stages are used with semiconductors (largely discrete) for all other functions. The basic transceiver operates from ac mains and covers ssb and cw operation. Optional extra facilities at added cost include boards for a.m. or fm operation, 12V dc inverter board, fan, and narrow bandwidth cw filters. A large range of accessories is available and, in addition, all the accessories intended for the FT902 are compatible with the FT101Z and FT101ZD. These include analogue and digital remote vfos, speakers, antenna tuner, monitor scope and panadaptor, transverters for 50, 70, 144 and 432MHz, rtty demodulator and linear.

The sample obtained for review comprised an FT101ZD with fm board, fan, and 350Hz cw filter as fitted options.

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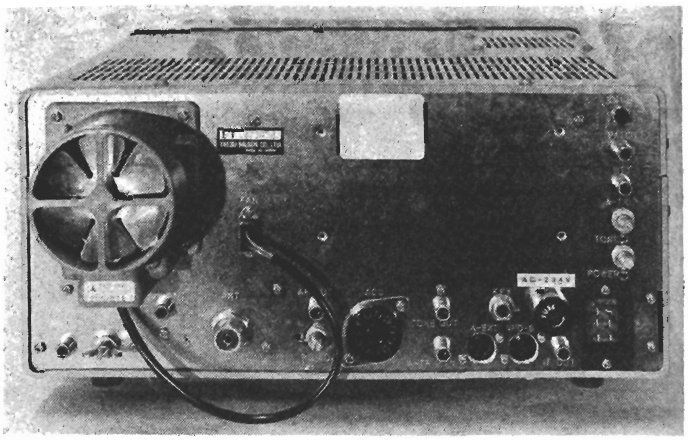


Rear view of the FT101ZD

Principal features

This transceiver incorporates all the features which are generally regarded as standard on modern hf transceivers. Full coverage of the nine current and future hf allocations is provided in 500kHz tuning ranges, with 28–30MHz covered in four bands. Principal features include clarifier (irt) operation on both receive and transmit, three-position input attenuator, two agc time constants plus off, noise blanker, speech processor, variable bandwidth i.f. 300Hz–2·4kHz, audio peak and notch filters, metering of three functions, and full cw and ssb vox controls.

The rear panel includes the following connectors: antenna socket, antenna outlet for external receiver, low power rf output for transverter operation, key jack, remote vfo, transmitter af input, receiver af output, wideband i.f. output for panadaptor or spectrum analyser, fan power and eleven-pin accessory socket providing relay control switching and control for the pa valve heaters. The accessory socket no longer provides power outlets as on earlier versions.

Description

In common with most Yaesu equipment, the transceiver is sturdily constructed and well engineered. A substantial chassis system is used with a diecast front panel, and the 10 boards are interconnected by plug and socket flying leads. The transceiver measures 34·5 (w) by 15·7 (h) by 32·6cm (d) and weighs 15kg; similar in front panel size to the earlier FT101 but a little deeper. It is not as small as some transceivers, but a mains psu is built-in and the front panel size enables full-size knobs and switches to be used. The controls are generally well laid out, but the cluster of four dual-purpose vox, drive and gain controls on the top left-hand corner of the front panel can be fiddly to use. All controls are mounted on the front panel, and a 9cm

