Want your own wireless station? Build this

We've designed this low-power AM Radio Transmitter for the opposite ends of the age spectrum! First, it's every kid's dream to play disc jockey and transmit programs around the house or maybe even next door. And the second, (mainly for our older readers) to let you "listen in" to the programs of your choice on that vintage radio set that you've lovingly restored.

AM Radio Transmitter

By JIM ROWE & NICHOLAS VINEN

Why would you want a broadcast band AM transmitter with a power output so low that it can only be received within a radius of just a few metres?

Well, apart from wanting to keep it all legal, let's say you've just finished building a replica of a classic 1940s' era AM radio, which you're entering a club competition. Wouldn't it be great if you could tune it into an "authentic" old time radio program, to recreate the way it might have sounded back then?

With this little transmitter, you'll be able to do just that, by rebroadcasting historic radio programs like those available on CD from Screensound Australia or even downloaded from the internet (eg, www.archive.com). Or you could play some classic tunes that you happen to have on CD or in MP3 format.

Alternatively, you might want to play the music from your personal MP3 or CD player through your car radio when you're out driving – but the car radio lacks direct audio inputs. With this little transmitter, that's no problem.

In short, the whole idea of this project is to allow any line-level audio signal to modulate an RF carrier in the AM broadcast band so that it can be played through a nearby conventional AM radio.

The carrier frequency of the transmitter can be tuned over most of the broadcast band, ie, from 650kHz to about 1500kHz. This allows you to choose a frequency that's away from any of the broadcasting stations operating in your area, to ensure interference-free reception.

The audio quality from the transmitter's signal is very close to that of the program material you feed into it because it uses a special balanced modulator IC.

There's also a modulation level control, so you can easily adjust the transmitter for the best balance between audio volume and minimum distortion.

But the best part is that the whole transmitter uses just a handful of parts and fits inside a standard UB3 sized plastic jiffy box. It's low in cost and easy to build, as all the parts fit on a small PCB. And there are no SMD components to worry about! You can run it from a plugpack power supply or a 9 or 12V battery, so safety isn't a problem, even for beginners.

Features & specifications

Transmission range:	~20cm (ferrite rod only), ~2-4m (with wire antenna)
Tuning range:	650-1500kHz (typical)
Supply voltage:	9-24V
Operating current:	9mA @ 12V DC
Adjustments:	tuning, fine tuning, modulation depth (volume), carrier balance

How it works

Although it's designed for very low output power, this transmitter uses the same basic principles as a high-power AM radio transmitter.

Fig.1 shows the details. It consists of an RF (radio frequency) oscillator, a modulator and an RF output amplifier or "buffer".

The RF oscillator generates a sinewave of constant amplitude, with a frequency in the AM broadcast band. This provides the transmitter's RF carrier, which is the frequency you tune your AM radio to.

In most full-size AM transmitters, the RF oscillator uses a quartz crystal and is fixed in frequency, so the station concerned is always found at exactly the same place on your radio's tuning dial. However, in this case, the oscillator is tunable, so that you can set the transmitter's frequency to a part of the band that's unoccupied in your area, for clear reception.

The signal produced by the RF oscillator is fed into the modulator, which is the heart of the transmitter. As shown in Fig.1, this also receives the audio signal.

Stereo signals from the audio source are blended to mono via a simple mixing circuit. The resulting mono signal is then fed to the modulator via potentiometer which sets the modulation level.

Incidentally, if you wanted to transmit voice, you could use a microphone preamplifier to boost the tiny microphone output to a level that the transmitter can use (a microphone by itself would not be enough).

And if you wanted to do the whole "disc jockey" thing (voice AND music), you could use an audio mixer to handle both a microphone and a music source (for a suitable mixer, see siliconchip.com.au/Article/644).

The modulator uses the audio signal to vary the amplitude of the RF signal. the carrier).

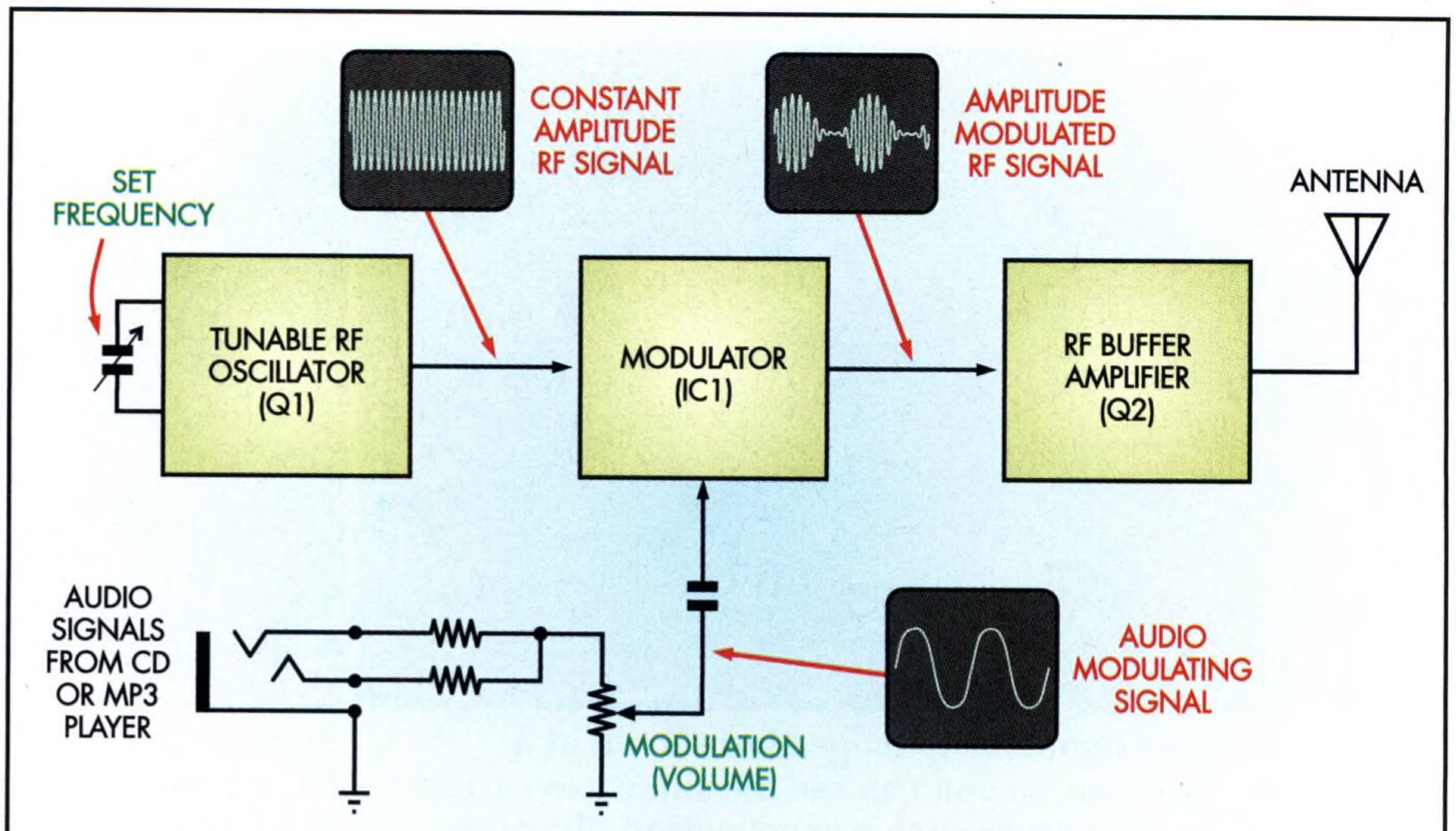


Fig.1: the block diagram for the AM Transmitter. A tunable RF oscillator sets the carrier frequency and this is amplitude-modulated by the audio signal. The modulator's output is then amplified and fed to an antenna.

When the audio signal swings positive, the amplitude of the carrier is increased and when it swings negative, the carrier's amplitude is reduced. In other words, the RF carrier is "amplitude-modulated". The waveforms in Fig.1 show the basic concept.

Amplitude modulation or AM is just one way of using an RF signal to carry audio or other kinds of information from one place to another.

The amplitude-modulated RF output from the modulator is very weak, so before it can be fed to our transmitting antenna (which is just a short length of wire), we have to increase its level by passing it through the third building block: the RF buffer amplifier.

