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The Heathkit Mohican

Dr Bruce Taylor HB9ANY describes a ground-breaking shortwave transistor receiver.

Although the Heath Company started producing electronic kits in 1947, and the US manufacturer had sold a crystal controlled three-valve CW transmitter as early as 1952, it was from 1956 that the Heathkit brand name became well known in the world of amateur radio, with the launch of the popular DX-100 transmitter. This was followed in 1959 with the first of the *Native Indian Tribes* series, the Apache transmitter and Mohawk receiver. All these rigs were vacuum tube designs, for transistors with high performance at HF were expensive at that time. (The retail price of a humble OC45 in mid 1959 was 35/-, about £43 in today's money).

But in March 1960, three years before Eddystone launched the transistorised EC10, and four before National introduced the transistor version of the HRO, the fully solid-state Heathkit GC-1 Mohican receiver kit was produced using ten transistors, four diodes and a Zener voltage stabiliser. This was followed in 1962 by the more successful GC-1A version, with improved audio quality and better HF stability. These attractively styled sets were some of the earliest of what became the extensive series of successful Heathkit *Green Machines*.

Although it was possible to import US Heathkits to the UK, they often had 115V power supplies and were subject to high customs duty and purchase tax. Hence Daystrom Ltd (a subsidiary of the Daystrom Group that owned the Heath Company at the time) decided to produce a British version of the Mohican that used largely UK components, including Mullard transistors instead of 2N series types. It was designated the GC-1U, **Fig. 1**.

In its heyday, Daystrom Ltd employed almost 200 people and occupied part of a large facility near Gloucester, **Fig. 2**. It also had Heathkit Centres in London and Birmingham and a mobile showroom that displayed kits at amateur radio events across the country. US advertisements claimed that an experienced amateur could assemble the GC-1A from the kit in around 30 hours. The GC-1U required less work because the RF front-end was preassembled and Daystrom also offered ready-built sets for a cost supplement. During the golden Heathkit years, some Daystrom employees (and at least one teenage son) earned a bonus doing 'out working', assembling kits in their homes in the evenings to keep up with demand.

The GC-1U kit was launched in the UK in August 1961 at a price of £38.75. (About £920 in today's money). It remained in production until 1969, when the price of the kit was £37.88 while the ready-built model (A/GC-1U) cost £45.88. Short term hire purchase was offered, but modern day XYLs would be astounded that in the zeitgeist of the 1960s any married woman who applied for this credit was required to submit the employment details of her husband! Today, Mohicans are typically offered on eBay and at swap meets and SK sales for around £50-150, depending on condition. While this classic receiver is outperformed by modern sets, it was a historic milestone in portable shortwave transistor radio development and makes an interesting restoration or educational training project.

Design

Because the Mohican is a conventional single-conversion superhet that uses discrete components, and was designed for home assembly, it is particularly straightforward to work on and restore to original specifications. The 60-page GC-1U instruction manual, which in 1961 could be purchased separately for 88p, specifies every step of the assembly in minute detail and contains all the information required for a complete strip-down and rebuild of the receiver. Normally a manual should accompany a built receiver but if it is missing, original ones can be found for around £15 on eBay, while a digital file can be purchased for even less. The numerous assembly drawings are much more comprehensive than those given in the maintenance manuals of any ready-built radio equipment. Nine of the diagrams in the manual were even provided in the form of separate folded 34 x 43cm sheets for attachment to the wall above the working area. An example is shown in **Fig. 3**.

I've provided the original factory circuit diagram and some documents for the GC-1U here:

Schematic diagram:
https://tinyurl.com/GC1USchematic
Parts list:
https://tinyurl.com/GC1UPartsList
Performance graphs:
https://tinyurl.com/GC1UPerformance
Sales brochure:
https://tinyurl.com/GC1USalesBroch

Note that the 2.2kΩ collector resistor of IF transistor X5 is missing from the schematic diagram. A minor inconvenience is that the component designations (R1, R2, etc) shown in the diagram are not carried over to the parts list.

The Mohican provides continuous coverage from 550kHz to 30MHz in five bands (the GC prefix stands for General Coverage), so it is suitable for both MW broadcast reception and general shortwave listening. On the shortwave bands the receiver has adequate sensitivity of 2μV for a signal-to-noise ratio of 10dB at 50mW audio output.

