An all-in-one device for testing and aligning AM radios

The H-field Transanalyser

Many SILICON CHIP readers are into restoring, repairing or even building AM radio receivers. With this test set, you don't need to make any direct connections to the radio's front end. This ensures that the tests are realistic and the alignment is spot-on. While it's a fairly complex device, all the construction steps are quite straightforward and using it is a breeze.

I spent many years of adjusting and tuning up transistor radios using some very expensive laboratory RF generators and oscilloscopes.

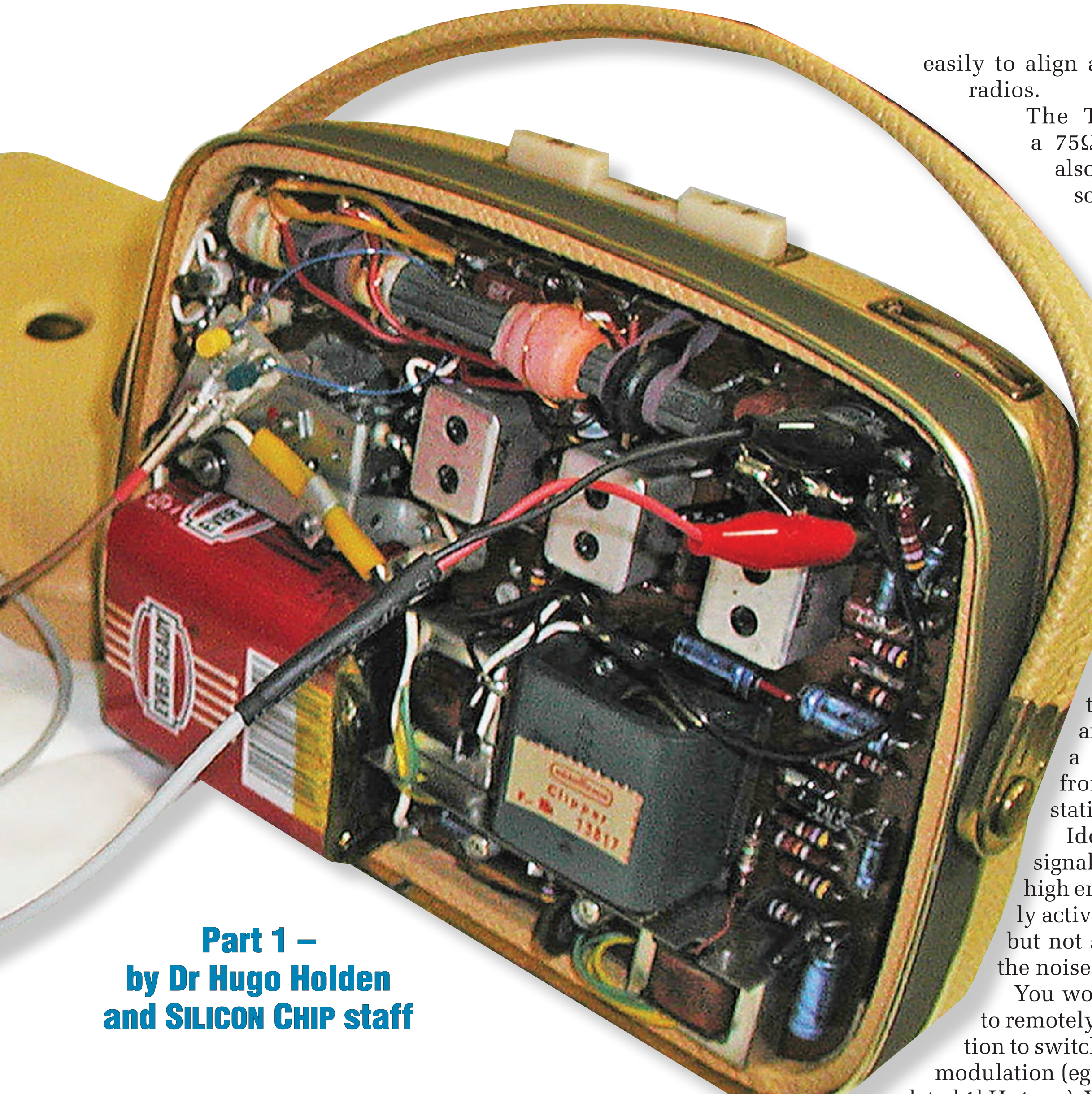
Eventually, I realised that it was best to avoid feeding signals directly into any part of a radio's circuitry.

While technicians often do this and it is recommended in service manuals, the coupling of any signals fed into a radio needs to be very loose, or else the stage that the generator's signal feeds into is always detuned to some degree.

Any adjustment made using this test signal will be partially (or sometimes wholly) incorrect after removing the generator's connection.

So I decided to create short-range loop transmitting antennas, driven by controlled energy, to generate near-field magnetic radiation.

By carefully controlling the level, modulation etc it is possible to provide a radio with signals of similar intensities to those that it would pick up from the magnetic component of the EM wave from a far-off radio station. This



Part 1 – by Dr Hugo Holden and SILICON CHIP staff

is an ideal way to test and align a radio.

This is called near-field radiation because the region close to the loop antenna, say within 10 meters, is much smaller than the wavelength of the transmission, eg, 300m for a 1MHz signal.

Also, as most small transistor radios do not have external antenna sockets, the ability to deliver a controlled and known RF voltage level into their input circuits is otherwise difficult.

The standard solution is to inject a signal into some part of the input circuit. But this gives different results than injecting a signal into a radio with external antenna inputs designed to handle a particular source impedance.

The H-Field Transanalyser described here is a system where an 'H field' is generated by a controlled RF source derived from a 1kHz-modulated variable frequency carrier wave. It has attenuator control to a level below which any transistor radio can detect. This magnetic radiation is coupled to the radio's ferrite rod with a single loop of wire around the ferrite rod, and the rod's tuned main winding area.

The H-Field Transanalyser gives the ability to both objectively and subjectively analyse the performance of an AM radio.

It also provides a 1kHz test signal for the radio's audio amplifier system. It is a complete tool to fully and accurately calibrate a broadcast band AM transistor radio, including the radio's intermediate frequency stages.

The VFO was made to go below 455kHz (to around 205kHz) so that most AM band transistor radio IF stages, including those which operate at 262kHz, can be aligned.

With another switch added, the frequency range can be down-shifted easily to align and test long-wave radios.

The Transanalyser has a 75Ω output so it can also be used as a signal source (with a dummy antenna consisting of a series 330Ω resistor and 250pF capacitor) over the range of 205-1800kHz. This is useful for aligning and testing valve-based AM radios.

The ideal alignment signal

The ideal RF test signal to align a transistor radio (or any radio) would be a transmitted signal from a distant radio station.