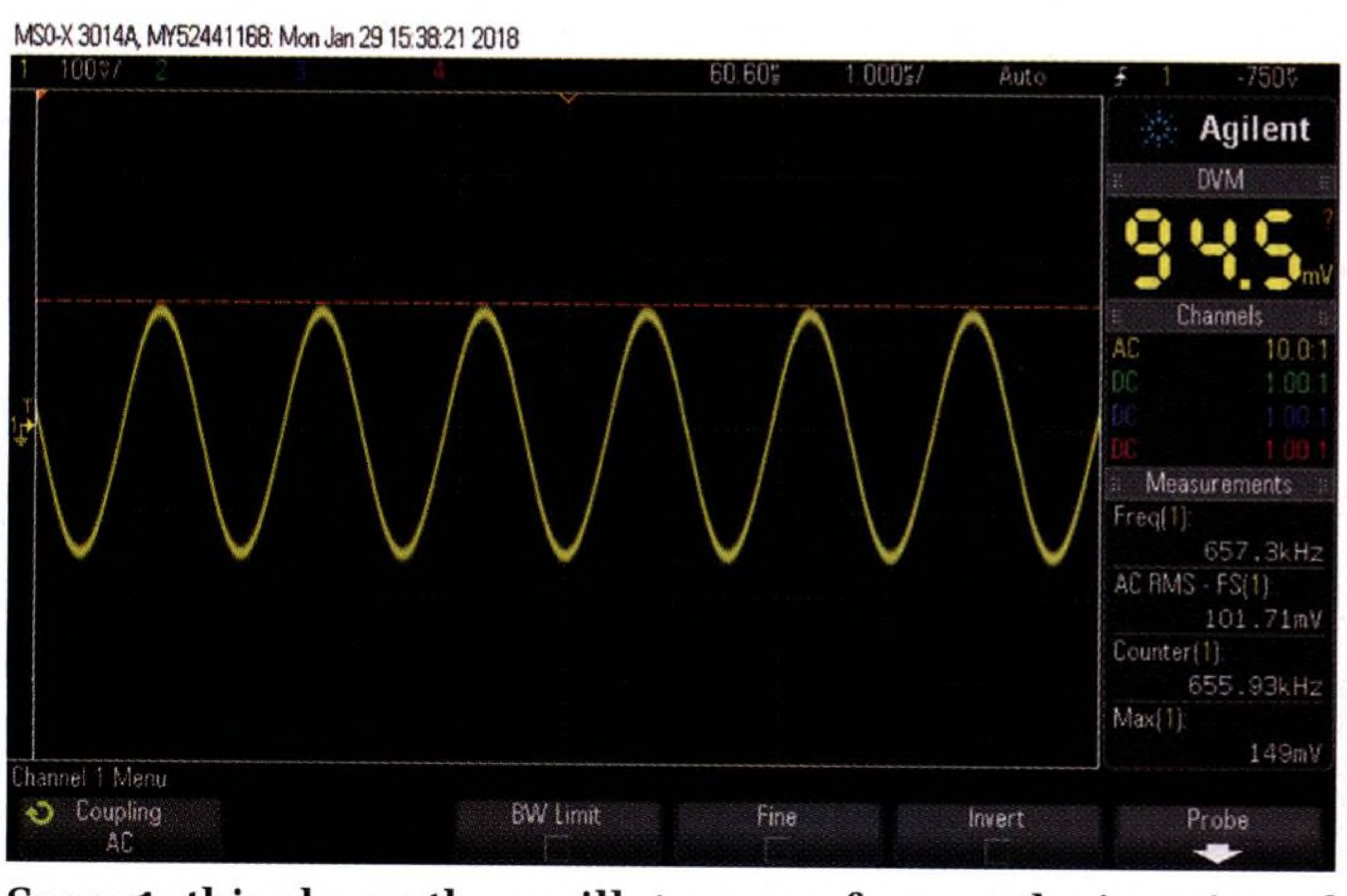
This stage amplifies the modulated RF signal to a level that's just high enough to cause weak radio signals to be radiated from the antenna.

Circuit details

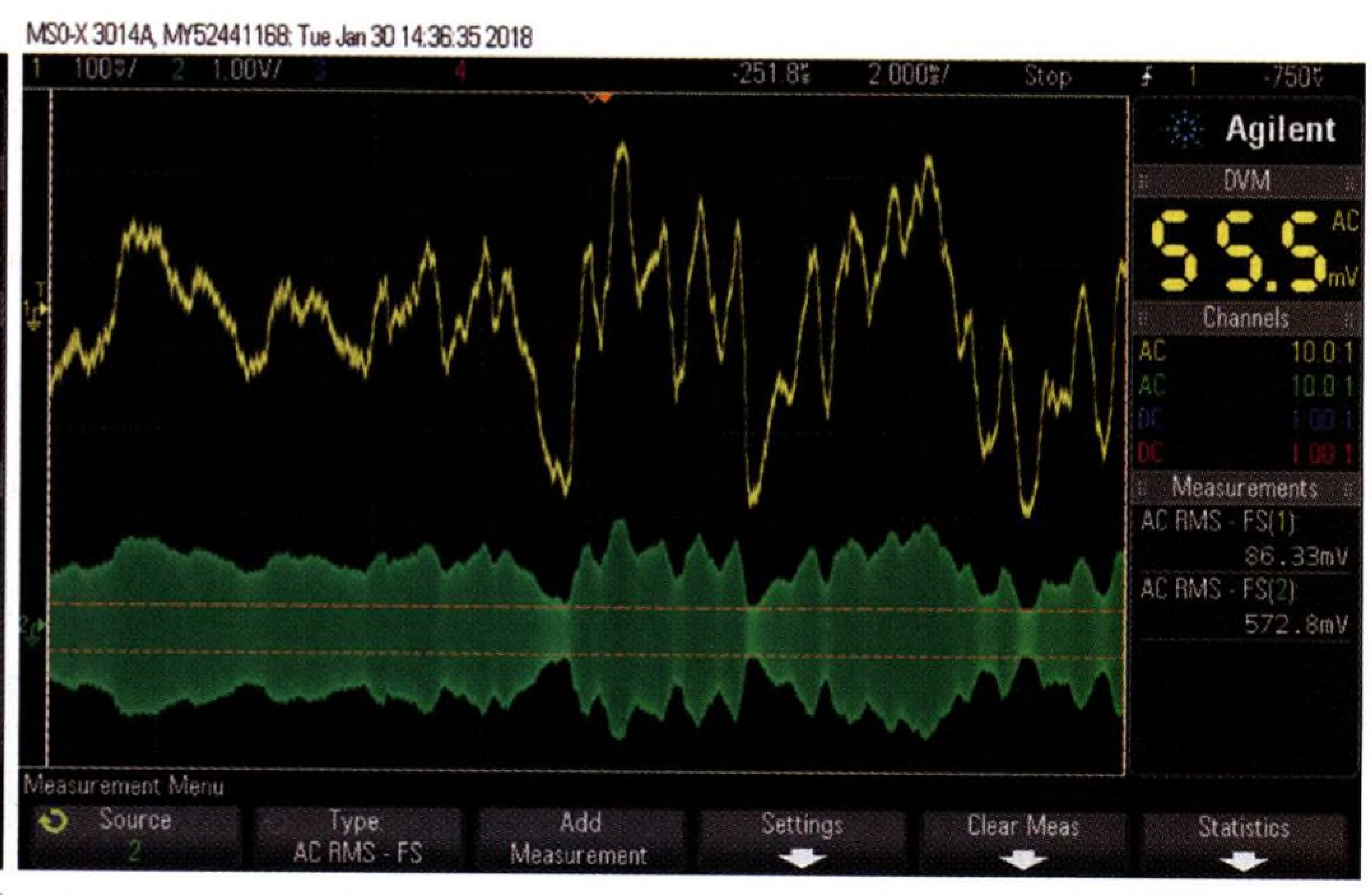
The full circuit of the AM Transmitter is shown in Fig.2. The RF oscillator is a Colpitts configuration, based around transistor Q1.

This uses the primary winding of RF transformer T1 as the inductive arm of its resonant circuit, along with fixed 470pF and 22pF capacitors and a miniature tuning capacitor (VC1). T1 is a local oscillator transformer from a low-cost AM receiver coil kit.

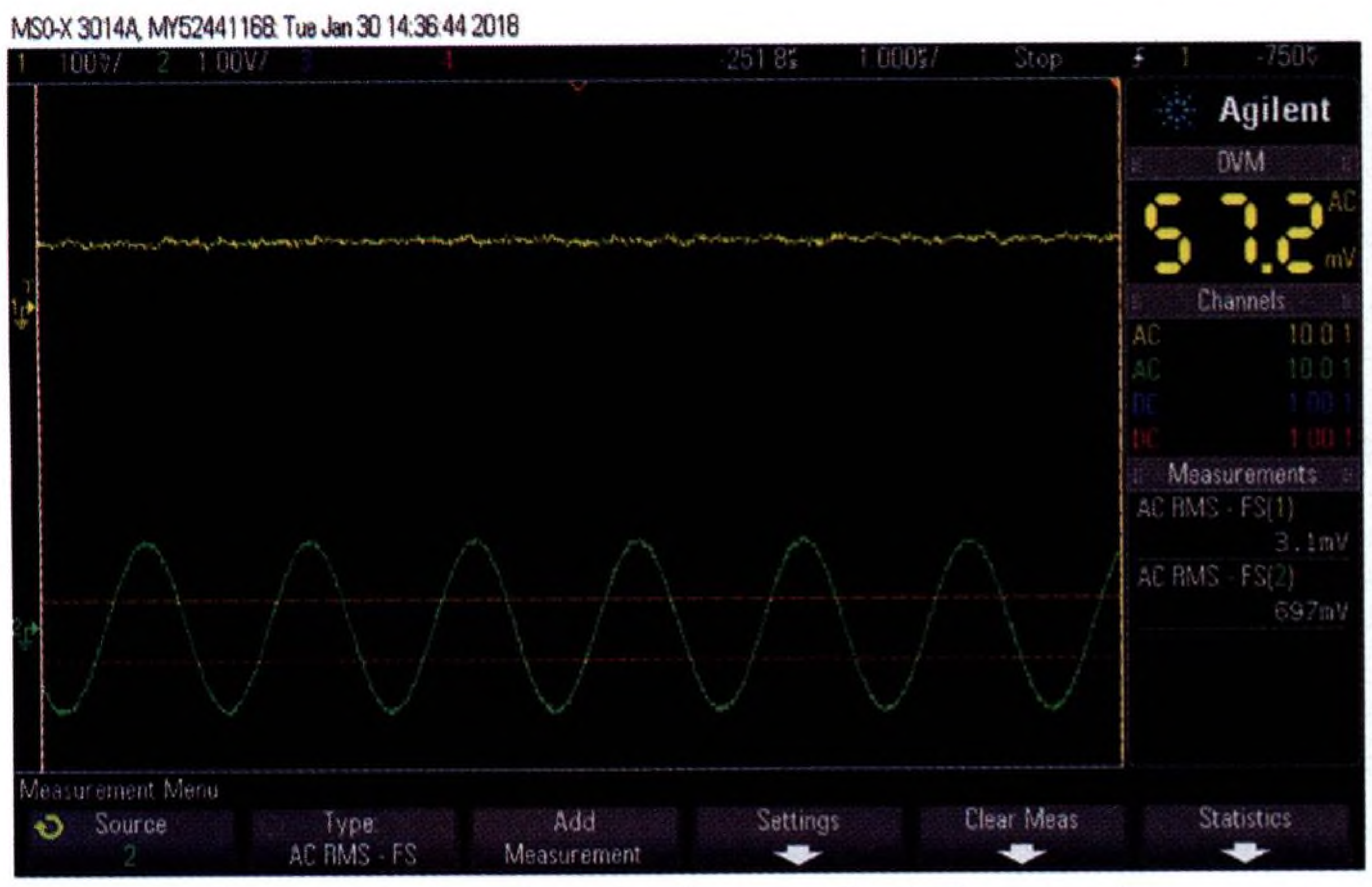
The output of the oscillator is taken from the secondary winding of T1. This is then fed through a 4.7nF DC blocking capacitor and a series 1kΩ resistor to one of the two carrier inputs (pin 10) of IC1, an MC1496 balanced modulator which has been designed