Fig. 1: The 10-transistor Mohican was a milestone in portable shortwave receiver design.
Fig. 2: Until 1976 Heathkits were produced in a part of this large facility near Gloucester.
Fig. 3: Seven large assembly drawing sheets complement the figures in the instruction manual.


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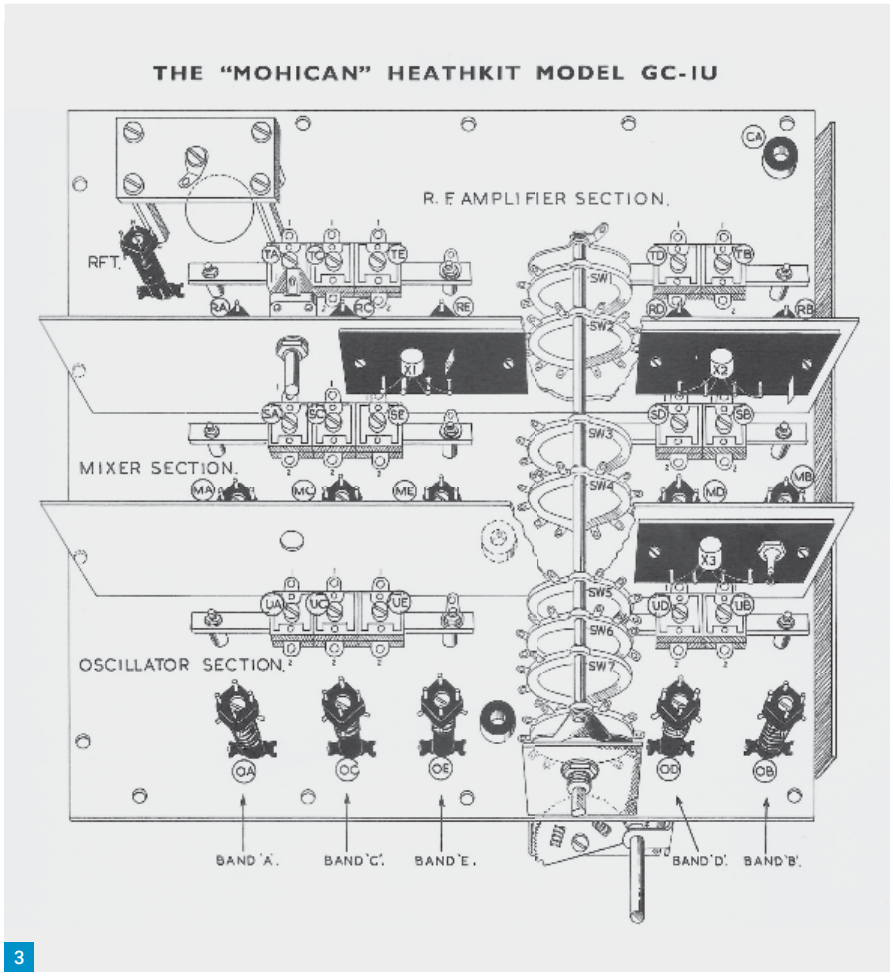

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But delicate manipulation of the tuning, RF and AF gains, antenna trimmer and BFO is required to resolve SSB signals satisfactorily.