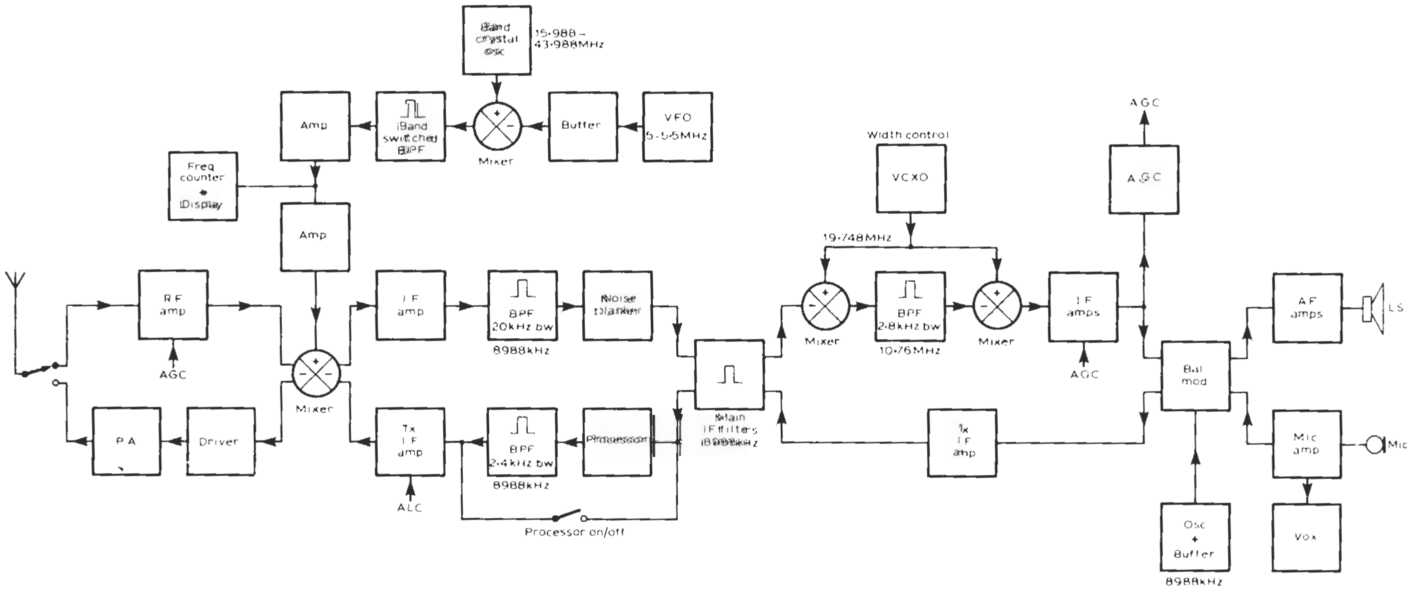


Fig 1. Simplified block diagram of the FT101ZD omitting fm and a.m. sections

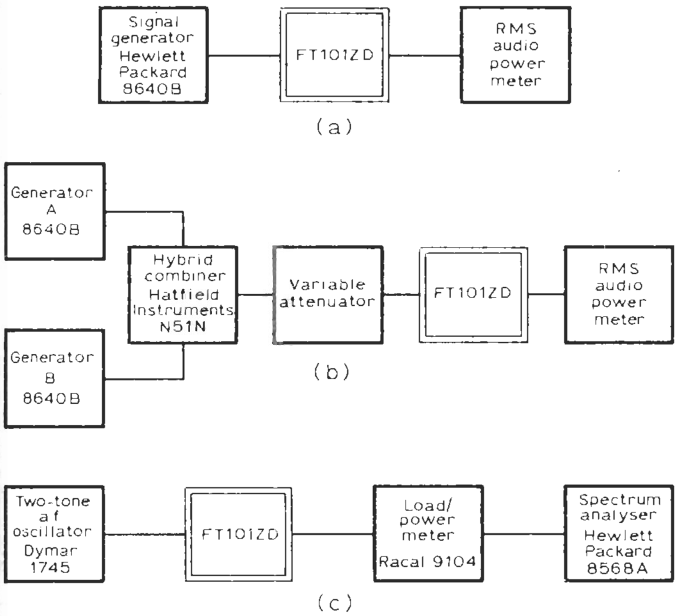


Fig 2. Test arrangements. (a) Single generator receiver measurements. (b) Two generator receiver measurements. (c) Transmitter measurements

diameter speaker is mounted in the top of the case. As usual the key jack is relegated to the rear panel—the reviewer would much prefer to see this located on the front panel. The tuning rate is 17kHz/revolution of the 50mm diameter control knob.