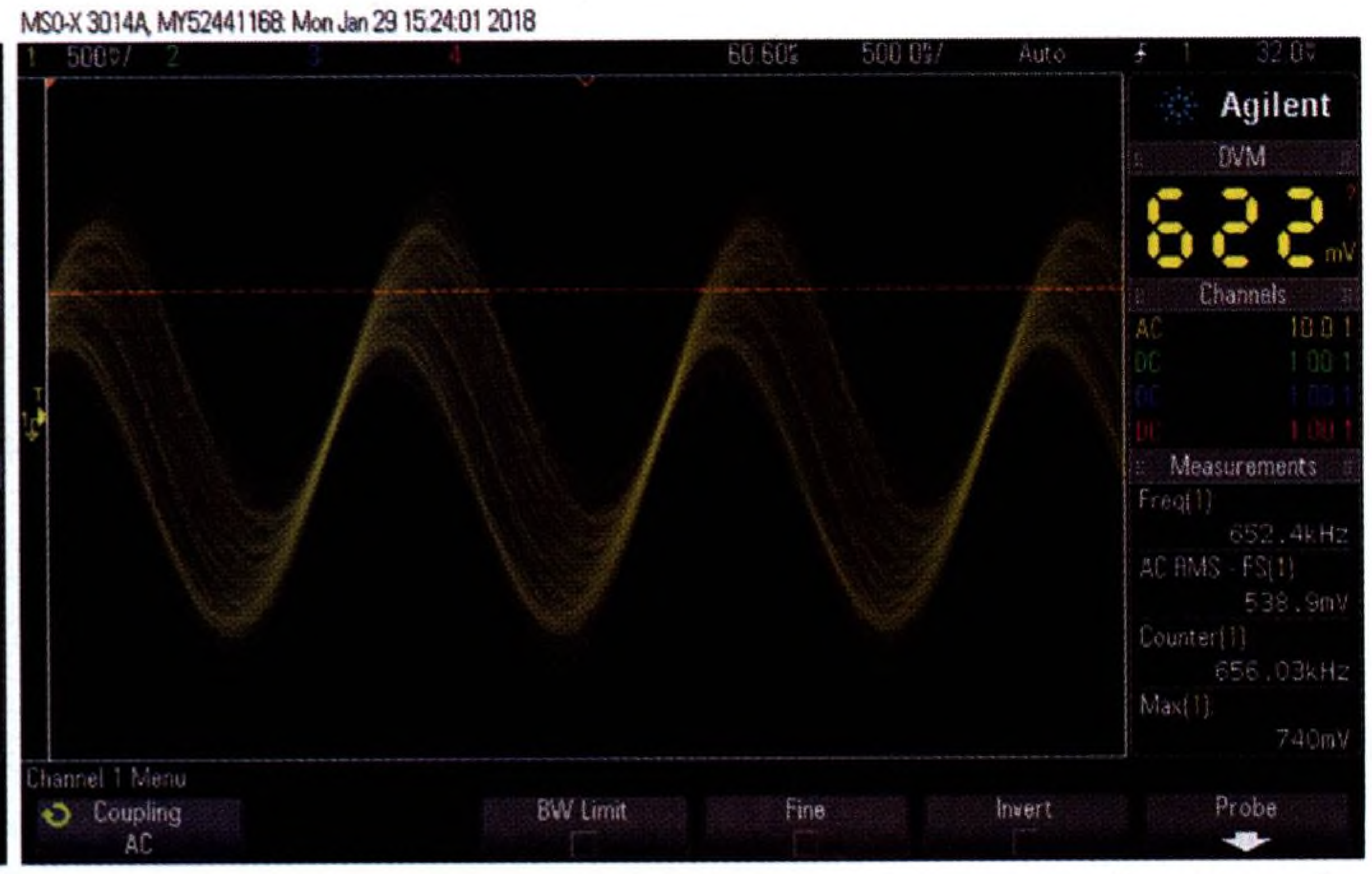
Scope1: this shows the oscillator waveform at the junction of T1 and the 4.7nF capacitor. The amplitude is around 100mV RMS, reduced from the 1V RMS at Q1's emitter due to T1's turns ratio. This is at the bottom end of the tuning range (around 650kHz) and the sinewave is quite clean.



Scope2: an audio signal that we fed into the transmitter is shown in yellow at the top while the AC voltage across the ferrite rod coil (L1) is shown below in green. Due to the long timebase, you can't see the carrier sinewave but you can see how its amplitude is being modulated by the audio signal.



Scope3: the same signal as in Scope2 but shown at a much faster timebase, so you can see the sinewave carrier waveform (in green). Over such a short period, the audio signal (in yellow) is not varying.



Scope4: this shows the modulated carrier across ferrite rod L1 but the scope was set up to overlay subsequent traces. The resultant "jitter" in the waveform is due to the audio modulation.

specifically for this kind of use.

The second carrier input of IC1, pin 8, is tied to ground as far as RF signals are concerned, via a 10nF capacitor.

However, the IC needs both its carrier inputs held at a DC bias level of about +6V and that's the purpose of the voltage divider network involving the 1.5kΩ, 560Ω and 1kΩ resistors between +12V and ground.

The 22µF capacitor filters out any low-frequency variations in this bias voltage.

The 1kΩ resistor between pins 8 and 10 ensures that both carrier inputs are biased at the +6V level. It also forms a voltage divider with the 1kΩ resistor from T1, to reduce the unmodulated carrier level at IC1's inputs to below 60mV RMS – the maximum level which can be applied to its carrier inputs for undistorted output.

You can see an example of the signal at the output side of T1 in the screen grab, Scope1.

IC1's audio modulating signal inputs are at pins 1 and 4 and these have to be biased lower than the carrier inputs, to about +4V DC.

The 560Ω and 1kΩ resistors form a divider between the +6V DC bias point and ground to derive the +4V DC bias voltage. This is applied to the two audio signal input pins (pins 1 & 4) via 1.5kΩ resistors.

The two 10kΩ resistors connected to trimpot VR1 reduce the bias voltage at these two inputs slightly but VR1 also allows the DC offset between these two pins to be adjusted over a small range.

This affects the minimum carrier modulation level and careful adjustment of VR1 allows for a minimum carrier signal feed-through with maximal negative swing of the input audio signal.

The stereo audio input signal is fed into the unit via jack socket CON2 and mixed together via two 10kΩ resistors to form a mono signal. This signal is then fed to modulation depth (volume) control VR2.

Two 10kΩ resistors have been connected between the audio inputs of CON2 and ground. These are used to provide suitable loads for your signal source.

In some cases, if you are using the headphone output of a CD/MP3 player, mobile phone etc, its output amplifier may not operate if the load impedance is too high. 10kΩ will be sufficient for many devices but if necessary, these two resistors can be reduced in value (eg, to 1kΩ).

Keeping It Legal

This AM transmitter has very low RF power output (a tiny fraction of a watt) and is specifically designed to have a range of no more than a few metres, thus keeping it legal.

Do not attempt to modify the circuit with the aim of increasing its power output or to increase its range by feeding its output into any form of gain antenna, because this would greatly increase the risk of interfering with the reception of licensed broadcasting stations.

It would also make you liable to prosecution by the broadcasting and spectrum management authorities and probable confiscation of your equipment as well.

As shown in Fig.2, the modulating signal from VR2 is fed to just one of the modulator's audio input pins – in this case, to pin 1 via a 4.7µF DC blocking capacitor. The second input (pin 4) is tied to ground via a 100µF capacitor, so the full audio (AC) voltage from VR2 is effectively applied between the two input pins.

The 1kΩ resistor connected between pins 2 & 3 of IC1 is used to set the internal gain of the modulator, while the 10kΩ resistor from pin 5 to +12V sets the IC's internal bias and operating current level.

Modulated carrier outputs

The modulated carrier outputs from IC1 appear at pins 6 & 12, which are both connected to the +12V rail via 3.3kΩ load resistors.

In this circuit, we only use the output from pin 12 and this drives the base of RF amplifier transistor Q2 via a 220pF capacitor. The transistor's base bias is supplied by the 2.2MΩ connected to the +12V supply

Q2 is connected as a common-emitter amplifier and its output is developed across the collector load formed by L1, a broadcast-band antenna coil wound on a small ferrite rod.

As well as forming Q2's collector load, L1 actually forms part of the transmitter's antenna, because the ferrite rod inevitably radiates some RF energy.

However, its very small size makes it a rather poor radiator, so an external wire antenna (about two metres long) is also connected to Q2's collector via a 10nF coupling capacitor.