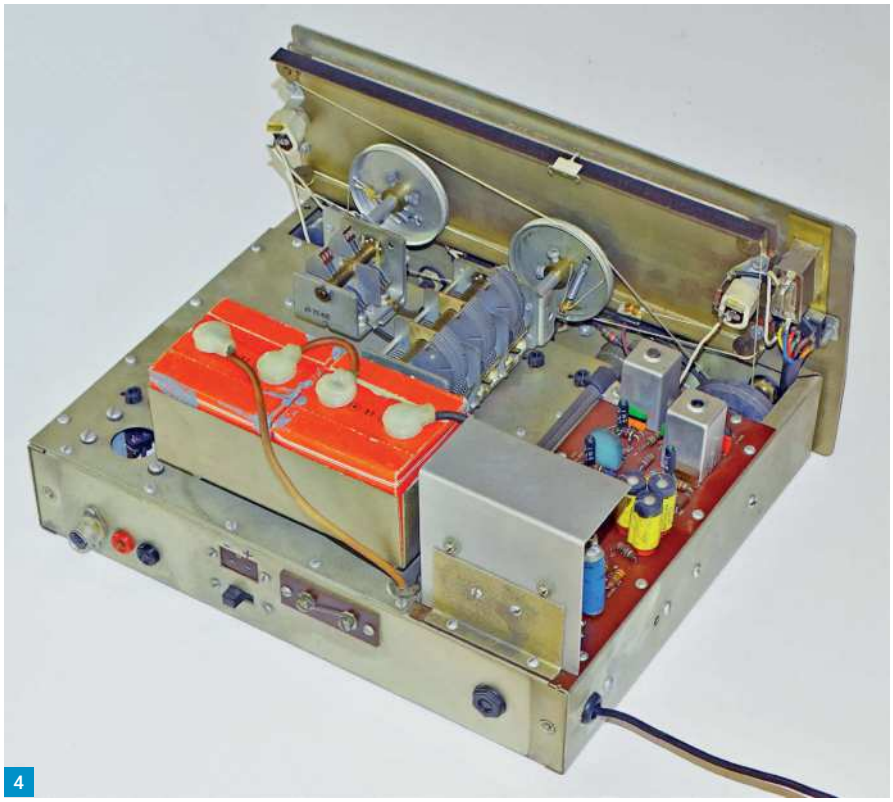
The main tuning is supplemented by a separate control that provides calibrated bandspread tuning specifically for the 10, 15, 20, 40 and 80 metre amateur bands, as well as an additional general logging scale with 100 finer subdivisions. This is achieved by a small two-gang variable capacitor effectively in parallel with the oscillator and mixer sections of the main three-gang tuner, **Fig. 4**. The US GC-1A has only a single-gang bandspread capacitor, which tunes the oscillator.

Both of the 24cm wide slide-rule scales have quite different calibration from those of the GC-1A, reflecting the different amateur frequency allocations in Europe at the time. For example, the 4th bandspread scale of the US receiver covers the range 26 to 29.7MHz, thus including the 11m citizens band, whereas the GC-1U spreads the narrower range 28 to 30MHz over more than 75% of the dial width. Of course, the absolute accuracy of the wide bandspread scales depends on the precision of the main dial setting. Note that the main tuning calibration is only correct when the bandspread tuning is at the 'Set' mark at 97 on the 0-100 logging scale. The tuning drives of the GC-1U are smooth and they both have anti-backlash split gears and lead flywheels, but the plastic knobs are of poorer quality than the metal ones fitted to the GC-1A. Only the small knobs have internal metal bushings and the bandswitch knob in particular is easily broken if its set screw is overtightened.

Although they use different transistor types, both the US and UK receiver models have an RF amplifier, three IF stages, a simple impulse noise limiter, a BFO that is tuned by a varicap diode and AVC that can be switched off for CW and SSB reception. They have a useful 1mA edge-reading relative signal strength meter, calibrated from 0 to 10 rather than in S units. An important difference between the GC-1A and GC-1U for amateur station use is that only the UK model has RF input transformers with low impedance primary windings for a 75Ω coax antenna input. Both models have sockets for a higher impedance wire antenna and a ten-section telescopic whip that can be extended to a total length of 131cm. When the coax input is in use the whip antenna can easily be unmounted to prevent the pickup of local interference and RF when transmitting. Contrary to what is stated in the manual the high and low impedance inputs are not switch selected. A front panel antenna trimmer is provided by a 20pF variable capacitor that parallels the main 290pF RF tuning one. Since Daystrom Ltd couldn't find a UK supplier for the whip antenna, this component had to be imported from the US. To avoid delaying shipments to early customers the kits were sent out without the antenna, and this part was supplied at a later date after they arrived in the UK.

Three Mullard AF115 transistors are used for the grounded base RF amplifier and local oscillator of the GC-1U, as well as the common emitter mixer stage. There is no trap to reduce IF breakthrough. The other seven transistors are mounted on a single-sided PCB, **Fig. 5**. Four OC45s are used for the common emitter IF amplifiers and the grounded base BFO. The audio amplifier uses

Fig. 4: This general view of the Mohican chassis shows the rear panel components and the cord-driven main and bandspread tuning capacitors. Fig. 5: A single printed circuit board carries the IF strip, the detector, the noise limiter, the BFO and the audio output stages. Fig. 6: The IF characteristic is shaped by Clevite transfilters (light blue) and emitter traps (dark blue). Fig. 7: All the trimmers and cores for the realignment of the RF front end are readily accessible.