A block diagram of the FT101ZD is shown in Fig 1. On receive, incoming signals are amplified in a dual-gate mosfet rf amplifier and converted down to the i.f. of 8,988kHz in a Schottky diode double-balanced mixer. Resonant circuits tuned by the preselector are located at the input and output of the rf amplifier. The i.f. signal is amplified by grounded gate fet amplifiers and filtered to a bandwidth of 20kHz before passing through the noise blanker to the main i.f. block filters. The variable i.f. width function is achieved by mixing the i.f. signal up to 10·76MHz, passing through an additional 2·8kHz wide crystal filter and then mixing back down to 8,988kHz again. The same local oscillator is used for both conversions and hence no net change in frequency results. By altering the frequency of this oscillator by ±3kHz, the overall passband shape can be modified as described in [1]. The 8,988kHz i.f. signal is further amplified and demodulated before passing to the audio amplifier and switchable peak and notch filters. On a.m., a separate detector is incorporated. On fm the i.f. signal, before passing through the ssb filter, is converted down to an i.f. of 455kHz, where it is filtered, amplified, limited and then demodulated.

On transmit, dsb is generated at 8,988kHz using the same balanced modulator as is used for the receiver detector. The dsb signal is amplified, passed through the main ssb filter and, with the processor off, further amplified and converted to signal frequency. With the processor switched on, the 8,988kHz ssb signal is further amplified, limited and filtered before being converted to signal frequency. The signal frequency mixer is the same mixer as is used on receive. The main amplification at signal frequency is achieved using valves, a 12BY7A driver and two parallel 6146B pa valves. Selectivity at signal frequency is achieved by resonant circuits at the input and output of the driver, tuned by the preselector control and also the pi-tank pa output circuit. On both a.m. and fm separate microphone amplifier, oscillator, modulator and amplifier stages at 8,988kHz are used which feed the transmitter drive into the signal frequency mixer.

The local oscillator injection for the receive/transmit signal frequency mixer is derived from the premix unit. The vfo tuning 5-5·5MHz is mixed with one of 12 crystal oscillators (a separate oscillator for each band) using an integrated circuit double-balanced mixer. The local oscillator output is then filtered using band-switched filters and amplified to provide a suitable injection level for the signal frequency mixer.

Measurement technique

The measurement technique adopted was substantially the same as that described in [1]. Unless stated otherwise, all measurements were made on ssb with the audio gain set to give 100mW af output. In all cases signal input voltages are quoted in pd across the antenna terminal. A block diagram of the measurement arrangements is shown in Fig 2. A single signal generator

Table 1. Receiver measurements

Frequency	Sensitivity on ssb for 10dB s + n:n		Input for S9
1·8MHz	0·16μV	(−123dBm)	7·5μV
3·5MHz	0·14μV	(−124dBm)	4·8μV
7MHz	0·13μV	(−125dBm)	4·3μV
10MHz	0·13μV	(−125dBm)	4·1μV
14MHz	0·11μV	(−126dBm)	4·0μV
18MHz	0·11μV	(−126dBm)	3·7μV
21MHz	0·11μV	(−126dBm)	4·1μV
24MHz	0·10μV	(−127dBm)	3·8μV
28MHz	0·11μV	(−126dBm)	5·0μV

Table 2. Receiver measurements

Frequency	Image rejection	8,988kHz i.f. rejection
1·8MHz	98dB	118dB
3·5MHz	99dB	115dB
7MHz	85dB	93dB
10MHz	66dB	82dB
14MHz	73dB	114dB
18MHz	61dB	115dB
21MHz	64dB	115dB
24MHz	53dB	119dB
28MHz	51dB	118dB

was used to evaluate sensitivity-based measurements and spurious responses, including S-meter calibration, agc performance and selectivity. Two coupled signal generators were used to evaluate signal handling, ie measurements on blocking and intermodulation.