Ideally, the received signal level would be not high enough to significantly activate the radio's AGC, but not so low in level that the noise was too dominant.

You would need to be able to remotely order the radio station to switch on or off its carrier modulation (eg, with a 30% modulated 1kHz tone). You would also need to be able to alter its transmission frequency, to check the radio across the whole band for its sensitivity and frequency-dial calibration. Such a notion is impractical, of course.

However, if you consider that a transistor radio responds to the magnetic component of the far-field of a transmitted radio wave (ie, the H field), then a replica H field can be generated locally by a small loop placed around the ferrite rod antenna.

The loop is then driven by a modulated and controlled-level RF current source.

This is not a new idea. For example, a three-turn electrostatically shielded 10in diameter loop, placed 24in from the radio, is recommended for the alignment of English radios such as the Hacker Sovereign and others in the book *"Radio and Television Servicing"* by R. N. Wainwright, published

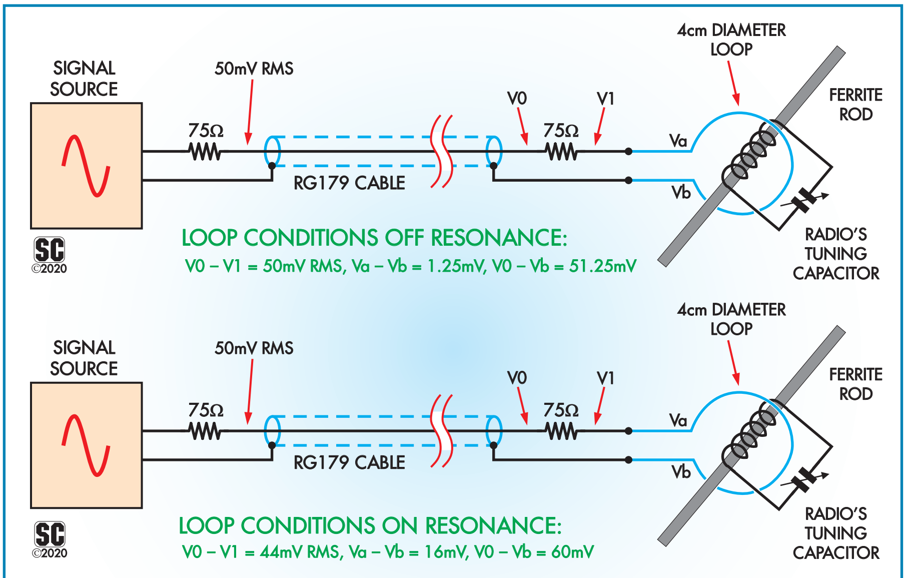


Fig.1: when the signal generator frequency is significantly different from the radio's tuned frequency, there is little voltage across the loop; most of the 50mV signal voltage is dropped across the 75Ω resistor in series with the loop. When the frequencies match, the voltage across the loop rises to around 16mV RMS.

by McDonald & Co in 1971.

But the exact signal level supplied by the generator was not specified, and the resultant H-field intensity is dependent on the exact spacing between the radio and the loop.

The H-field intensity is proportional to IR^2, where I is the loop current and R the radius of the loop. But it is also inversely proportional to $(Z^2 + R^2)^{1.5}$, where Z is the distance from the loop plane to the centre of the receiving antenna.

The H field (magnetic intensity in amps per meter) from the loop is converted to a B field (flux density in Teslas) by the ferrite rod.

The relationship is B = UoUrH, where Uo is $4\pi \times 10^{-7}$, and Ur is the relative permeability of the rod, which for a transistor radio is usually around 125.

Designing the H-field generator

My first experiment was to place a loop around a standard ferrite rod and tuning coil assembly on a typical AM broadcast band radio, over the main resonant winding area. I then loaded the loop with a series of resistors and observed the effect that this had on the performance of the tuned antenna circuit.

With the radio tuned to a weak distant station, I found that the loop needed to be loaded with less than 30-50Ω to noticeably reduce the sensitivity of the radio. The effect of loading it with 75-150Ω was only just detectable.

Therefore, I decided that a source impedance of 150Ω would be satisfactory to inject current into the loop, without altering the tuning conditions and Q of the radio's tuned antenna coil.

This impedance was organised by using a generator with a 75Ω output impedance and adding a 75Ω series resistor.

Fig.1(a) shows an RF source driving a small loop. The actual loop size is not too important, as it represents one magnetic turn around the ferrite rod. It is ideal if it passes over the central area of the main tuned winding on the rod. The wires leading to the loop can also be twisted together (or not) with little effect.

Experiments with a 1400kHz test signal showed that the reactance of a 4cm loop (with negligible DC resistance) is so low over the applied frequency range that it can be ignored. For example, with a 50mV RMS signal across the 75Ω resistor in series with the loop, the voltage across the loop was only about 0.8mV RMS.

Then, with typical radio ferrite rod (Ur = 125) through the loop's centre, still only about 1.25mV was developed across the loop. This is the case when the radio's input tuned frequency is significantly different from the generator frequency.

However, when the tuned circuit on the radio's ferrite rod is tuned (peaked) to the same value as the applied RF frequency, the impedance of the loop elevates, and the phase of the voltage across the loop becomes in-phase with the generator voltage. Fig.1(b) shows the voltages under this resonant condition.

The voltage across the loop rises to about 16mV and V0 elevates by about 10mV, to 60mV as the load current is reduced. Therefore, resonance effects coupled back by mutual coupling into the loop results in the applied loop current dropping, but only by a little. The previous 50mV developed across the 75Ω resistor immediately in series with the loop drops from 50mV to 44mV RMS.

Due to the relatively small change in the loop current (and therefore H-field intensity drop) from a non-resonant to a resonant condition, I considered it unnecessary to create a constant-current drive for the loop. Therefore, I decided to use my test arrangement of a 75Ω generator with a 75Ω series resistor, in the final design.

One major advantage of this is that the Transanalyser unit can act as a standard 75Ω output modulated laboratory generator where required (say, for aligning valve radios).

Transanalyser design

In my design, 0dB on the attenuator results in an unmodulated 50mV RMS signal applied to a 75Ω load from the 75Ω source. Philips used this standard arrangement in their wonderful PM5326 RF generator.

The Transanalyser, in effect, produces an identical RF output to the PM5326 generator, but has a stepped attenuator (rather than a variable one) and operates over the frequency range of 205-1800kHz. In contrast, the PM5326 goes to 125MHz. However, as noted above, this range can be easily altered by changing the timing capacitor on the MAX038.

The VFO in the Transanalyser has been built around a MAX038 frequency synthesiser IC, primarily because its output level is perfectly uniform across the whole frequency range.