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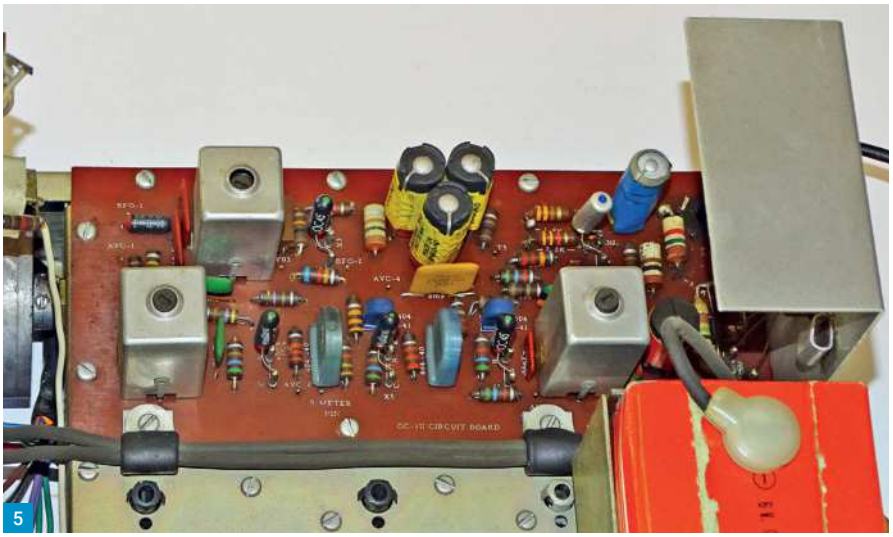

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an OC81D driver transistor, transformer-coupled to match the lower base impedance of a pair of push-pull OC81s that are capacity coupled to an internal 25Ω loudspeaker. This loudspeaker is disconnected when headphones or an external loudspeaker are plugged into a jack socket on the rear panel.

The 1mm cadmium-plated sheet steel chassis and 1.3mm front panel are well made and quite sturdy, but the construction hardly compares with the machined aluminium castings of Eddystone receivers of this era. The dual-tone stove enamelled paint finish of the front panel is durable but the silk-screened control markings tend to wear off. There are no markings to identify the sockets, terminals and switch on the rear panel. Instead, the kit included a full-size gummed paper sheet with appropriate lettering (see URL below, at 100% scale). This appears to have been an afterthought, as there is no mention in the manual of how it was intended to be used. (The lettering could be cut out, or the entire sheet stuck to the panel and holes made in it for the components.)

https://tinyurl.com/GC1URearPanel

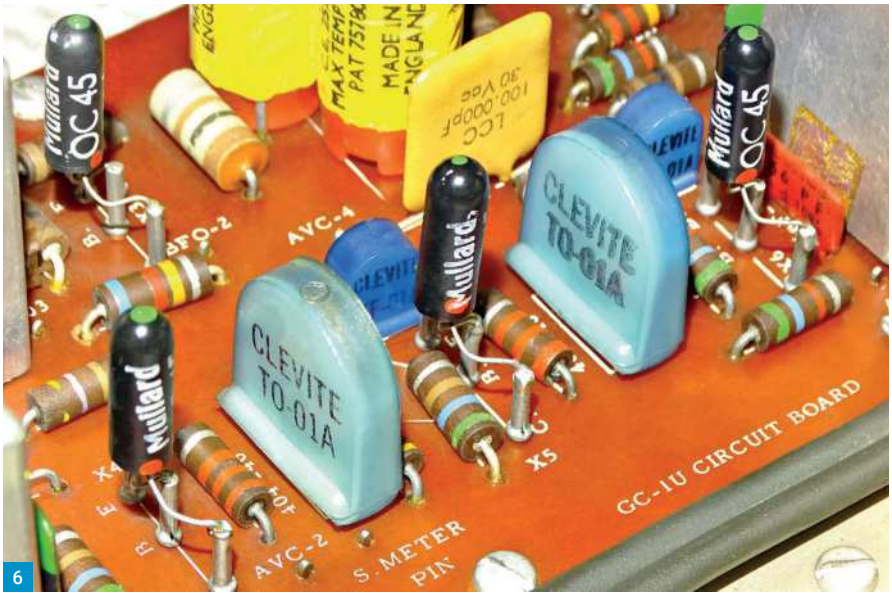
The elliptical loudspeaker of the GC-1A is mounted inside the top of the cabinet, and the carrying handle can optionally be fixed to the top or to the right side. While a case of this type is shown in early catalogue pictures of the GC-1U, most production kits had the loudspeaker mounted on studs inside the right-hand side and the handle can only be mounted on the top.