Receiver measurements

Sensitivity

Sensitivity measurements were made at a signal-plus-noise-to-noise ratio of 10dB with the af filter, width and input attenuator switched off. The results are shown in Table 1. On the higher frequency bands the receiver exhibits a noise floor of −135 to −136dBm in ssb bandwidths, or a noise figure of approximately 5 to 6dB. This is very sensitive for an hf receiver. Sensitivity measurements were also made at 28MHz with the receiver switched to fm; in this case the signal generator was frequency modulated by a 1kHz audio tone to give a peak deviation of 3kHz. The sensitivity for 10dB s + n:n ratio was 0·13μV, and the ultimate signal-to-noise ratio of about 40dB was achieved with input levels greater than 10μV.

The accuracy of the input attenuator was checked on 7MHz. In the 10dB position, the attenuation was measured as 9·3dB, and in the 20dB position as 18·4dB.

S-meter calibration

The input signal level required to give a reading of S9 is shown in Table 1. At 7MHz the S-meter calibration was:

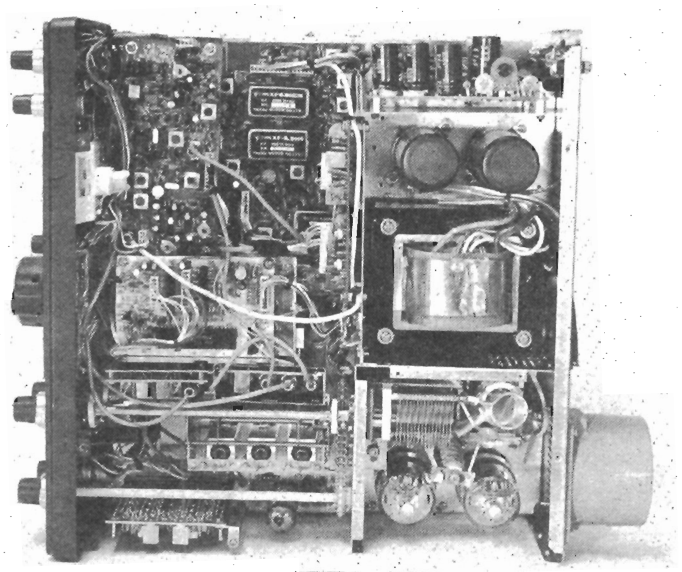
S-reading	Input signal	Relative increase
S3	1·1μV	
		2dB
S5	1·4μV	
		4dB
S7	2·2μV	
		6dB
S9	4·3μV	
		30dB
S9 + 20	140·0μV	
		26dB
S9 + 40	2·8mV	
		17dB
S9 + 60	20·0mV	

Spurious responses

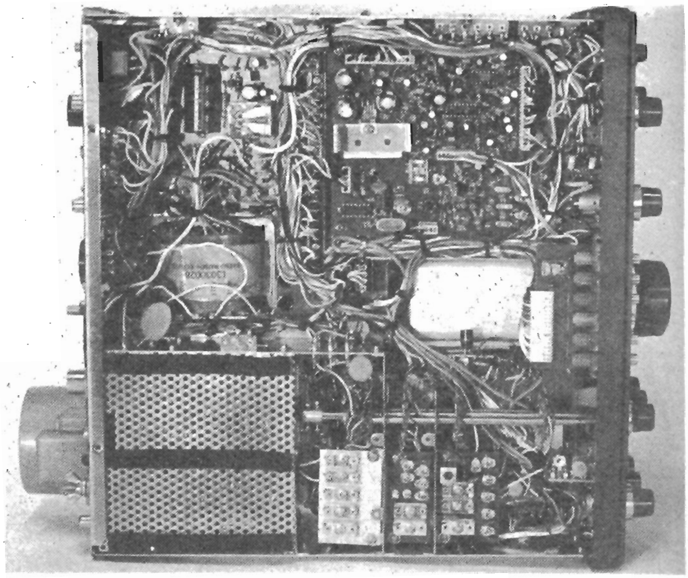
The 8,988kHz i.f. rejection and the primary image rejection at 17,975kHz above the frequency to which the receiver is tuned are shown in Table 2. These levels are all measured by setting the signal generator to give the required spurious response at a level giving 10dB s + n:n ratio and relating this level to an on-tune signal of 10dB s + n:n ratio. Rejection of the 10·76MHz i.f. was greater than 125dB on all bands, except on 10MHz where a figure of 88dB was measured.