I tried other discrete transistor VFOs based on the red oscillator coils from transistor radios, but they required many additional parts to level the output over the full tuning range.

Although the MAX038 is obsolete, they are still easy to get. But some of these chips coming of China are re-

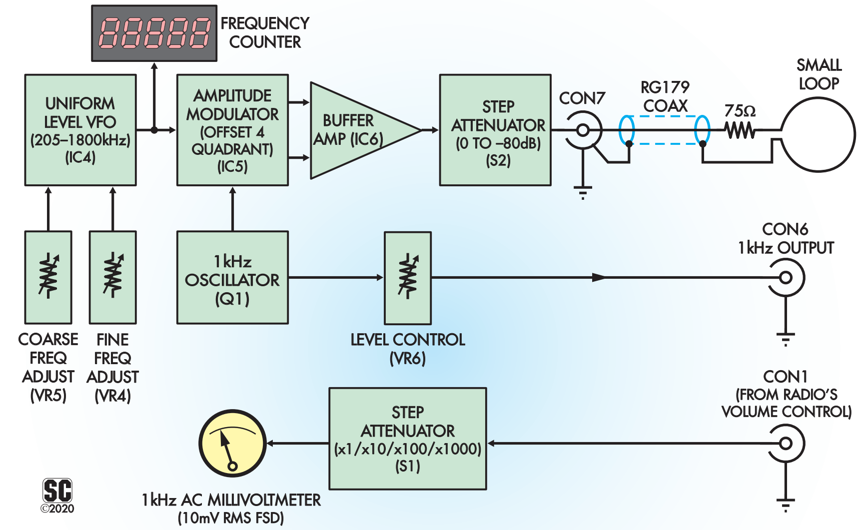


Fig.2: the Transanalyser block diagram. VR4 and VR5 set the VFO frequency, which is read out on an LED display. The VFO output and 1kHz test signal are fed into modulator IC5, and the 30% modulated signal is then buffered by IC6 and fed to the 0-80dB step modulator before going onto CON7 and the test loop. A separate 1kHz output is available, as well as a millivoltmeter which has a full-scale reading of between 1mV and 10V in decade steps.

labelled fakes. All the working chips are of Maxim origin, though; the fakes appear to be another type of 20-pin IC that has been re-labelled.

The block diagram of the Transanalyser is shown in Fig.2. Two potentiometers are used to adjust the VFO frequency, to allow for both quick changes and fine-tuning. Its output is fed to a frequency counter, so you can see the frequency you've set, and then on to the modulator, which is also fed from a 1kHz oscillator to provide the modulating signal.

The output of the modulator is buffered and then fed to a nine-step attenuator. The attenuator output goes to a BNC socket. A length of coax is used to connect the small loop with integral 75Ω resistor, to produce the H field.

The 1kHz oscillator output is separately fed to a level control and thence to a second BNC socket to provide a low-frequency test signal if required. A third BNC socket acts as a test input, and the signal from that is fed to a four-step decade attenuator and on to an analog meter.

Circuit description

The circuit of the Transanalyser is shown in Fig.3. You can see how the block diagram corresponds to this circuit by looking for the component designators mentioned in the block diagram; eg, IC4 is the VFO, IC6 is the mixer, IC3 is the mixer buffer etc.

The components which set the VFO output frequency are shown to the left of IC4. VC1 allows its range to be calibrated while trimpot VR2 is the carrier level calibration control. The signal from its wiper is AC-coupled to the pin 8 carrier input of mixer IC5, with a 1kΩ resistor from +5V supplying current to that input. The other carrier input at pin 10 is unused so is tied directly to +5V.

IC5 is an MC1496 transistor array, operating as a four-quadrant multiplier. This provides very linear amplitude modulation of an RF carrier. It needs to be biased correctly so that an offset is produced; otherwise, its output spectrum would be suppressed carrier double sideband modulation (DSB). The ±5V and 9V supplies are used to set up the required DC conditions for the MC1496.

NPN transistor Q1 operates as an RC phase-shift type sinewave oscillator, with component values chosen to get a low-distortion 1kHz sinewave. This signal is AC-coupled to the inputs of buffer op amps IC3a and IC3b, with a 100kΩ resistor to 0V to remove any DC bias.

I settled on this oscillator configuration after experimenting with op amp-based oscillators, including those stabilised with incandescent lamps. Q1 has significant DC degeneration to provide sufficient AC gain for the oscillator to start reliably, despite the expected hFE variations. The 1kHz waveform has some very mild distortion, but overall it is a good-looking sinewave.

The output of IC3b is fed to the 1kHz output at CON6 via level control potentiometer VR6, while the identical output from IC3a goes to modulation calibration trimpot VR3 and then into the pin 1 signal input of IC5.

The other signal input at pin 4 is unused and so is DC-biased to around 1V via a pair of resistors bypassed by two capacitors to ground, so that the mixer within IC5 is properly balanced.

The 2kΩ gain adjustment resistor between pins 2 and 3 of IC5, and the 3.9kΩ bias resistor from pin 5 to ground are required to set up the internal conditions for the mixer to operate properly.

In addition to loading the outputs at pins 6 and 12, the 300Ω resistors to +9V also supply current for the chip's output stage to operate.

The differential signals from these pins are AC-coupled to input pins 5 & 6 of 300MHz video op amp IC6b. This is configured as a low-gain differential amplifier. Its single-ended output is fed to non-inverting input pin 3 of IC6a, the other half of the dual op amp, which provides a further gain of two times. The output signal from IC6a then goes to the switched output attenuator via a 75Ω resistor.

This attenuator uses parallel pairs of resistors, with 150Ω//3.6kΩ (equivalent to 144Ω), 110Ω//3.9kΩ (equivalent to 107Ω) and 75Ω//1.8kΩ (equivalent to 72Ω).

These values set up the attenuation ratios for 10dB steps down to -80dB. The output impedance of this divider is 37.5Ω, so a pair of parallel 75Ω resistors in series with the switch output terminal sets the required 75Ω output impedance.

For properly testing radios, it must be possible to attenuate the RF signal below the level which any reasonable receiver can pick up.

My experience using the Philips PM5326 generator to test and align radios suggested that 10dB steps are adequate for the attenuator; there is no need for it to be continuously variable.

I decided to configure it as though it is a terminated 75Ω ladder attenuator with a 75Ω input impedance.

The source impedance is 75Ω ÷ 2 at each point along the ladder, provided the attenuator is fed with a 75Ω source impedance and also terminated by 75Ω.

The attenuator resistor values could have been doubled to give a 150Ω output impedance, and then the two parallel 75Ω resistors at the output would not be required. It would also require a lower input voltage for the same output signal.

But I decided against that as the lower impedance design helps to minimise capacitive cross-coupling effects within rotary switch S2.