Alignment

The 455kHz IF characteristic is shaped by a pair of Clevite TO-01A piezoelectric overtone ceramic transfilters in conjunction with conventional double-tuned input and output IF transformers and TF-01A emitter traps, **Fig. 6**. The traps increase the selectivity by providing an RF bypass of the emitter resistors at their series resonant frequency. The passband is about 2.9kHz wide at 6dB down and 3.7kHz wide at 10dB down. The transfilters require no alignment, a good feature for a kit that might be assembled by people without test equipment. They are normally reliable and in the case of performance degradation they can be opened to allow the discs and spring contacts to be cleaned with isopropyl alcohol.

If a wobbulator is not available, the IF transformers can be aligned simply by adjusting the upper and lower cores in each transformer for maximum signal strength, after setting the signal generator frequency to the peak of the transfilter response. Image rejection was specified as 'average 30dB over the five bands' but with a 455kHz IF and only one RF amplifier stage, it can be as low as 12dB on the higher frequency bands. The core in the BFO coil is adjusted for zero beat with a signal that is centred in the IF passband and with the front panel control set at the midway position.

To avoid the problem of home alignment, the RF front-end of the GC-1U was supplied as a preassembled, wired and aligned unit, **Fig. 7**. However, the compound securing the ferrite cores of the inductors is not entirely stable and even a newly built kit could normally benefit from realignment. Before starting the work, adjust the positions of the dial cord pulleys on their shafts such that the tuning and bandspread capacitors are fully closed when the pointers are at the left-hand end of the scales. Then move the bandpass tuning to the 'Set' position near the opposite end of the scale. Realignment follows normal procedure, iteratively adjusting the cores of the coils at the low frequency ends of the ranges and the trimmers at the high frequency ends and checking that the image signal has not been tuned in error. Note that on the highest frequency band the local



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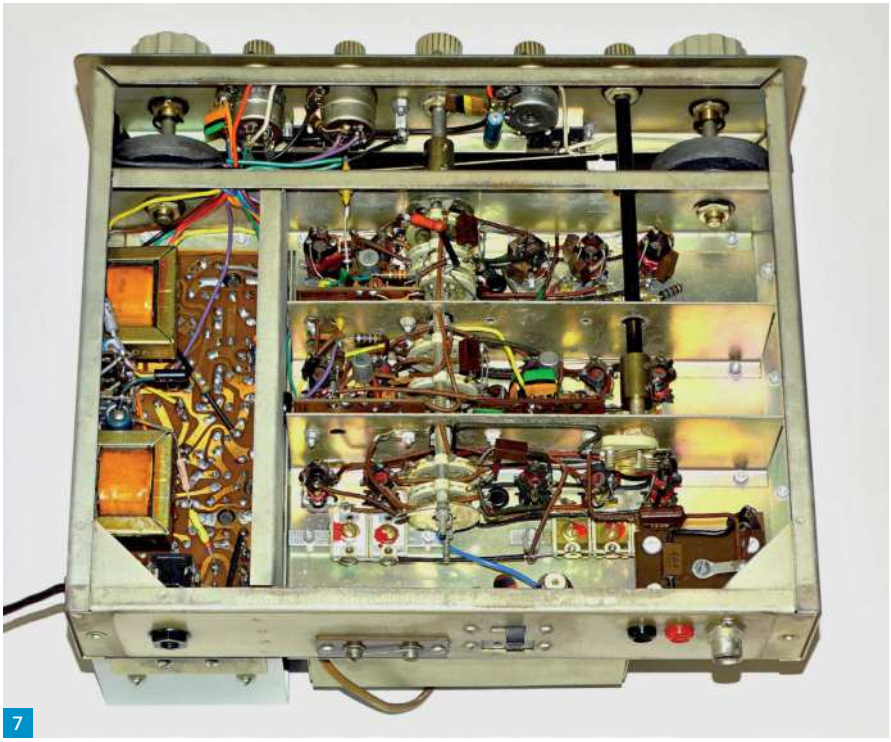
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oscillator is on the low frequency side of the signal instead of the high side. However, it may be found that performance is improved by aligning it on the high side instead.