To check for internally-generated spurious signals, the antenna socket was terminated in 50Ω and the receiver carefully tuned over each band. There was no spurious response which was strong enough to move the S-meter, and of the eight spurii logged, the three strongest were located in the 28MHz band.

Other spurious responses were checked by setting the signal generator on



Top view of the FT101ZD with cover removed



Bottom view of the FT101ZD with cover removed

either side of the on-tune frequency and noting the amplitude for any responses obtained corresponding to an S1 meter reading. The generator was tuned from 100kHz off frequency down to 1MHz (ignoring generator harmonics) and from 100kHz off frequency up to vhf.

Frequency	Worst response	Other responses
1·8MHz	No response measured up to 250mV	
3·5MHz	No response measured up to 250mV	
7MHz	7mV	One up to 250mV
10MHz	80mV	Two up to 250mV
14MHz	4mV	Three up to 250mV
18MHz	Two at 80mV	Three up to 250mV
21MHz	14mV	Nine up to 250mV
24MHz	10mV	Several 15 to 70mV
28MHz	2·5mV	Several 7 to 70mV

AGC performance

The agc performance was measured at 7MHz. The threshold was found by slowly increasing the input signal until the af output ceased to rise linearly with the input. This occurred at about 1·2μV. A further 10dB increase in signal above this level resulted in a 1dB increase in audio output, and a further 110dB increase in signal resulted in a further 0·7dB increase in audio. The attack time was measured as about 5ms, and decay times as 20ms in the fast position or 300ms in the slow position.

Signal handling

Measurements on signal handling properties were made at frequencies of 7 and 28MHz using the test arrangement shown in Fig 2(b).

Blocking was evaluated by setting generator A on-tune at a level of 500μV. Generator B was set 50kHz off frequency, and the level increased until the S-meter just started to decrease. This occurred at a level of 60mV on both 7 and 28MHz. Repeating the measurement on 28MHz with 100kHz frequency offset gave identical results.

Third-order intermodulation distortion was measured by setting the two generators 20 and 40kHz away, respectively, from the frequency to which the receiver was tuned, and increasing the levels equally until a third-order intermodulation product was generated in the receiver passband at a level giving an s + n:n ratio of 10dB. This occurred when each generator was set to give a signal input to the receiver of −49·7dBm (730μV) on 7MHz or −49·3dBm (760μV) on 28MHz. This corresponds to a third-order intercept of −12dBm on 7MHz and −11dBm on 28MHz (See 1). Referencing the above measurements to the noise floor of the receiver gives a spurious-free dynamic range of approximately 83dB.

Cross-modulation and reciprocal mixing measurements were not performed.

Reducing the rf gain control did not improve the intermodulation performance, and the noise blanker had little effect on strong signal performance except when the threshold control was fully turned up. At this setting, the intermodulation performance was noticeably degraded.

Audio power output and distortion

The maximum audio power output into a 4Ω load was measured as 2W before the onset of clipping. An output power of 2·5W was obtained at 10 per cent distortion. Maximum audio output could be achieved with a 0·35μV input signal.