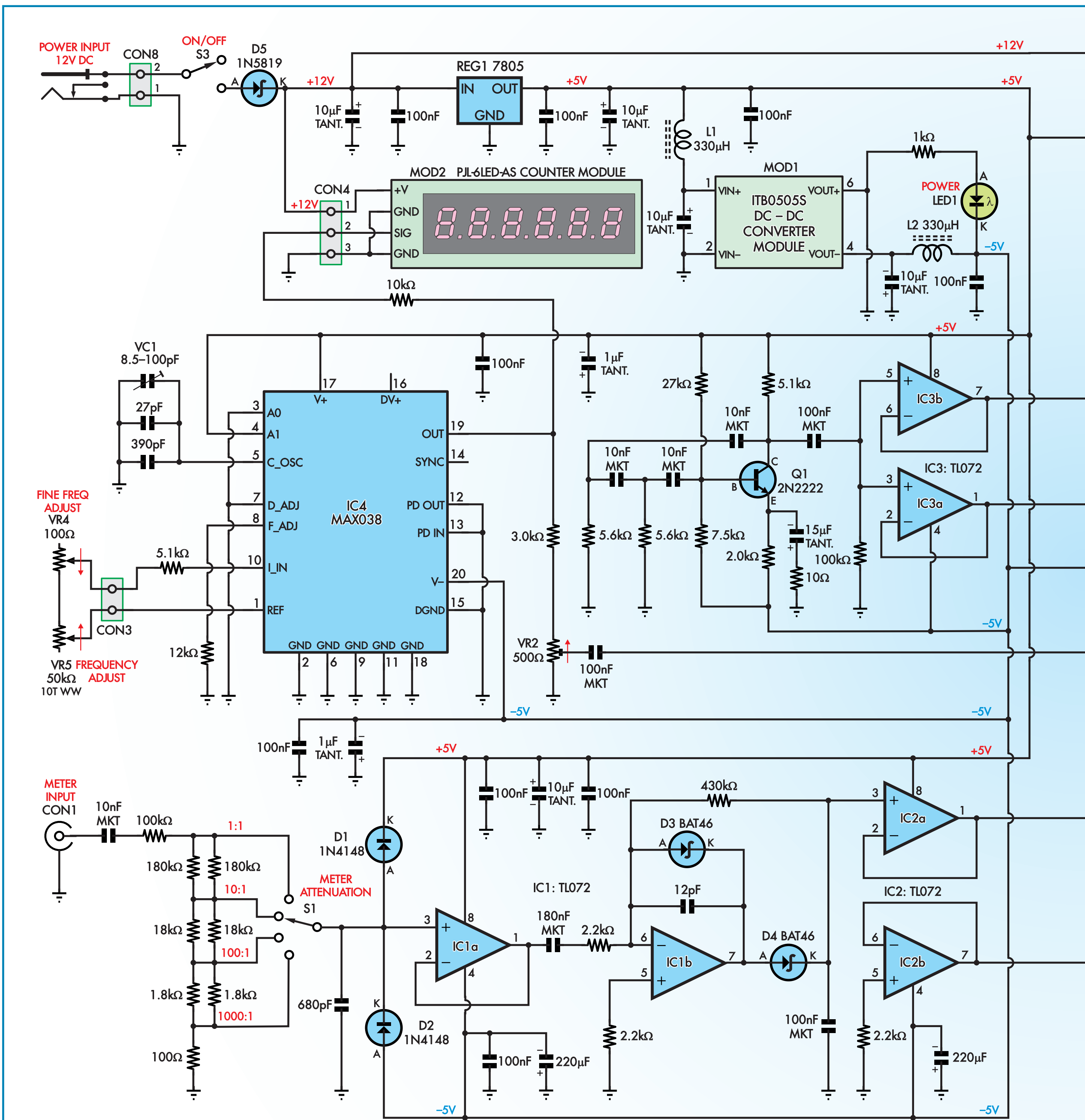
The result is an attenuator which is accurate down to -80dB with no leakage or cross-coupling effects detectable at AM radio frequencies.

IC6a has no trouble delivering the 200mV RMS required to get the required 50mV RMS output into a 75Ω load.

Metering section

CON1 is provided to feed an AC voltage back into the unit, to measure the output of a radio for a given input signal. This signal is AC-coupled to a high input impedance switched divider (200kΩ) to provide 10V (1:1), 1V (10:1), 0.1V (100:1) and 10mV (1000:1) ranges.

The 680pF suppresses any residual RF in the signal while diodes D1 and D2 protect the input of op amp IC1a from overload. IC1a buffers the signal,



which is then AC-coupled to IC1b, operating as a precision half-wave rectifier. This produces a DC voltage proportional to the peak negative voltage from the attenuator.

The meter is designed to receive signals from the test radio's volume control; the precision rectifier operates to very low levels for accurate readings.

The filtering was designed so that its calibration is accurate at 1kHz, the modulation frequency of the received carrier. The response for low and high-frequency audio signals is reduced to help noise immunity. It works as follows.

IC1b operates as an inverting amplifier; its non-inverting input (pin 5) is tied to ground, and both the incoming signal and feedback go to its inverting input (pin 6).

When the incoming signal swings negative, to maintain 0V at pin 6 (to match the voltage at pin 5), output pin 7 must swing positive.

Pin 7's voltage increases until diode D4 is forward-biased, charging up the 100nF capacitor at its cathode. Feedback via the 430kΩ resistor results in the pin 6 input reaching 0V. So the gain of this stage is 195 times (430kΩ÷2.2kΩ).