This dual-antenna system gives the

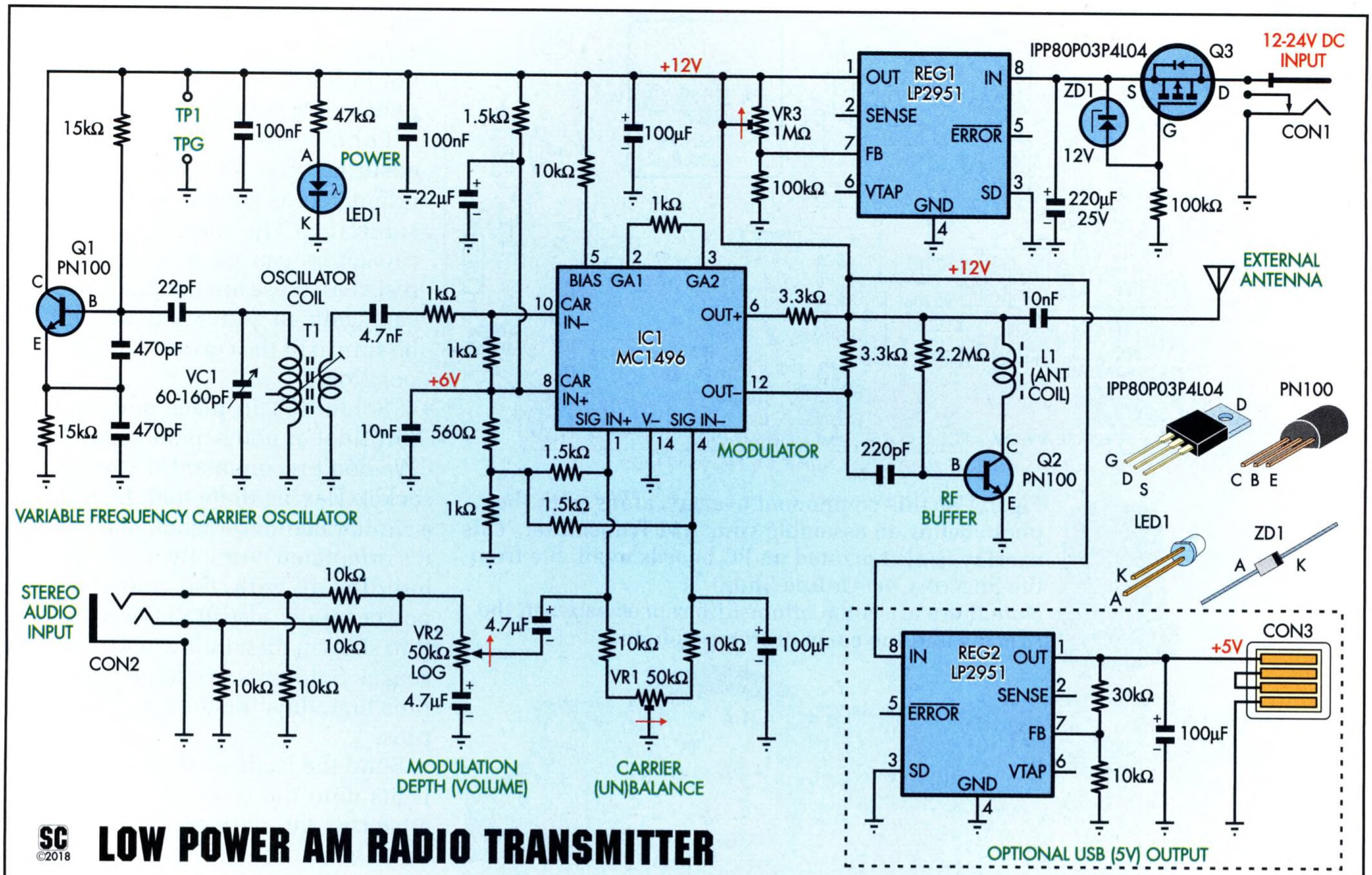


Fig.2: the circuit uses a Colpitts oscillator based on transistor Q1 to generate the carrier frequency which is then modulated by the audio signal fed into pin 1 of IC1 (MC1496). The modulated RF signal is then amplified by common-emitter amplifier stage Q2 and fed to the antenna. Potentiometer VR2 sets the modulation depth.

transmitter a range of about three or four metres, despite its very low RF power output.

You can see an example of the modulated carrier at the antenna terminal in screen grabs Scope2, Scope3 and Scope4.

Power supply and polarity protection

The circuit is powered by a regulated rail, shown as +12V in Fig.2 for simplicity, but it's actually set to around 11.7V. The reason for this is that we want to ensure a stable, regulated DC voltage even if a 12V supply is used. So we've arranged for 300mV of "headroom".

This not only suits regulated 12V DC mains supplies but also most 12V batteries and it has a negligible effect on the operation of the AM transmitter.

This requires the use of a low-dropout regulator and in this case, we are using a low-cost, micropower LP2951 adjustable regulator which can supply up to 100mA.

But normally this circuit only draws a few milliamps which means it has a "dropout voltage" under 200mV.

The input supply is connected via CON1 and Mosfet Q3 provides reverse polarity protection. If the supply is connected correctly, current flows through Mosfet Q3's parasitic diode and simultaneously, its gate is pulled to ground via the 100kΩ resistor, switching it on.

When on, the Mosfet channel "shorts out" the internal diode, resulting in almost no voltage drop across Q3. Hence, it does not raise the required supply voltage for regulation.

But if voltage is applied with the wrong polarity, the internal diode is reverse-biased and does not conduct. And with the gate pulled high, the Mosfet is switched off and so no current can flow through the channel.

The 12V zener diode between gate and source prevents damage to Q3 if a supply voltage beyond its +16/-5V gate-source rating is applied and the 100kΩ resistor limits the current through ZD1 in this condition.

The output voltage of REG1 is set to 11.7V by adjusting VR3. This forms a divider with the 100kΩ resistor across the output and controls what proportion of the output voltage is fed to feedback input pin 7. The regulator uses negative feedback to maintain this pin at a nominal +1.23V.

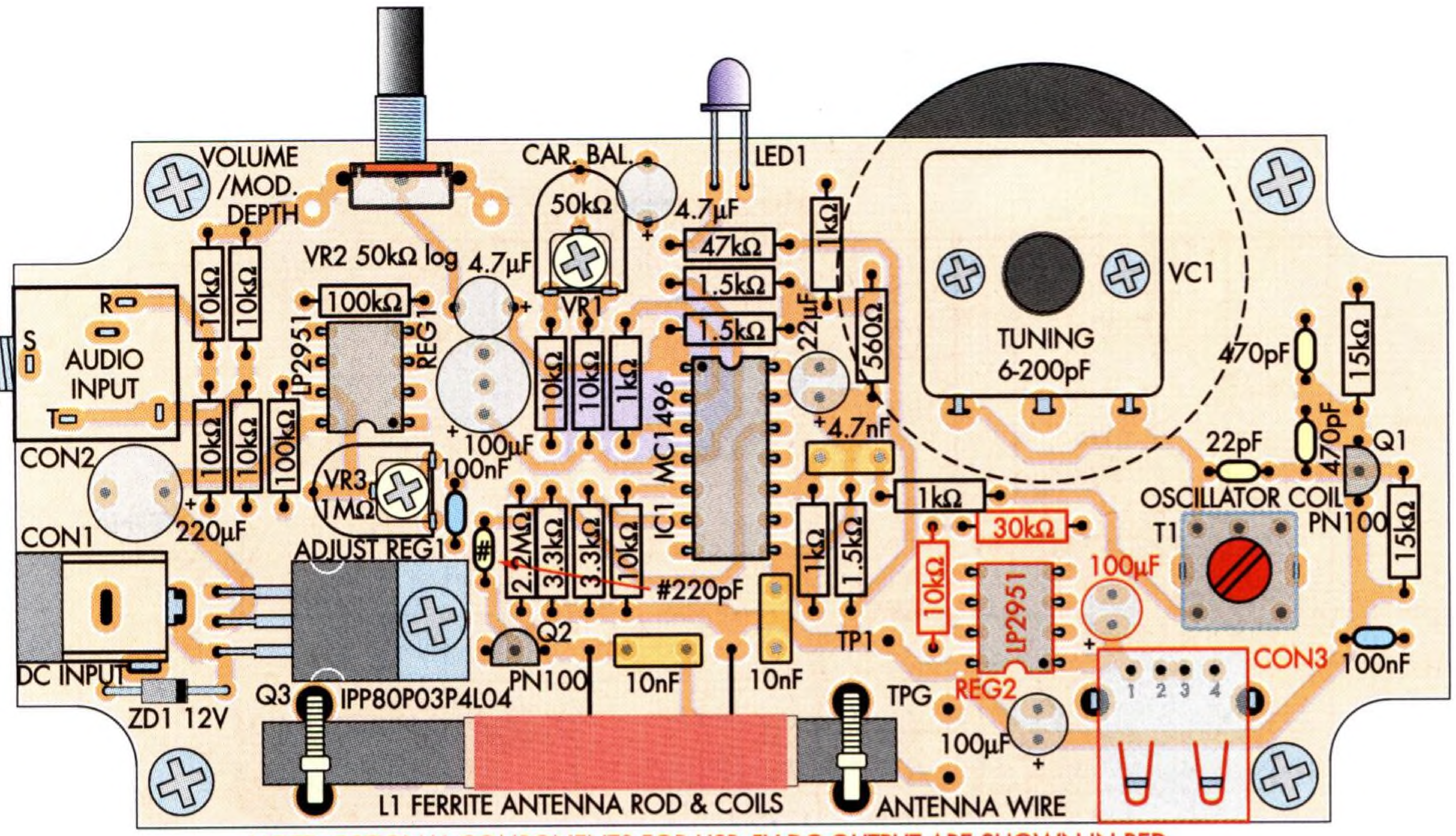
So we need a division ratio of 9.5 times (11.7V ÷ 1.23V) and this will be achieved when VR3 is adjusted for a resistance of 850kΩ [100kΩ x (9.5 – 1)]. Hence the use of a 1MΩ potentiometer. We need some extra adjustment range to account for variations in the internal 1.23V reference voltage.