Selectivity

The i.f. selectivity curve was plotted by tuning a signal generator across the receiver passband and noting the level required to give an S-meter reading of S2. It was found possible to measure about 70dB down the skirts of the filter before reciprocal mixing, generator noise and signal overloading problems became apparent. The results for both the ssb filter and the 350Hz cw filter were:

Response	SSB filter bandwidth	CW filter bandwidth
−3dB	2·2kHz	200Hz
−6dB	2·4kHz	300Hz
−20dB	2·8kHz	500Hz
−40dB	3·2kHz	800Hz
−60dB	3·5kHz	1,100Hz
−70dB	3·7kHz	3,000Hz

The total passband ripple on the ssb filter was about 3dB, and the skirt response was symmetrical. The gain using the cw filter was 6dB lower than using the ssb filter. The cw filter also exhibited a number of spurious responses between −50 and −70dB.

Transmitter measurements

CW power output

Adopting the tuning procedure described in the handbook for maximum power output gave the following results:

Band	Power output	Anode current
1·8MHz	108W	270mA
3·5MHz	114W	260mA
7MHz	107W	260mA
10MHz	110W	260mA
14MHz	110W	270mA
18MHz	107W	270mA
21MHz	100W	250mA
24MHz	102W	260mA
28MHz	80W	230mA

The drive control may be used to reduce the power output virtually to zero and hence set the power output on 1·8MHz to 8W (9dBW).

Harmonics and spurious outputs

Harmonics and other spurious outputs were measured on cw at full power output.

Band	Harmonics	Other spurii
1·8MHz	−43dB	Less than −80dB
3·5MHz	−43dB	78dB
7MHz	−46dB	−50dB. −80dB at lower power
10MHz	−49dB	−62dB
14MHz	−58dB	Less than −80dB
18MHz	−52dB	−24dB. −40dB at lower power
21MHz	−49dB	−63dB
24MHz	−32dB	−55 to −65dB
28MHz	−50dB	Several −60 to −70dB

On 7 and 18MHz substantial reductions in spurious outputs could be achieved by reducing the power output slightly. The figure of −24dB to −40dB for spurious output on 18MHz is not surprising and is the inevitable consequence of using a 9MHz i.f.. This spurious signal is the second harmonic of the i.f. and cannot be reduced by signal frequency selectivity. The only solution is to use a balanced mixer, which is used in this transceiver, and to operate the mixer in as linear a manner as possible. The mixer linearity improves at reduced power levels, and hence the dramatic improvement in spurious output.

SSB power output and distortion
The test arrangement for making ssb measurements is shown in Fig 2(c); 600Hz and 2kHz equal amplitude audio tones were used. Measurements were made with the processor switched off and adopting the tuning procedure described in the handbook. In all cases the intermodulation product level is quoted with respect to the amplitude of either tone of the two-tone test signal.

Band	Power output (p.e.p.)	Third-order ips	Intermodulation products at ±10kHz	±20kHz
1·8MHz	32W	−38dB	−80dB	−80dB
3·5MHz	100W	−32dB	−80dB	−80dB
7MHz	100W	−25dB	−80dB	−80dB
10MHz	100W	−25dB	−70dB	−80dB
14MHz	100W	−26dB	−80dB	−80dB
18MHz	100W	−28dB	−80dB	−80dB
21MHz	100W	−22dB	−70dB	−80dB
24MHz	100W	−24dB	−75dB	−80dB
28MHz	80W	−26dB	−75dB	−80dB

On 1·8MHz 100W p.e.p. output can be obtained at −22dB ip level.

With the speech processor in operation it is important not to overdrive the pa as intermodulation product levels as high as −12dB can be generated.

The carrier suppression was −56dB and the sideband suppression at 1kHz was −66dB, both measured with respect to 100W output.

Audio response
The transmitter audio response with the processor off was measured as 300 to 2,700Hz between the −6dB points. The microphone sensitivity was such that 4mV audio input gave full output with the processor switched off. The microphone input impedance is 600Ω.

Frequency stability
The frequency drift was measured in the transmit mode on 28MHz with the pa heaters switched off and the low-level rf output connected to a frequency counter. After allowing an initial 5min warm-up period, the transceiver drifted 240Hz during the first 15min, a total of 450Hz during the first hour and 120Hz during the second hour.