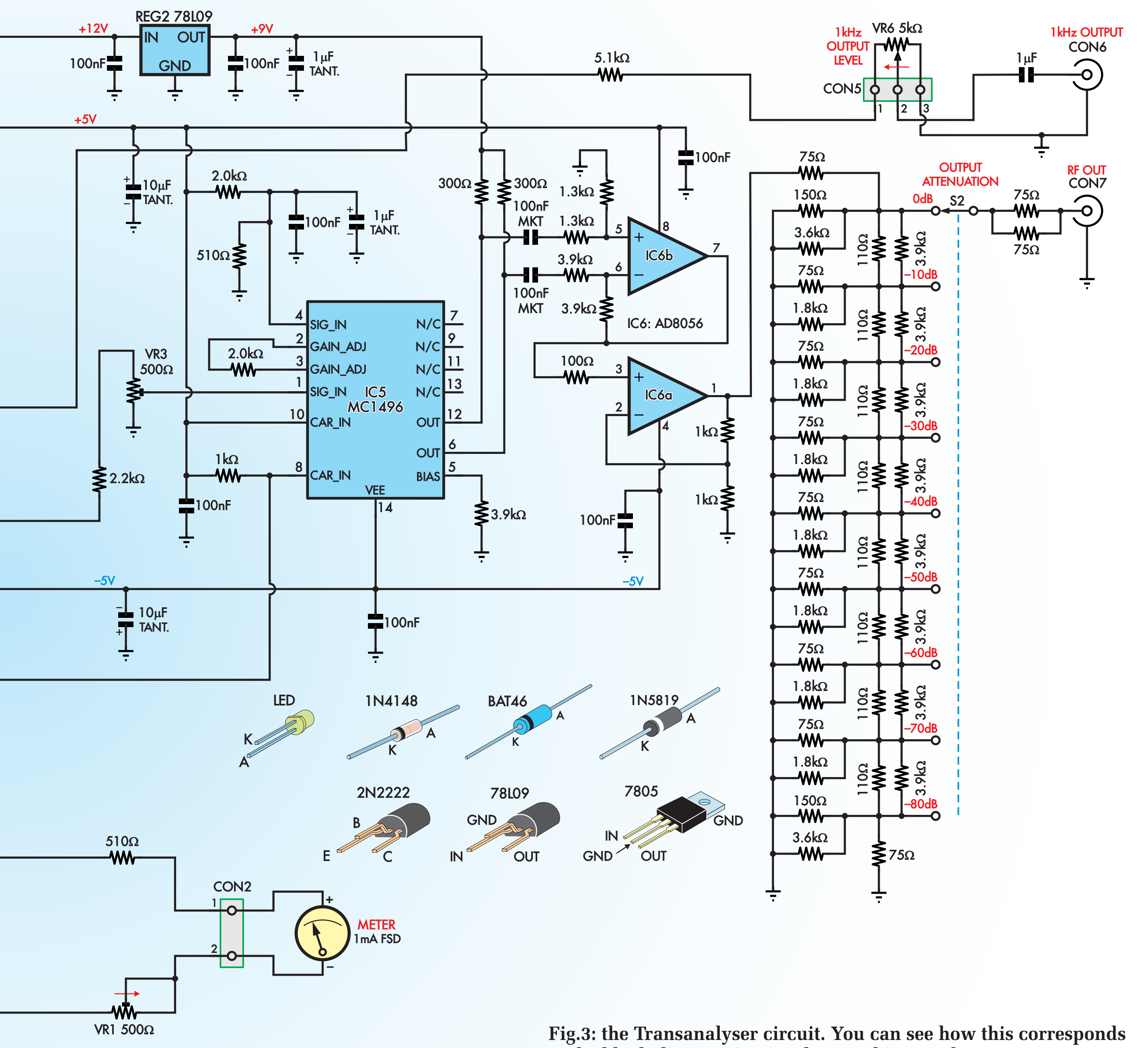


Fig.3: the Transanalyser circuit. You can see how this corresponds to the block diagram in Fig.2 by matching up the component designators. The VFO section around IC4 is at left, with the phase-shift oscillator based on Q1 to its right. IC5 and surrounding components form the modulator while IC6 is a differential amplifier feeding the stepped attenuator based on rotary switch S2. The metering section is at the bottom, with the power supply at the top.

SC ©2020 **H-FIELD TRANSANALYSER**

The rear panel is quite spartan, housing only the power input (right) and from the left the meter in, 1kHz signal out and, of course, the RF out socket. All user controls are on the front panel.

With D4 forward-biased, diode D3 is reverse-biased, so it has little effect. The 12pF capacitor improves this stage's stability by rolling off its gain at high frequencies.

When the signal from the attenuator is positive, IC1b's output pin 7 goes negative, forward-biasing diode D3 and so pulling its pin 6 input down to 0V. In this case, D4 is reverse-biased so the 100nF can only slowly discharge through the 430kΩ resistor.

The voltage across the 100nF capacitor representing the incoming signal level is then buffered by op amp IC2a and fed to the positive end of the 1mA meter via a 510Ω fixed resistor. The negative end of the meter is connected to the output of op amp IC2b, which is held at 0V, via 500Ω calibration trimpot VR1.

The meter scale is set up in millivolts, so VR1 is adjusted to give a maximum reading with say 1V applied to CON1 and S1 set to the 10:1 (1V) range.

Frequency counter

The frequency counter is a PJL-6LED model from SANJIAN Studio, which is good value at around $15, including delivery. This type is readily available on eBay and AliExpress. It has an adjustable display brightness, eight modes and resolution setting (and remembers its settings).

For this project, it is set to 100Hz resolution mode. On brightness level 3, the display is still bright, and the current consumption only around 30mA. I also tested an LCD-based counter, and it actually consumed more current! The timebase has a very nice crystal oscillator assembly and the ones I bought had spot-on calibration.

Power supply

The circuit runs from 12V DC. There are three regulated rails: +5V, -5V and +9V. The ±5V rails provide a split supply to run all the ICs in the circuit, plus the oscillator built around transistor Q1.

The 9V rail is used only to power the output stage of mixer IC5. It is derived from the incoming 12V supply by linear regulator REG2.

The only component that runs directly from the incoming 12V supply is the frequency counter module.

Like the 9V rail, the +5V rail is derived from +12V by linear regulator REG1. However, generating the -5V rail is a little more involved. This is done by an isolated DC/DC converter, MOD1. This module produces a 5V regulated output from a 5V input, but its outputs are floating. This means that we can connect its VOUT+ terminal to ground, and get -5V from its VOUT- terminal.

Inductor L1 forms an LC filter for the input of MOD1, so that any switching noise caused by pulses of current drawn at its input does not make its way back into the circuit.

Similarly, switching noise and ripple at the -5V output is filtered by a pi filter made from a 10uF capacitor, inductor L2, and the following 100nF and 10uF capacitors.

LED1 lights up when the -5V rail is present to indicate that the circuit is operating. Switch S3 provides power on/off control while diode D5 protects the circuit against accidentally reversed supply polarity.

PCB assembly

The first Transanalyser prototype was made using protoboard connected to bare copper laminate with point-to-point wiring and many 'air-wired' components.

However, building it this way is difficult and laborious, and the chance of making mistakes is high.

So we have designed a proper double-sided PCB for this project and had it commercially manufactured. It is coded 06102201 and measures 125 x 112mm. This is shown in the overlay diagram, Fig.4.

All the components are through-hole types, except for the attenuator resistors. This has the advantage that those resistors are over an essentially unbroken ground plane. Start by fitting those attenuator resistors. Each will be printed with a code indicating its value, such as 362 (36×10^2) or 3601 (360×10^1) for 3.6kΩ.

Once you have located the correct resistor for a position, tack solder one end in place and check that part's alignment. If it's off, re-heat that end and gently nudge the body. Once it's in position, solder the other end, wait a little while for the joint to solidify, then add a little fresh solder (or some flux paste and heat) to the first joint.