Power Supply

Since the Mohican was designed to be suitable for portable or mobile use, provision is made to power it at 12V from batteries housed inside the case. The battery box of the GC-1A takes eight C-size 1.5V cells, which are held in place by a pair of long coil springs. For mains operation, the entire pack can be unplugged and replaced with a 117V AC power supply through a large opening in the rear panel. This optional 12V 200mA mains power supply, Model XP-2, was sold in kit form for $9.95 at a time when the receiver cost $109.95 as a kit, or $193.50 assembled. It is a simple design with no voltage regulation and a two-section 0.483Ω/1000µF RC filter instead of a smoothing choke. As the dial lamps in the receiver act as a bleeder resistor, they are permanently on when mains power is in use and the voltage will rise if they fail. Since most US users installed the XP-2, the original GC-1A battery boxes became separated and are now somewhat rare.

On the other hand, the GC-1U battery box, **Fig. 8**, is permanently fixed to the chassis and is designed to hold a pair of 6V batteries such as Ever Ready PP1, GEC BB21, Vidor VT1 or Leclanché Type 812. To secure the batteries in place the box has an internal foam lining that disintegrates with time, but can easily be stripped out and replaced. It should be noted that whereas all these batteries have the same press-stud connector spacing of 35mm, on some they are oriented at right angles to those on others. Today these batteries cost about £10 each, and it is more economical to power the receiver from an external rechargeable battery or a small mains power supply. In 1963, Daystrom offered a Model UBE-1 230V AC 'battery eliminator' for the set for £2.88. The external supply can be selected by a switch on the rear panel and a socket is provided to connect it with a special polarised plug, **Fig. 9**, that was provided with the kit. The supply should be fused, since the plug has male pins, so there is a danger of accidental short-circuit when it is not inserted. Since the GC-1U wasn't designed to accommodate an internal mains power supply, its cabinet is not provided with ventilation holes.

In 1961 I fitted a GC-1U in my 307E Ford Anglia van and used it until 1969 as a normal car radio for broadcast reception. During my daily commute I also operated it very successfully as GM3NZI/M on the 80m band with a 25W transmitter, a boom microphone and a centre-loaded whip antenna. Since the Mohican has PNP transistors its chassis is positive, which is compatible with the electrics of many vehicles of that vintage. The external power supply input is filtered by a 1.1mH RF choke and 1000pF bypass capacitor and there were no problems with alternator noise.

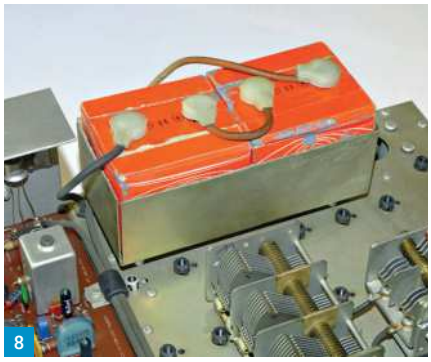
Modifications

After the printing of the Mohican instruction manual, Daystrom made a number of modifications to the circuitry and published the list of errata that I have provided here:

https://tinyurl.com/GC1UErrata

The values of several resistors were changed and the 8V Zener diode was replaced by a 6.4V one having a lower temperature coefficient. Hence the voltages of the first stages are lower than indicated in the table in the manual. Frequency pulling can be reduced by adding a second Zener diode to stabilise the oscillator bias separately from the RF amplifier and mixer. A 0.05µF capacitor was added between the cathode of the detector diode and the slider of the volume potentiometer. The audio driver transistor was changed from an OC78D to an OC81D, while the audio output transistors were changed from OC78s to OC81s. Towards the end of production a Mk.2 version of the GC-1U was produced but these are very rare.

When the AVC is switched off, a reverse polarity voltage can be applied to the 8µF electrolytic capacitor C27. Failure of the capacitor can be averted by changing it to a non-polarised 0.1µF component, while adding an 8µF or 16µF electrolytic capacitor across C96 to restore the AVC time constant.