Low-power (transverter) output
A low-power output facility is provided, coupling to the pa grid circuitry through a 10pF capacitor. Although the output impedance is high, in most cases a 50Ω load impedance will probably be used. On 21, 24 and 28MHz, 150mW output power into 50Ω is available. On bands below 21MHz the available power reduces rapidly. With a 50Ω load connected to the low-power output socket, a slight difference in preselector tuning between transmit and receive is obtained. It is probably advisable to unplug any leads connected to this socket when not required.

On-the-air results
The transceiver was used from the home location for a period of two months which also encompassed operation in two contests—AFS and ARRL CW. It is largely to the credit of this transceiver that 160 contacts were made in AFS and 1,400 in the ARRL event.

The receiver generally performed very well. The sensitivity on 28MHz was perfectly adequate, and on the lower frequency bands, with 20dB attenuation, clean results were obtained. Careful use of the attenuator was essential for best results. The noise blanker was effective but could generate signal-handling problems if the threshold control was advanced too far. The width and audio filter controls have their uses, and the notch filter was found to be particularly useful.

On transmit good clean reports were received on ssb, with most stations contacted preferring the processor switched on. The preselector tuning was rather critical on the lower frequency bands, requiring repeaking after a frequency shift of only a few kilohertz. Preselector drift with temperature or time was also experienced. FM on 29MHz was also used and gave good results.

Several stations who were also using the FT101ZD were worked. In all cases the owners were entirely satisfied with the performance and the reliability. Mobile operation was not contemplated. The size of the transceiver together with the power consumption due to the valve driver and pa stages dictates that it is more suitable for home station use.

Microphone and headphone accessories
A number of microphones and headphones marketed by Yaesu are suitable for use with the FT101ZD. Two types of microphone and two types of headphone were provided with the review transceiver, and the following purely subjective observations were made.

Of the headphones, the YH55 with full-size ear muffs provided complete isolation from external noise, gave excellent communications quality with low distortion at high volume levels, but had a rather high clamping force on the ears which would probably reduce with use. The YH77 lightweight headphones are suitable for use where complete isolation from the outside environment is not required. They were comfortable to wear, but were less sensitive than the YH55 headphones—requiring more audio gain—and, at little more than average listening levels, the audio stages in the FT101ZD overloaded causing distortion. Using the headphones in conjunction with hi-fi audio equipment showed that the frequency response of the YH55 is largely tailored for communications use, whereas the YH77 gave full hi-fi performance.

The microphones were evaluated during local contacts. Very complementary reports were obtained using the YE7A dynamic microphone, particularly with the processor on. The YM21 noise-cancelling microphone was generally regarded as lacking punch, being described as rather "thin" with the noise-cancelling switched off and "woolly" with the noise-cancelling on. However, it is understood that this microphone really comes into its own in noisy mobile environments.

Conclusions
The FT101ZD is provided with an accessory plug, two phono plugs, a spare fuse and a 63-page manual. Full operating instructions are given in the manual together with installation instructions for the various options. Circuit descriptions with diagrams and photographs of the various boards are given, together with alignment details and a full parts list. The circuit description and the overall block diagram do not agree in several places. The block diagram appears to be of an earlier version.

The basic FT101ZD is about £635 incl VAT, and the analogue dial version, the FT101Z, is about £559 incl VAT. The various options are extra.

Acknowledgements
The transceiver used in this review was kindly loaned by South Midlands Communications Ltd of Totton, Southampton. The reviewer would like to thank G3UFY and G3WBN for their critical on-the-air comments, and fellow members of the Addiscombe Amateur Radio Club for their comments on the performance during the ARRL CW contest.

Reference

[1] "The Icom IC720A hf transceiver," P. J. Hart, G3SJX. *Rad Com* February 1982, pp129–33.