Make sure your iron tip touches the edge of each resistor and the PCB pad, so that solder flows onto both.

Once those are all in place, install the fixed-value through-hole resistors in the usual manner. It's best to check their values with a DMM set to measure ohms before installation, as the colour-code bands are easy to misread.

Follow with the five diodes. There are three different types, so don't get them mixed up, and make sure they are orientated as shown in Fig.4.

If you are using IC sockets, fit them now. Make sure their pin 1 end notches are orientated as shown. Sockets make it easier to replace a damaged IC, but they are not great for long-term reliability. So if possible, we suggest you instead solder the ICs directly to the board. If doing that, make sure you don't get the similar TL072 and AD8056 ICs mixed up, and be extra careful to get their orientations right!

Next, bend the leads of the 7805 regulator down and attach its tab to the PCB using a 10mm machine screw and nut. Make sure the screw and nut are done up tight before soldering and trimming the leads.

This is a good time to fit the PC pins which will support the shields later. A total of 49 pads are provided, but we suggest that you only need to use about half of these (21). The suggested pads used to support the shield are circled in Fig.4 and on the PCB. Push the PCB pins down firmly and solder them. You will need a hot iron due to the thermal mass of the copper they are soldered to.

If your PCB pins are a tight fit, take care when inserting those near components. While it's a little tricky, you can hold them in the jaws of a pair of snub-nose pliers, sticking out the front, then carefully force them into the holes. Those which are further away from components could be hammered in.

Alternatively, use slightly smaller PCB pins (0.9mm diameter), which are not such a tight fit, or component lead off-cuts.

Now you can fit the three identical 500Ω trimpots, followed by the single trimmer capacitor (VC1). Then install regulator REG2, which is in a small plastic TO-92 package. Bend its leads out to fit the PCB pads before soldering it in place.

Transistor Q1 may come in the same TO-92 plastic package, in which case you mount it in the same manner as REG2. If it's in a TO-18 metal can package, unfortunately, the pinout is reversed compared to the TO-92 package; in other words, with the leads pointing down and the base at the rear, the left-hand lead is the collector while the emitter is on the right.

We've added an extra base pad for Q1, near the front, to make it easier to fit the TO-18 package version but it's still going to be a bit of a squeeze, and you will need to bend the base lead a bit so that it's nearly between the other two to match the PCB pads.

It's a good idea to wait until the surrounding capacitors have been fitted before installing Q1 in the TO-18 package.

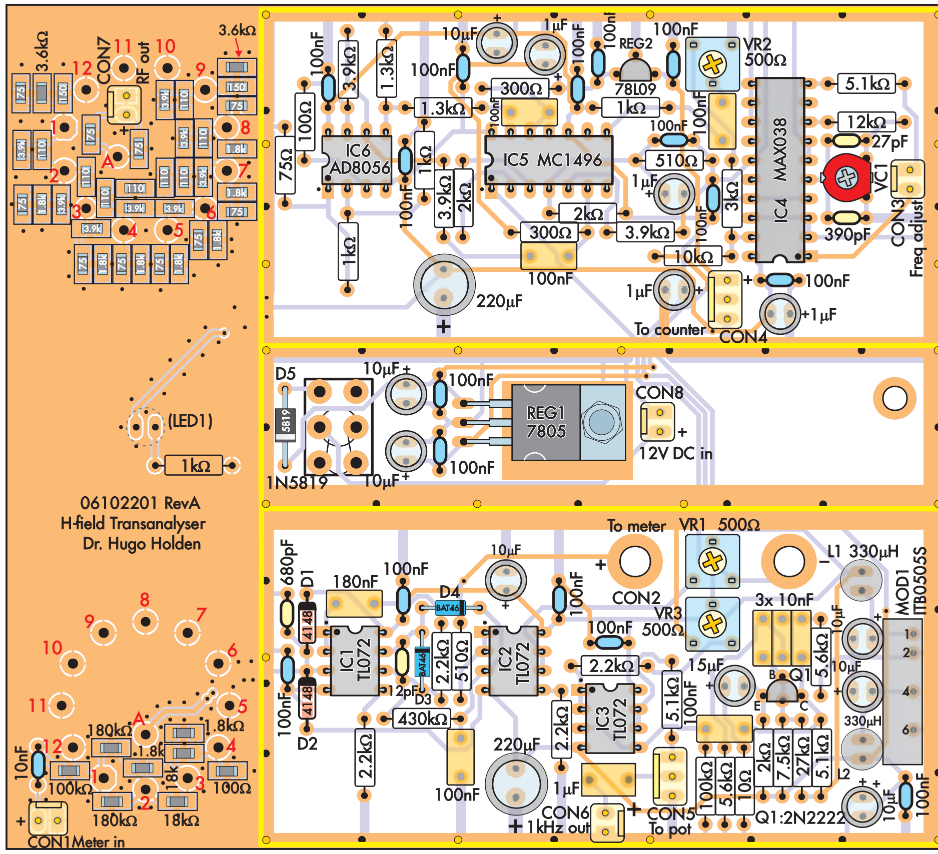
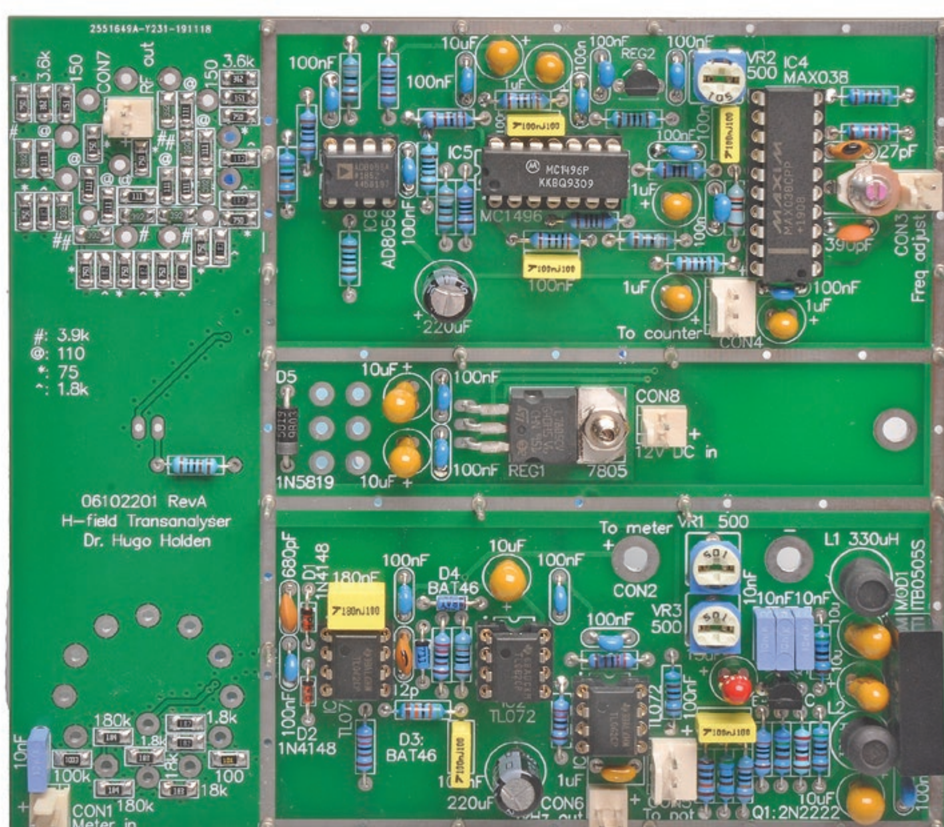