Note that the 100kΩ/1MΩ divider resistor values are quite high and this is because REG1 has a minimum load specification of just 1μA and a quiescent current of around 70μA.

By keeping the resistor values high, we reduce the amount of current "wasted" in the feedback divider, which could otherwise swamp the quiescent current.

LED1 provides power-on indication. It's connected across the 12V supply in series with a 47kΩ current-limiting resistor (ie, the current through the LED is around 0.25mA).

By using a blue LED, we can get a



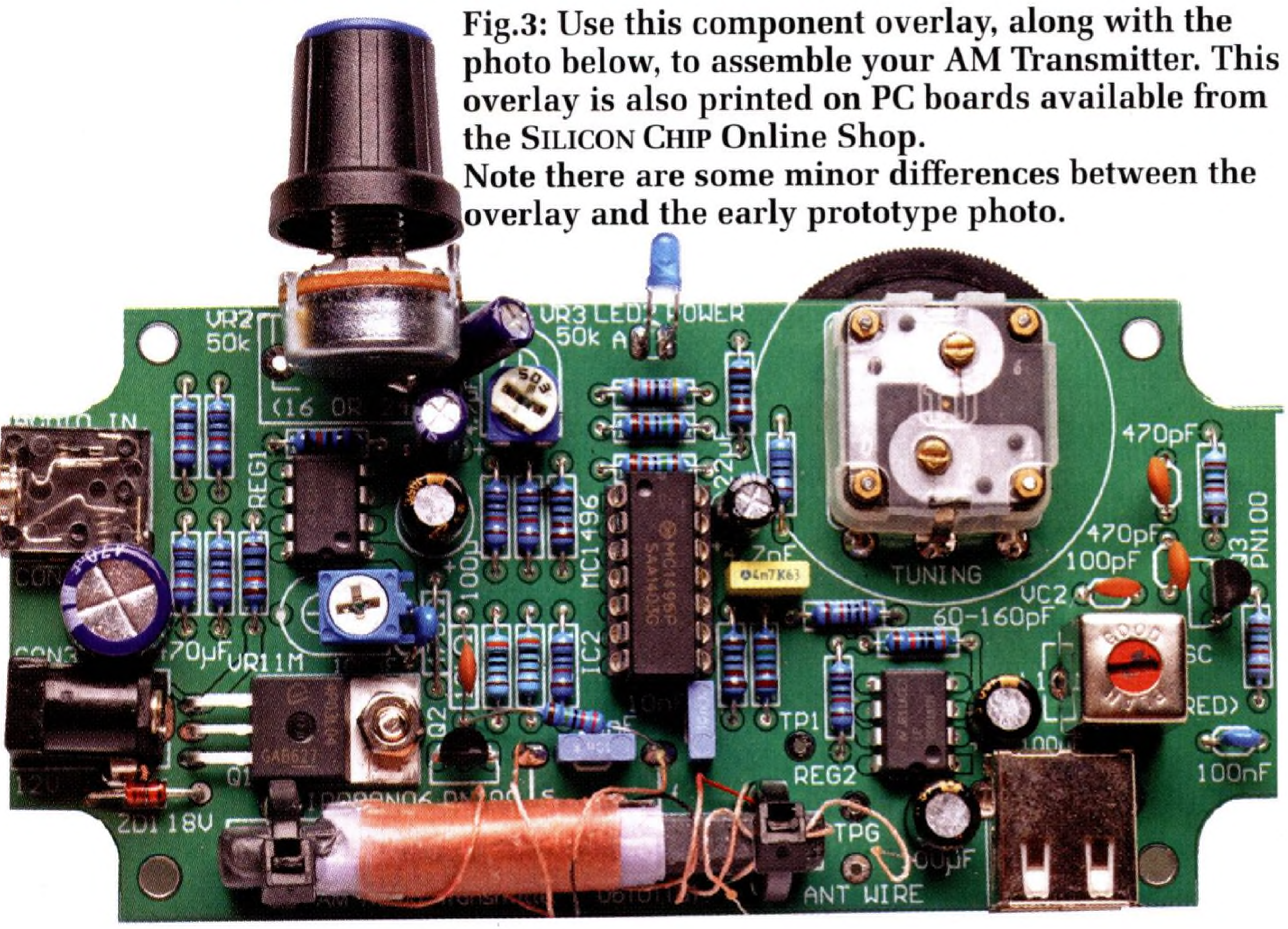


Fig.3: Use this component overlay, along with the photo below, to assemble your AM Transmitter. This overlay is also printed on PC boards available from the SILICON CHIP Online Shop.
Note there are some minor differences between the overlay and the early prototype photo.

sufficiently bright indicator without wasting too much current.

Optional USB supply for Bluetooth receiver

The PCB has provision for a second LP2951 regulator to provide a 5V, 100mA output. This is intended to power a Bluetooth audio receiver, so that you can wirelessly transmit audio from a mobile phone (or similar) to the AM Transmitter. The audio output of the Bluetooth receiver can be fed to CON2, so that the audio is then re-broadcast.

This only requires five extra components and is quite convenient since the Bluetooth receiver then simply plugs into the AM Transmitter and a separate power supply is not required.

These extra components are REG2, CON3, two resistors and a 100µF filter capacitor. Again, we've used an LP2951 since it has a low quiescent current. The resistors are chosen to give an output very close to 5V.

Construction

Construction is easy, with all the parts mounted on a small PCB measuring 122 x 57.5mm. This board has cutouts in each corner, so it fits inside a standard UB3 size jiffy box. The overlay diagram, Fig.3, shows where each component goes on the board. The extra components for the optional USB power socket are shown in RED.

Start by fitting the 26 small resistors. The resistor colour code table shows each value's colour coding bands. However, it can be difficult to distinguish certain colours even under the best conditions, so we strongly recommend that you check the value of each resistor with a digital multimeter (DMM) to verify it is correct before soldering.

Remember that you don't need to fit the 10kΩ and 30kΩ resistors nor the 100µF capacitor near REG2 if you are not building the unit with the USB power output option.

Follow with zener diode ZD1, ensuring that its cathode stripe is orientated as shown in Fig.2 before soldering. The ceramic and MKT capacitors can go in next. Like the resistors, these are not polarised and can again go either way around but be sure to fit the correct value in each position.

Solder IC1 in place now, with its pin 1 dot or notch as shown in Fig.2. We don't recommend that you use a socket. Having done that, fig REG1 in a similar manner – again, making sure it's orientated correctly. And if you're building it with the optional USB power supply, also fit REG2 in the location shown, then follow with the USB socket. Solder its two larger mounting pins first, then the four smaller signal pins.

Bend the leads of Mosfet Q3 so that it fits onto the board as shown, then attach its tab with an M3 screw and nut. Do the nut up tight and ensure the Mosfet is sitting straight before soldering and trimming the three leads.

Now fit jack socket CON2, ensuring it is sitting flat on the board and aligned with the edge before soldering its five pins. Proceed by installing trimpots VR1 and VR3; these are different values, 50kΩ for VR1 and 1MΩ for VR3 so don't get them mixed up. Mount the two small transistors next. They are the same type but you may need to crank their leads out with small pliers so they fit the patterns on the board before soldering.

The electrolytic capacitors can now be fitted, including the 4.7µF tantalum type. The aluminium types, in cylindrical cans, have a stripe on the negative side and a longer lead on the positive side, so ensure the positive lead goes through the pad marked "+" on the PCB, as shown in Fig.2. The tantalum type will have a "+" printed on its body and this should be lined up with the corresponding marking on the PCB.

One of the 100µF capacitors only needs to be fitted if you have already fitted REG2; its position is shown in Fig.4

You can now fit DC input connector CON1, again, making sure it's pushed down fully and aligned with the edge before using plenty of heat and solder to form good fillets between the three flat tabs and the PCB pads.

The final capacitor to fit is tuning capacitor VC1. This fits on the top of the board, with its spindle stub shaft and three connection tabs passing down through matching holes in the board.

Turn the board over and attached the tuning cap body to the board using two of the M2.5 x 4mm screws supplied with it. Don't lose the third screw, though – you'll need it later to attach the disc knob to VC1's spindle. Now solder VC1's three pins to their corresponding board pads.

The oscillator coil T1 is next on the list. This is effectively polarised because there are three connection pins on one side of its base and only two on the other – be sure to orientate it correctly before pushing it all the way down onto the board. There are seven solder connections to make in all; five pin connections plus two for the can lugs.

You will need to cut the shaft of pot VR2 short, to around 10mm from the threaded ferrule, so that the knob doesn't stick out too far later. It's easier to do this before mounting VR2 although it can be done later if necessary. Having cut the shaft to length, solder VR2 in place.

Then fit LED1 with its body about 20mm above the board, making sure that the longer lead (anode) goes into the pad marked "A". Then bend its leads down through 90° about 14mm above the board, so that the LED faces away from the board and will later protrude through a matching hole in the side of the case later.

Antenna rod & coil

The final component to fit to the transmitter board is the antenna rod and coil assembly (L1). This is secured using two small cable ties, each of which loops around under the board through the pairs of 3mm holes provided for this purpose.

Do not replace the cable ties with wire or any other metal bands. A metal loop would form a "shorted turn" and this would absorb RF energy and seriously degrade the performance.

Unfortunately, making the coil's connections to the board can be a bit tricky. In most cases, there are four leads and it's not easy to work out which are the correct two to use – ie, the actual start and finish of the coil.

With the ferrite rod we used, the wires were marked with black, green, red and unmarked and the two we used were the black and unmarked wires. But other coils may use a different colour scheme.

In fact, the only reliable way to identify the start and finish leads is to check all lead combinations with an ohmmeter and go with the combination that gives the highest reading – typically around 11Ω.

Another little trap is that with many of these coils, the intermediate leads actually consist of two fine gauge insulated wires, twisted tightly and soldered together at their outer ends.

