

Vintage Radio

By Ian Batty



Welcome To The Jet Age: Pye's Excellent C-2 Jetliner Transistor Radio



Pye's C-2 "Jetliner" meets all the obvious criteria for a successful portable radio. It's good-looking, has loads of audio output, picks up distant stations with ease, runs on almost-flat batteries and offers a tuning meter to precisely locate the "sweet spot". But it's what's under the hood that's really interesting.

AN ADDENDUM to the landmark 1960 "Mullard Reference Manual of Transistor Circuits" described a portable radio using the (then) new family of alloy-diffused transistors, the OC169/170. This design had a sensitivity of $20\mu\text{V}/\text{m}$ and considering that a ferrite rod antenna has a "loss" of some 10:1 (20dB in voltage terms), this implied a basic sensitivity of about $2\mu\text{V}$.

At the time, the Mullard circuit demonstrated that transistor portables had developed to a point where they could compete with valve sets and win the contest. Very few valve radios could get anywhere near this figure without an RF amplifier stage.

Both the Bush TR82C Mk.2 and the Kriesler 41/47 (described in this column in September & December 2013) adopted the basic Mullard design. The TR82C, in particular, achieved out-

standing sensitivity but suffered from excessive noise on its broadcast band.

As with the above two sets, Pye's Jetliner follows the iconic "Mullard Design". And like the 41-47, the Jetliner uses a PCB (the TR82C used a metal chassis and point-to-point wiring).

PCB construction often means restricted access to the circuit for servicing. Most sets, including the Jetliner, mount the board "component side" up, leaving the connecting tracks on the "inside" of the case. The Pye service data helpfully includes a component layout diagram. You can download the circuit and service details from Kevin Chant's excellent website at www.kevinchant.com

Circuit Description

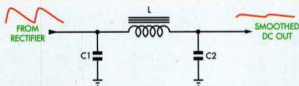
Fig.1 shows the circuit details of the Pye Jetliner. Like the TR82C and

41-47, it follows the design that had become standard for the time: a self-oscillating mixer (TR1), two IF stages (TR2 & TR3), a diode demodulator and a transformer-coupled audio driver (TR4) feeding a push-pull transformer-coupled output stage (TR5 & TR6).

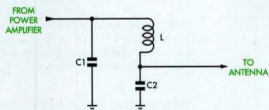
It uses six transistors (seven really), so it's the standard "trannie" that we all know. The transistors used in mine are Philips/Mullard germanium PNP types – alloy-diffused in the RF/IF section and alloyed-junction in the audio.

Bottom-coupled IF coils

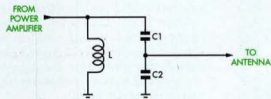
Whoever put this circuit together threw away the conventional handbook when it came to designing the 455kHz IF strip. That's because it uses separate bottom-coupled IF coils in each stage (rather than conventional IF transformers).



(a) 'PI' FILTER AS USED IN MAINS POWER SUPPLY



(b) 'PI' FILTER AS USED IN TRANSMITTER OUTPUT



(c) CAPACITIVE DIVIDER AS USED IN TRANSMITTER OUTPUT

Fig.3: (a) shows the conventional Pi filter configuration, (b) shows how it's used for RF impedance matching (C2 many times larger than C1) and (c) shows a reconfigured version with a capacitive voltage divider as used in the Pye Jetliner (again C2 is much larger than C1).

Basically, we need to match a high-impedance tuned circuit to a transistor's low input impedance. Transmitter circuits also need to match into low-impedance antenna feedlines, usually 50 ohms. As well, load impedances may be less than the feedline, requiring a step-up in impedance matching.

Although tapped coils can be used, it's easier to use some kind of capacitive voltage divider. This removes the "cut and try" method often needed at very high frequencies, where a coil may be only two or three turns and the exact tap location can be difficult to determine.

Most of us are familiar with the Pi-filter configuration that's used in mains-derived power supplies to smooth pulsating DC. What's not so obvious is that it can also be used in a tuned circuit to match impedances.

Fig.3(a) shows the conventional Pi-filter configuration, while Fig.3(b) shows how it can be for RF impedance matching. Finally, Fig.3(c) shows a reworked version with a capacitive voltage divider, as used in the Pye Jetliner.

In a conventional power supply

Pi-filter, C1 and C2 are often of equal values, eg, 8 μ F in vintage radio sets. However, in the RF version (Fig.3(b)), C2 is usually several times larger than C1, so that C2's lower circuit impedance matches the antenna impedance. C1, on the other hand, provides a high-impedance load as required by the power amplifier's output stage.