Fig.4: most, but not all components are mounted on this double-sided PCB. It has extensive ground planes, but shielding plates are still required between the three major sections where shown. They are supported by, and soldered to, numerous PC stakes. The major off-board components are potentiometers VR4-VR6 and the power and signal input/output connectors, all of which connect via locking headers.



Parts list – H-field Transanalyser (AM Radio Alignment Aid)

1 double-sided PCB, code 06102201, 125 x 112mm
1 222 x 146 x 55mm sealed diecast aluminium enclosure [Jaycar HB5050]
1 12V DC, 400mA+ regulated plugpack
1 set of front and rear panel labels for enclosure
1 ITB0505S isolated 5V to 5V DC/DC converter (MOD1)
1 PJL-6LED-AS 6-digit red frequency counter module (MOD2)
1 laser-cut acrylic bezel for the frequency meter
1 0-1mA MU45 moving-coil panel meter [Altronics Q0500A, Jaycar QP5010]
1 0-1mV paper label for the analog panel meter
5 2-pin polarised headers (CON1,CON3,CON6-CON8)
7 2-pin polarised plugs with pins (for CON1,CON3,CON6-CON8 & frequency meter)
2 3-pin polarised headers with matching plugs and pins (CON4,CON5)
2 330μH high-frequency ferrite bobbin chokes (L1,L2)
2 single-pole, 2-12 position rotary switches (S1,S2)
1 chassis-mount DPDT toggle switch (S3) [eg Altronics Cat S1345; Jaycar ST0355]
1 chassis-mount DC barrel socket (to CON8; pin diameter to suit plugpack)
1 chassis-mount BNC socket (to CON7, RF out)
2 chassis-mount RCA or BNC sockets (to CON1 [meter in] & CON6 [1kHz out])
5 knobs to suit S1, S2 & VR4-VR6
1 3mm LED bezel
1 12mm-long M3 tapped spacer
6 M3 x 10mm panhead machine screws
1 M3 x 10mm countersunk machine screw
3 M3 hex nuts
21 0.9-1mm PC pins (or use component lead off-cuts)
2 brass strips [eg K&S 12.7mm x 0.41mm x 304.8mm; ebay]
4 small rubber feet with mounting hardware
1 1m length of shielded cable
1 1m length of RG179 coax with a BNC plug at one end
1 RCA or BNC (to suit CON1) to 2 x alligator clip cable
1 200mm length of light-duty figure-8 cable
1 250mm length of wire-wrap wire (aka Kynar)
4 8-pin DIL sockets (optional; for IC1-IC3 & IC6)
1 14-pin DIL socket (optional; for IC5)
1 20-pin narrow DIL socket (optional; for IC4)

Semiconductors

3 TL072 dual JFET-input op amps, DIP-8 (IC1-IC3)
1 MAX038 function generator IC, DIP-20 narrow (IC4)
1 MC1496 balanced modulator/demodulator IC, DIP-14 (IC5)
1 AD8056 dual 300MHz video op amp, DIP-8 (IC6)
1 7805 5V 1A linear regulator, TO-220 (REG1)
1 78L09 9V 100mA linear regulator, TO-92 (REG2)
1 2N2222A or MPS2222A NPN transistor, TO-92 or TO-18 (Q1)
1 3mm green LED (LED1)
2 1N4148 small signal diodes (D1,D2)
2 BAT46 schottky signal diodes (D3,D4)
1 1N5819 1A schottky diode (D5)

Capacitors

2 220μF 10V electrolytic
1 15μF 6.3V tantalum electrolytic
7 10μF 16V tantalum electrolytic
4 1μF 16V tantalum electrolytic
1 1μF 100V MKT
1 180nF MKT
16 100nF MKT or multi-layer ceramic
5 100nF MKT
4 10nF MKT
1 680pF ceramic
1 390pF ceramic
1 27pF ceramic
1 12pF ceramic
1 8.5-100pF trimcap (VC1) [Jaycar RV5722]

Through-hole resistors (all 1/4W 1% metal film)

1 430kΩ	1 100kΩ	1 27kΩ	1 12kΩ	1 10kΩ
1 7.5kΩ	2 5.6kΩ	3 5.1kΩ	3 3.9kΩ	1 3kΩ
4 2.2kΩ	3 2kΩ	2 1.3kΩ	4 1kΩ	2 510Ω
2 300Ω	1 100Ω	1 75Ω	1 10Ω	

3 500Ω mini horizontal trimpots (VR1-VR3)
1 100Ω 16mm linear potentiometer (VR4)
1 50kΩ 10-turn linear potentiometer (VR5) [eg, RS Cat 536-11-503]
1 5kΩ 16mm linear potentiometer (VR6)

SMD resistors (all 3216/1206 size, 1%)

2 180kΩ	1 100kΩ	2 18kΩ	8 3.9kΩ	2 3.6kΩ
9 1.8kΩ	2 150Ω	8 110Ω	1 100Ω	10 75Ω

Now mount the ceramic capacitors and then the MKT capacitors, none of which are polarised. See the capacitor codes table if you're having trouble reading their values.

Note that 16 of the 100nF capacitors can be ceramic (including multilayer) or MKT types, while five others must be MKT. These five have square outlines on the PCB, and are shown as MKT types in Fig.4.

The electrolytic capacitors, including the tantalum types, are polarised. In both cases, the longer lead is positive and must go into the pad marked with a + symbol in Fig.4 and on the PCB. Aluminium electrolytics also have a stripe on the negative side of the can, while tantalums normally have a + symbol printed on the plastic encapsulation nearest to the positive lead.

With all the capacitors in place, if you fitted IC sockets earlier, plug all the ICs into their sockets, taking care not to fold up any of the leads under the bodies.

Don't get IC6 mixed up with the other 8-pin chips.