This means that if you decide to cut these leads short, they must be bared and soldered together again – otherwise, you'll find that the coil has become an open circuit between start and finish. And of course, the transmitter won't function very well with L1 open circuit!

A word of advice: if you do shorten any of the coil leads, it's a good idea to check the coil continuity with your multimeter before you solder the start and finish leads to the board.

Then it's time to fit the tuning disc (thumbwheel) to VC1's shaft and fasten it in place using the remaining M2.5 x 4mm screw.

A wire antenna is not strictly necessary as long as you can place ferrite rod L1 near the receiving radio's own ferrite rod or antenna (within 10cm or so). If you need a longer range, solder a 2m length of insulated hookup wire to the antenna terminal now.

The board assembly is then ready to attach to the box lid (used here as the transmitter's base). Before doing this, however, you may need to drill and cut the various holes in both the lid and the box itself, if you're building the project from scratch. The location, size and shape of each of the holes is shown in Fig.5.

The PCB assembly is secured to the lid using four M3 x 10mm tapped spacers and eight M3 x 6mm machine screws.

Once that's been done, it's time to check the transmitter's operation.

Checkout & adjustment

The first step is to set the supply voltage and for this, you will need a source of 12-20V DC power and a multimeter set to read volts.

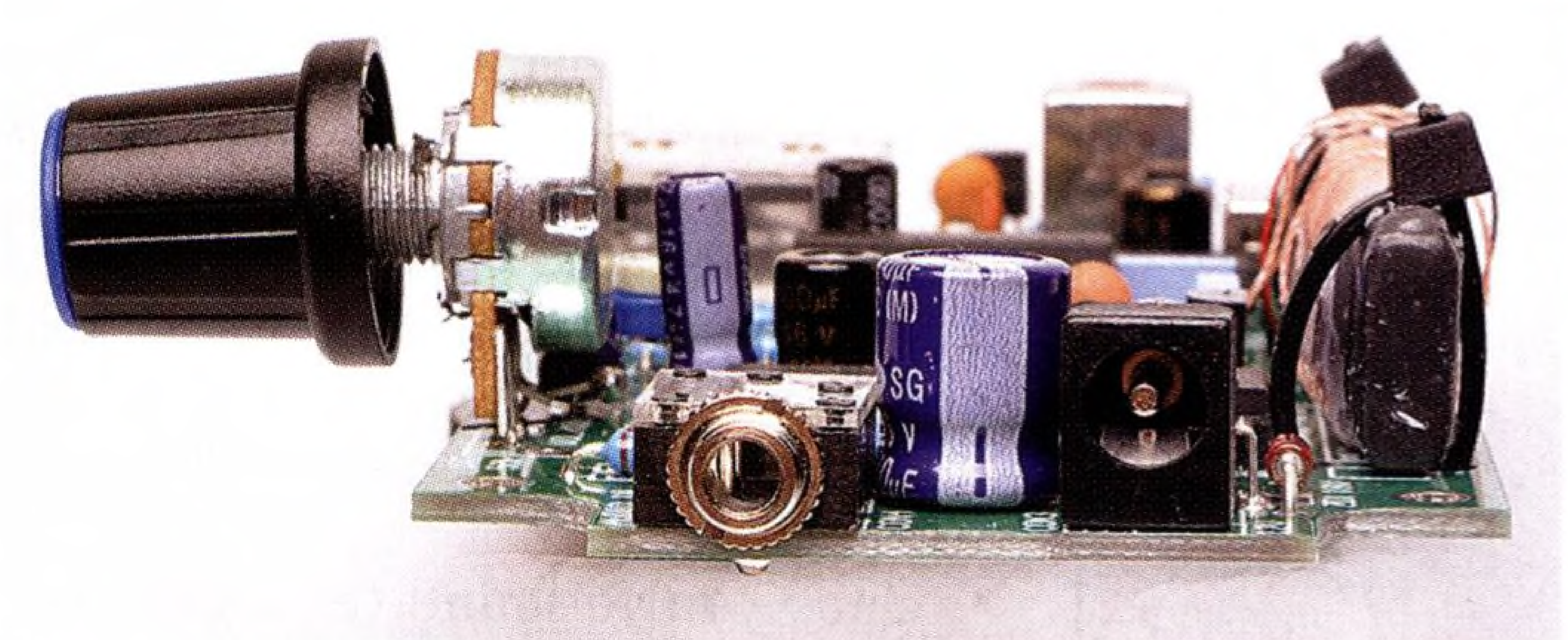
Rotate VR3 fully anti-clockwise, connect the DMM between TP1 (red)

Vintage Australian Radio Programs On CD

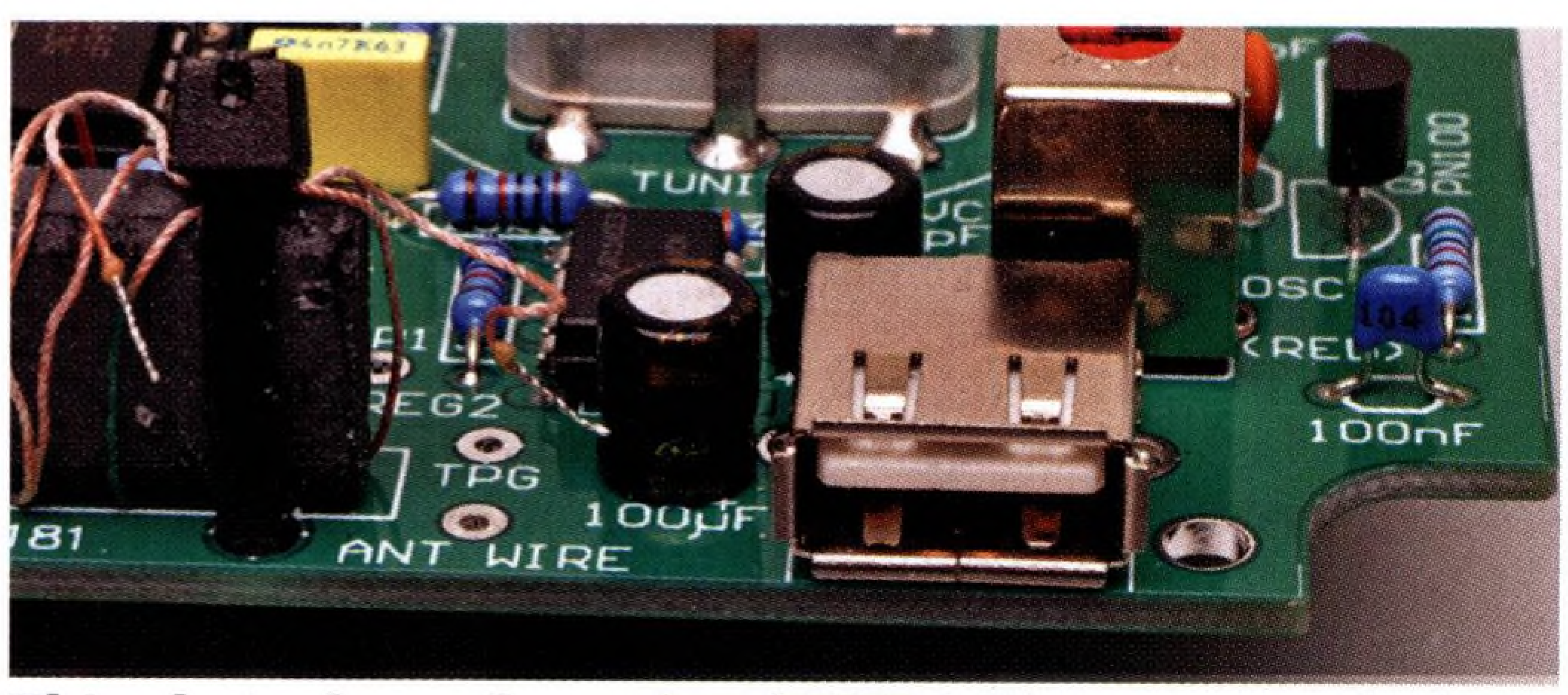
If you'd like to rebroadcast genuine old time Aussie radio programs through your AM Transmitter, you should know that many of the programs are available from ScreenSound Australia (the National Screen and Sound Archive).

You can purchase CDs with classic "golden age of radio" programs, including quiz shows, serials like Dad & Dave and Mrs 'Obbs, comedies like The Bunkhouse Show and McCackie Mansion, and so on. For more information on what's available, visit the ScreenSound website at https://shop.nfsa.gov.au/

That's not the only source of music – as mentioned earlier, the US site www.archive.org has an enormous library covering just about everything ever recorded. And most countries have, or are working towards, archives of their own.



There are only two connection points on the PCB: sockets for the audio input (left) and 12V DC power (right).



This photo shows the optional USB (5V) power supply for Bluetooth receivers, etc. If you don't need it, leave them out.

and TPG (black) and apply power. LED1 should light up and you should get a reading of around 1.23V. Slowly rotate VR3 clockwise until you get a reading close to 11.7V.

If you have fitted the optional USB power output, now would be a good time to move the DMM's red lead to pin 1 of REG2 (the square pad at lower right) and verify that you get a reading between 4.75V and 5.5V. No adjustment should be necessary.

For the remaining steps, you will also need a reasonably sensitive AM radio receiver. Switch off, then follow this step-by-step adjustment procedure:

(1) Adjust the two fine tuning capacitors on VC1 so that the metal half-discs do not overlap.

(2) Switch the radio on and tune it to a convenient frequency in the lower section of the broadcast band, away from any of the local broadcasting stations (in Sydney, you can tune to about 820kHz).

(3) Turn the volume up (you'll just hear static at this stage) and position the radio near the transmitter, orientated so that its internal ferrite rod antenna is roughly parallel to the transmitter's ferrite rod.

(4) Turn the transmitter's tuning control (VC1) to one end of its range, set trimpot VR1 well away from its centre position (this is important) and set VR2 (modulation depth) to its midrange position.