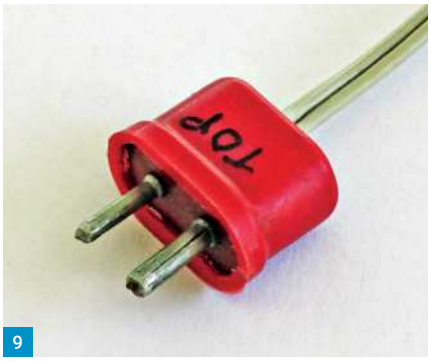


Fig. 8: Unlike the US Mohican, the GC-1U accommodates a pair of 6V PP1 batteries. Fig. 9: A polarised plug is used for connecting an external power supply. Fig. 10: Higher power audio output transistors can be mounted on an extended heatsink. Fig. 11: An output transformer (right) for a larger 3Ω loudspeaker can be fitted under the chassis.

Unlike the GC-1A, which has a momentary action dial lamp switch when battery power is in use, the UK Mohican has a normal on/off type. The original dial lamps are rated 6.3V 110mA. They are connected in series with a 12Ω resistor and this chain draws about 100mA from a 12V supply, more than the quiescent current drain of the receiver itself. This can be greatly reduced by replacing the lamps by a pair of LEDs with an appropriately larger value of series resistor.

The muting terminals provided at the rear of the GC-1U chassis allow the positive pole of the internal battery or external power supply to be disconnected from chassis ground by a relay or switch when transmitting. These terminals must be jumpered when muting is not in use. If the output of the external power supply is not floating, this configuration can't be used and the muting terminals can be rewired in series with the black wire from the main power switch instead. This will also prevent the dial lamps being extinguished on transmit, which is less than ideal in most circumstances. The antenna switch should ground the input to the receiver when transmitting and if the receiver is used in the proximity of a powerful transmitter, it may also be advisable to protect the RF amplifier transistor further by adding a small relay to short the input to C10 to ground during mute.

Since it was intended that the Mohican could be powered from dry batteries, it was designed to have a very low current consumption (with the dial lamps switched off) of around 35mA. As a result, the audio output power from the internal 25Ω loudspeaker is rather inadequate for the noisy conditions of mobile use. The power can be increased by replacing the OC81 output transistors by an IC amplifier or by higher rated ones such as OC206s mounted on an extended heatsink, **Fig. 10**. These can drive a more powerful 3Ω speaker via an output transformer that can be fitted easily under the chassis, **Fig. 11**. It's worth inserting a miniature connector inline with the internal loudspeaker cable to avoid having to remove the speaker or manipulate the whole cabinet when working on the chassis of the receiver.

Restoration

The glass encapsulated OC-series Mullard transistors used in the GC-1U are quite reliable but the AF115 transistors in the front end often develop internal short circuits due to the growth of very fine tin whiskers from the surface of their metal cases. The whiskers tend to grow even in unused transistors with no internal electric field present. This problem is not unique to transistors and has also been known to cause bridging between soldered joints, especially with modern lead-free solders that have a higher tin content than earlier alloys. The troublesome whiskering phenomenon is not well understood, although it has been known since at least the 1940s and is believed to have been the cause of the loss of the Galaxy IV telecommunications satellite in 1998 and the temporary shutdown of Millstone Nuclear Power Plant in 2005. For the GC-1U, replacement of the AF115 transistors by more modern types is the only sure solution to the problem. Occasionally such whiskers have been successfully cleared by tapping the transistor case, or fused by discharging a capacitor between the case and the affected pins, but they generally grow back later.

Other defects commonly found in any 60-year-old receiver are leaking or open-circuit electrolytic capacitors and carbon composition resistors that have drifted high in value. The faulty components can be located by voltage checks and individual testing with a DMM. But if an efficient desoldering tool is available (and this is a very useful accessory to have in any amateur workshop), the best approach can simply be to clip them all out and replace them with new ones. Snip the components in the middle and then extract the wire stubs individually from the PCB using the heated suction pump. Equivalent modern components are readily available and are not expensive.

Since the Mohican was designed for home construction, the receiver can be very simply and rapidly completely disassembled by reversing the detailed instructions. With new capacitors, resistors, wire and dial cord this creates a replica kit that can be built by a beginner to learn about electronics and acquire useful practical skills. In addition to the assembly instructions, the manual includes detailed circuit descriptions, construction notes, component drawings, information about chassis wiring and soldering technique, a glossary of radio terms and even a short introduction to alloy junction transistors.

In these days of complex factory-made black-box rigs that can't be serviced or modified by the average amateur, such a kit makes a valuable educational trainer for a novice. As with the original Heathkits, the sense of achievement evoked by the experience of successfully building the receiver can inspire an interest in amateur radio and electronics that could lead to an enjoyable hobby or a rewarding career. **PW**