Next, fit the two inductors; they are identical and not polarised. Follow with the two-pin locking headers (CON1, CON3 and CON6-CON8) and three-pin locking headers (CON4 and CON5). We've shown suggested orientations, but these are not critical as you can make up the plugs to suit later.

The next step is to cut your tinplate/brass sheet into 5-10mm wide strips and bend those strips around the PC pins you installed earlier.

There are various ways to achieve the desired result, which is to surround all three main sections on the right side of the board with shield plates.

We suggest that you use two strips, one to surround the top section, extending down at the left side to touch the bottom section; and one to surround the bottom section, extending up at the right side to touch the top section. This is shown as lines on the PCB.

Cut and bend the strips to shape, then solder them to the PC pins in the corners and at the ends of the strip, and finish off by soldering them to all the other PC pins.

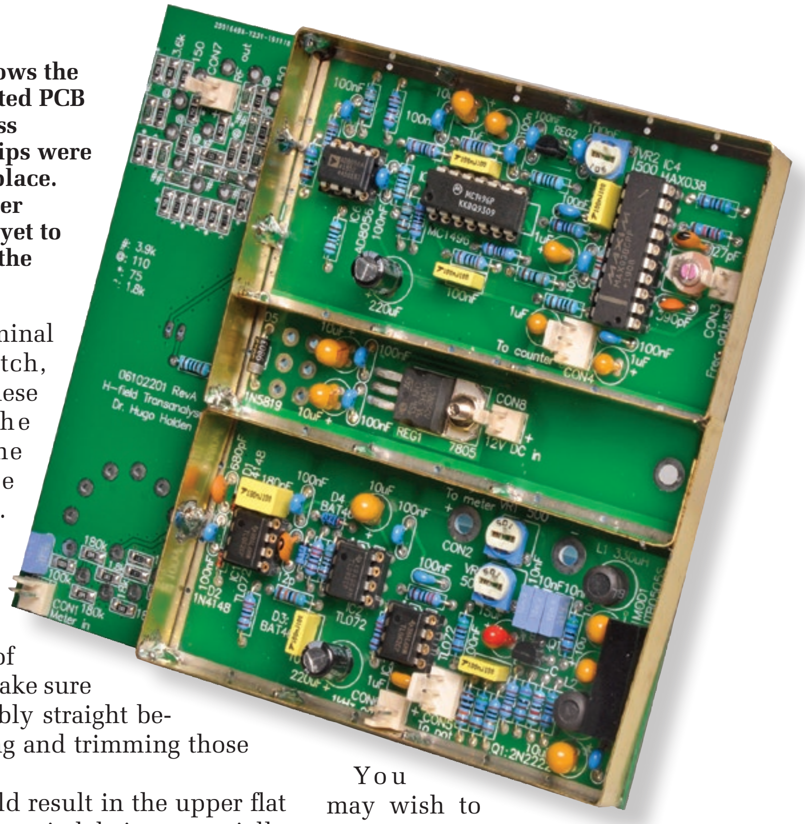
Now mount the switchmode module (MOD1) as shown. Push it right down onto the PCB. It can only fit with the correct orientation. That just leaves the three switches, which are all fitted to the underside of the PCB.

Before fitting S1 and S2, cut down their shafts to around 15mm above the threaded boss, so that when the knobs are pushed on, the bottom of the knob sits about 8mm above the top of the threaded boss. Also cut off the small locating posts in the bases, as we won't be using them.

You also need to adjust the two rotary switches to set them to the correct number of positions; four for S1 and nine for S2. To do this, rotate each switch full-anti clockwise, then remove the nut and lock washer and gently prise off the indexing plate beneath. Re-insert this with its pin going into the hole between the digits "4" and "5" for S1, and between "9" and "10" for S2, then re-attach the washers and nuts.

Now you can push these switches down into the underside of the PCB, ensuring that they are in the right positions and sitting flat before soldering all the pins.

That just leaves on/off switch S3. Solder 20mm lengths of tinned copper wire (or component lead off-cuts) to each terminal of this switch, then feed these through the pads via the underside of the PCB. The switch body should sit about 14mm off the surface of the board. Make sure it is reasonably straight before soldering and trimming those wires.



This shot shows the near-completed PCB after the brass shielding strips were soldered in place. The only other components yet to be fitted are the switches.

This should result in the upper flat surface of the switch being essentially level with the base of the panel meter, when it is fitted later (we're leaving it off for now, as it can only be permanently fitted when mounting the PCB to the case).

Finally, fit LED1 on the same side as switches S1-S3, with the base of its lens sitting just below the tops of those switches.

Make sure its longer lead goes to the pad marked "A".

You may wish to just tack its two leads to the PCB and not trim them just yet, as it may require a slight height adjustment when you fit the board into the case later.

Next month

We'll describe how to complete the wiring, test and calibrate the unit, put it all together in the case and give some advice on how to use it to test and align radios. SC

Through-hole Resistor Colour Codes

	Qty.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	430kΩ	yellow orange yellow brown	yellow orange black orange brown
❑	1	100kΩ	brown black yellow brown	brown black black orange brown
❑	2	27kΩ	red violet orange brown	red violet black red brown
❑	1	12kΩ	brown red orange brown	brown red black red brown
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	1	7.5kΩ	violet green red brown	violet green black brown brown
❑	2	5.6kΩ	green blue red brown	green blue black brown brown
❑	3	5.1kΩ	green brown red brown	green brown black brown brown
❑	3	3.9kΩ	orange white red brown	orange white black brown brown
❑	1	3.0kΩ	orange black red brown	red violet black brown brown
❑	4	2.2kΩ	red red red brown	red red black brown brown
❑	3	2.0kΩ	red black red brown	red black black brown brown
❑	2	1.3kΩ	brown orange red brown	brown orange black brown brown
❑	4	1kΩ	brown black red brown	brown black black brown brown
❑	2	510Ω	green brown brown brown	green brown black black brown
❑	2	300Ω	orange black brown brown	orange black black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown
❑	1	75Ω	violet green black brown	violet green black gold brown
❑	1	10Ω	brown black black brown	brown black black gold brown

SMD Resistor Codes

	Qty.	Value	Code
❑	2	180kΩ	184
❑	1	100kΩ	104
❑	2	18kΩ	183
❑	8	3.9kΩ	392
❑	2	3.6kΩ	362
❑	9	1.8kΩ	182
❑	2	150Ω	151
❑	8	110Ω	111
❑	1	100Ω	101
❑	10	75Ω	750

Small Capacitor Codes

Value	µF Value	IEC Code	EIA Code
180nF	0.18µF	180n	184
100nF	0.1µf	100n	104
10nF	0.01µF	10n	103
680pF	N/A	680p	681
390pF	N/A	390p	391
27pF	N/A	27p	270
12pF	N/A	12p	120