(5) Turn the adjustment slug in T1 anticlockwise until it stops rotating (do this gently or you could crack the ferrite slug).

(6) Feed an audio signal into the transmitter by plugging the audio cable from your signal source into CON2. Start the source up and make sure it has a sufficiently loud (high amplitude) output signal.

(7) Apply power to the transmitter. Check that the voltage at pin 8 of IC1 is close to +6V; you can again use TPG as a ground reference. If this is correct, your transmitter is very likely to be working properly.

(8) Listen carefully to the radio while you turn the transmitter's tuning knob very slowly towards the other end of its range. At some point, you should start to hear the music from your MP3 or CD player, after which you should be able to tune the transmitter so that its signal is received at a good strength.

(9) If you have trouble getting the tuning exactly right, you can use the two small trimmers on VC1 and/or the adjustment slug in T1 to fine tune the oscillator but be gentle with T1's slug (remember that we already set it fully anti-clockwise) and note that this will shift the overall tuning range down slightly (ie, you may no longer be able to tune up to 1500kHz).

Parts list – AM Radio Transmitter

1 double-sided PCB, code 06101181, 122 x 57.5mm
1 UB3 Jiffy box (130 x 67 x 44mm)
1 ferrite rod, 55mm long, with broadcast band coil (L1)
1 mini RF oscillator coil in can with red slug (T1)
4 M3 x 10mm tapped spacers
9 M3 x 6mm machine screws
1 M3 hex nut
1 2.1mm or 2.5mm ID DC barrel socket, PCB-mount (CON1)
1 3.5mm switched stereo jack, PCB-mount (CON2)
1 small knob (to suit VR2)
2 100mm cable ties
1 2m length of insulated hookup wire (for antenna)

Semiconductors
1 MC1496 balanced modulator, DIP-14 (IC1) [Silicon Chip Online Shop Cat SC4533]
1 LP2951 adjustable micropower regulator, DIP-8 (REG1)
2 PN100 NPN transistors (Q1,Q2)
1 IPP80N06 P-channel Mosfet (Q3)
1 3mm blue LED (LED1)
1 12V 1W zener diode (ZD1)

Capacitors
1 220µF 25V electrolytic
3 100µF 16V electrolytic
1 22µF 16V electrolytic
2 4.7µF 16V electrolytic or tantalum
2 100nF ceramic (disc or multi-layer)
2 10nF MKT
1 4.7nF MKT
2 470pF NP0/C0G ceramic
1 220pF NP0/C0G ceramic
1 22pF NP0/C0G ceramic
1 mini tuning capacitor 60-160pF, with thumbwheel and mounting screws (VC1)

Resistors (all 0.25W 1% metal film)
1 2.2MΩ 2 100kΩ 1 47kΩ 2 15kΩ 7 10kΩ 2 3.3kΩ 3 1.5kΩ 4 1kΩ 1 560Ω
1 50kΩ horizontal trimpot (VR1)
1 50kΩ 16mm PCB-mount logarithmic taper potentiometer (VR2)
1 1MΩ horizontal trimpot (VR3)

Optional extra parts for USB power output
1 LP2951 adjustable micropower regulator, DIP-8 (REG2)
1 horizontal PCB-mount type A USB socket (CON3)
1 100µF 16V electrolytic capacitor
1 30kΩ 0.25W 1% metal film resistor
1 10kΩ 0.25W 1% metal film resistor

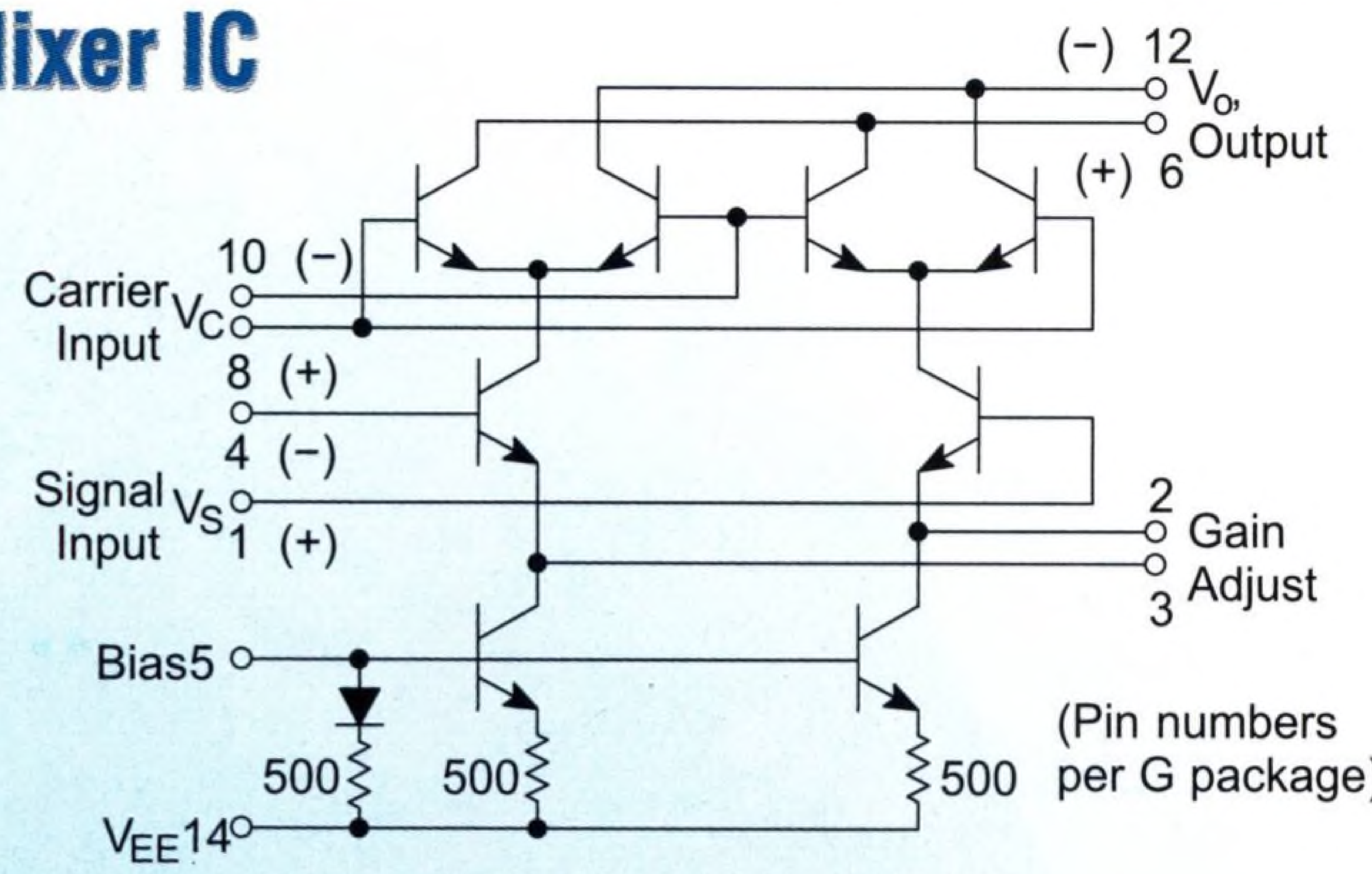
Troubleshooting

Can't find the signal? The first thing to do is to try tuning the transmitter back the other way but even more slowly and carefully than before. If this still doesn't bring success, try turning the adjustment slug in oscillator coil T1 anticlockwise another half-turn (or even a full turn if this later proves necessary).

This will shift the oscillator's tuning range up in frequency and should allow you to correctly adjust the transmitter when you tune VC1 over its range again.

Once you've found the signal and adjusted the transmitter's tuning control for the best reception, try

Inside the MC1496 Double Balanced Mixer IC



The circuit opposite shows what's inside the MC1496 IC which forms the "heart" of the AM Transmitter. Compared to some other ICs which may have thousands or even millions of components, this one is dead simple!

It comprises eight transistors (nine if you count the diode, which is almost certainly a transistor with its collector and base shorted) and three resistors.

Given the relatively low operating frequency in this circuit (sub-1MHz), the transistors don't even need to be a particularly special type. So you could build a double-balanced mixer from discrete components fairly easily. But why do that?

The MC1496 basically consists of adouble differential amplifier (the top four transistors), a standard differential amplifier (the two below these) and a current mirror for biasing the different amplifiers (the bottom section).

Starting at the bottom, an external current source is applied to pin 5 (Bias). This current flows through the diode and series 500Ω resistor to VEE (normally ground). This sets up a base bias voltage for the two transistors to the right. Since they also have 500Ω emitter resistors, and since their base-emitter voltage drop will be the same as the diode forward voltage, their collector currents will match the bias current.

The collector currents of these two transistors are ultimately sourced from the two outputs, at pin 6 (Vo+) and pin 12 (Vo-), shown at the top of the diagram. There is one current path from each output to each bias transistor. So say you supply 1mA to the Bias input.

That means that a total of 2mA will be drawn from Vo+ and Vo-, to supply the two 1mA current sinks at the bottom of the diagram. However, they will not necessarily be equal currents. For example, one could be 0.5mA and the other 1.5mA.

Notice that the upper two differential amplifiers are wired differently. In the left-hand differential amplifier, pin 8 (carrier +) drives the base of the transistor which controls current from pin 6 (V_0+) while in the right-hand differential amplifier, pin 8 (carrier +) drives the base of the transistor which controls current from pin 12 (V_0-).

So essentially, changes in the voltage of the + carrier input have the opposite effect on the differential output voltage compared to the – carrier input. And as you would expect, if you leave the signal inputs floating and simply apply a carrier, one output will simply duplicate the carrier signal while the other output will carry an inverted version of the same signal.

That just leaves us with the question of what the two extra transistors in the middle of the diagram do. These are connected to the signal inputs. The current through each transistor would be essentially fixed, because their emitters are connected to constant current sinks, except for the pin 2 & 3 connections, labelled "gain adjust".

A resistor is connected across these two pins and that allows current to flow from one side to another of the circuit, depending on which voltage is higher. And which voltage is higher depends on whether the voltage at pin 1 (signal input+) or pin 4 (signal input -) is higher, because these transistors are operating as emitter-followers.

Therefore, the differential input signal causes a differential voltage shift at the bottom of each of the differential amplifiers at top. And that shifts the current sharing between the two outputs, effectively controlling the gain of those upper pairs.

This has the effect of modulating the carrier signal which appears at the outputs, by an amount that depends on the resistor value between the gain adjust pins, because that controls how much current is shifted from one side to the other for a given signal input voltage swing.

The lower the resistor value, the greater the modulation (to a point).

And voila, we have generated a modulated RF carrier based on the applied signal.

turning up the transmitter's modulation control (VR2). This should make the reception even louder and clearer but if you turn the control up too far, the music will become distorted. Just back it off again until the distortion disappears.

Now is a good time to adjust trimpot VR1 for the best audio quality (maximum clarity).

We found that its optimum position was about halfway between the centre and one of the end positions of the rotor (on either side).

Don't set this trimpot (VR1) too close to its midway (centre) position, because this balances out the RF carrier altogether and gives double sideband (DSB) suppressed carrier modulation. And that gives quite a high distortion when you're using a normal AM receiver.

Once all the adjustments have been made, your AM Transmitter is working correctly and you're ready for the final assembly.

Final assembly

If your UB3 box has vertical PCB mounting ribs inside, you'll also have to cut some of these away.

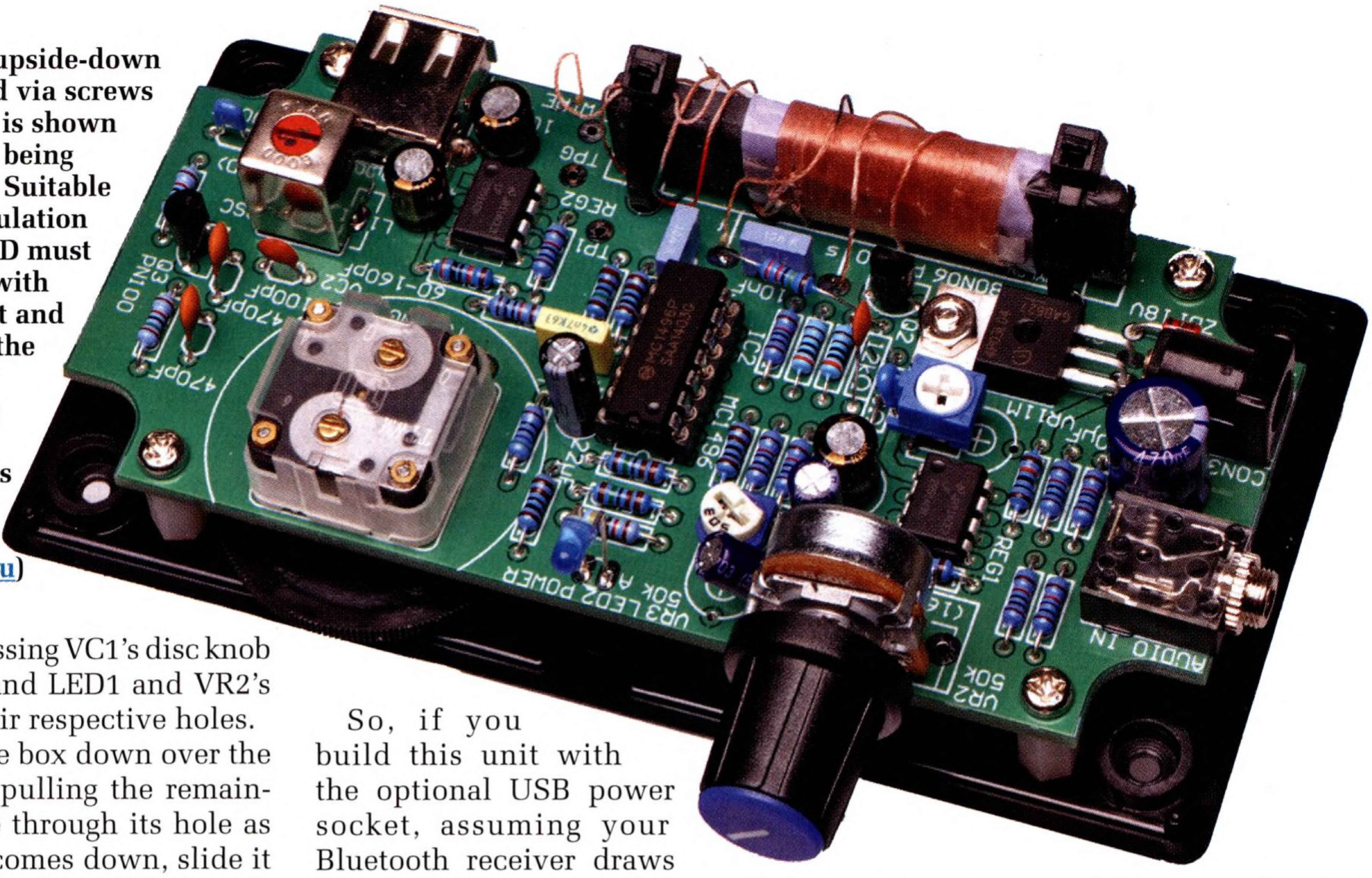
That's because the transmitter board assembly is a fairly tight fit inside the box and the ribs foul the ferrite rod and its coil.

The ribs to remove are mainly those at the rear side of the box, where they interfere with the ferrite rod. However, it's also a good idea to cut away any ribs on the end near the holes for CON1 and CON2 because these can make final assembly more difficult. You should also cut away any ribs on the front of the box, around the holes for LED1 and VR2, as this makes the final assembly even easier.

The ribs are easy to remove. The ABS material used in these boxes is fairly soft and can be cut away using a sharp hobby knife, small wood chisel or a rotary tool such as a Dremel.

Once the ribs are gone, remove the knob from modulation pot VR2 (if you have fitted it for the checkout) and unscrew the nut from VR2's ferrule.

You can now introduce the box to front of the lid/board assembly at a



The PCB mounts upside-down on the Jiffy box lid via screws and nuts – here it is shown in position before being fastened in place. Suitable holes for the modulation pot and power LED must be drilled (along with holes for the input and power sockets in the end; along with a slot for the tuning capacitor. (Drilling templates and panel art are available at siliconchip.com.au)

suitable angle, passing VC1's disc knob through its slot and LED1 and VR2's shaft through their respective holes.

Next, swing the box down over the board assembly, pulling the remaining antenna wire through its hole as you do so. As it comes down, slide it slightly towards the CON1/CON2 end, so that the ferrule of CON2 enters its clearance hole.

That done, you can fit the nut to VR2's threaded ferrule. Tighten it firmly and then refit the knob. Finally, turn the assembled box over and fit the four supplied self-tapping screws supplied to fasten everything together.

Connecting a Bluetooth receiver

A typical Bluetooth audio receiver is powered from a USB socket and has a 3.5mm stereo jack socket for the audio output.

Once you've paired your phone or tablet with it (see the supplied instructions) and your device is in range, it should connect automatically and any audio output will be received wirelessly and appear as a line-level signal at the output socket.

So, if you build this unit with the optional USB power socket, assuming your Bluetooth receiver draws no more than 100mA (most will be well under this), all you need to do is plug it into the power socket and connect a cable with 3.5mm stereo jack plugs at each end between the Bluetooth receiver audio output socket and the AM Transmitter's audio input socket.

You can verify the receiver is working by plugging a pair of headphones or earphones into its output socket and if so, you should have no trouble getting it to work with the AM Transmitter.

Just keep in mind that you will probably want to turn the Bluetooth and receiver volume controls right up and use the modulation depth control on the unit, to get the best audio quality.

Running it from a 9V battery

The AM Transmitter will operate from a 9V battery with slightly reduced output power and thus range. You just need to adjust VR3 to give around 8.5V at TP1.

The current consumption drops to around 7mA, giving more than 24 hours of runtime from a typical 9V alkaline battery.

Also, note our warning earlier about attempting to run from a higher voltage to achieve more output (and range). This would almost certainly make your transmitter illegal.

Tuning it to lower frequencies

It may be useful to modify the Transmitter to tune to around 450-455kHz, to allow you to inject a modulated test signal directly into a radio set.

This can be achieved by replacing the 22pF coupling capacitor with a 470pF ceramic capacitor. This should allow you to tune between 440kHz and 600kHz.

We do not suggest you add any extra capacitance across VC1 as it may prevent the oscillator from running. SC

Resistor Colour Codes

	Qty.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	2.2MΩ	red red green brown	red red black yellow brown
❑	2	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	47kΩ	yellow violet orange brown	yellow violet black red brown
❑	0/1	30kΩ	orange black orange brown	orange black black red brown
❑	2	15kΩ	brown green orange brown	brown green black red brown
❑	7/8	10kΩ	brown black orange brown	brown black black red brown
❑	2	3.3kΩ	orange orange red brown	orange orange black brown brown
❑	3	1.5kΩ	brown green red brown	brown green black brown brown
❑	4	1kΩ	brown black red brown	brown black black brown brown
❑	1	560Ω	green blue brown brown	green blue black black brown

Small Capacitor Codes

	Qty.	Value	µF Code	EIA Code	IEC Code
❑	2	100nF	0.1µF	104	100n
❑	2	10nF	.01µF	103	10n
❑	1	4.7nF	.0047µF	472	4n7
❑	2	470pF	N/A	471 or 470	470p
❑	1	220pF	N/A	221 or 220	220p
❑	1	22pF	N/A	220 or 22	22p