Similarly, in the capacitive divider (Fig.3(c)), C2 is much larger in value than C1. The design calculations are simple and any desired impedance step-down is easily achieved.

The capacitive voltage divider has an additional bonus: in the Jetliner, the mixer's collector voltage is blocked by the "top" capacitor. As a result, the bias network can apply bias directly to the first IF stage, as this point is also isolated from DC ground by the "bottom" capacitor. So we achieve resonance, impedance matching and DC blocking with just three components and no coil tapings.

Back to the Jetliner circuit

Unlike most 'broadcast-only' transistor sets, the Jetliner uses a tuning

gang with identical aerial and oscillator sections. In fact, it's quite unusual to see this in a Japanese-manufactured 'polyvaricon' that uses a sheet plastic dielectric rather than air-spacing.

As in its valve predecessors with identical tuning-gang sections, this means a that padder capacitor must be added to the oscillator provide tracking. This is the 315pF capacitor (C5) coupling the tuning gang to the top of the tuned oscillator coil (ie, just to the right of the 2N374/AF116n transistor - see Fig.1).

The mixer uses collector-emitter feedback, thereby reducing the amount of local oscillator radiation that's fed back out through the antenna rod. This design also includes an OA91 damping diode between the DC collector load of the first IF amplifier (2N373/AF117n) and the mixer's collector circuit. This diode considerably improves the performance of the AGC (automatic gain control) on strong signals.

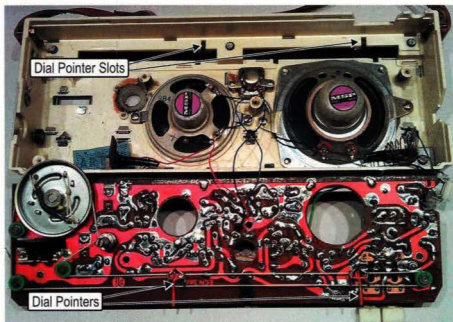
The mixer's output (ie, from TR1's collector) feeds the untapped primary of the first IF transformer and it's here that some thoughtful design work becomes apparent. Conventional broadcast-band IF amplifiers use tapings on the IF transformers to match impedances, especially on the secondary winding. This is necessary to match the low base impedances of the IF amplifier transistors and the low impedance of the demodulator diode.

By contrast, in this circuit, the first IF transformer's secondary is tuned by C9 (330pF) and C10 (5.6n) connected in series (giving 310pF). Importantly, C10's low reactance provides a good match for the first IF transistor's base impedance.

But it's even more complicated than that! The original Pye circuit drawing depicts the first IF transformer as the usual "two coils in the one can" configuration, coupled by their mutual magnetic fields. In reality, L3 and L4 are individual inductors in separate coil cans. They are bottom-coupled via the 33nF capacitor (C8) that appears to be a simple bypass.

In reality, the IF signal circulating in L3's resonant circuit is fed through capacitor C8, raising one end above signal ground. The signal at this end is in turn coupled through to L4 to create a signal current in its resonant circuit.

The use of bottom coupling also explains the unusual connection of L4's 'cold' end. Why not just connect



The PCB has been lifted free of the case here, revealing the two loudspeakers and the dial-drive mechanism. Note that the two dial pointers must be aligned with the case slots during reassembly.

and the Kriesler 41/47 suffer from increasing distortion with falling battery supply voltage, due to decreasing output stage bias. This is a common fault in many transistor radios, especially those using germanium transistors.

It's common to see a thermistor used in the output stage bias circuit but, in many cases, this only compensates for ambient temperature changes and cannot counteract falling bias with falling battery voltage. Worse, thermistors are often mounted on the circuit board and cannot compensate for overheating in an output stage that's being run at high volume. The Ferris M134 portable car radio was notorious for blowing OC72 output transistors caused by just this problem.

In many sets, increasing crossover distortion as the batteries age can be so bad that owners will discard batteries before they are truly "flat". As a result, I've actually modified some of these sets for family and friends to improve performance.

Unlike the TR82C and the 41/47, the Jetliner uses a semiconductor "diode" in the bias network. Well, it's not really a diode. Instead, it's a diode-connected transistor (TR7), which has its base directly connected to its collector.

The reason for doing this is straightforward. In operation, a simple germanium diode begins to conduct at around 0.2V but its forward voltage rises quite rapidly with current. This

means that a varying battery voltage would pass a varying current through a resistor in series with the diode and the diode's forward voltage would change accordingly.

Connecting TR7's base to its collector brings in transistor action. As soon as base current begins to flow, it will cause a larger collector current. This means that even a small increase in base voltage will cause a significant rise in total current, so the device acts as a diode with a sharper 'knee' than using the base-emitter junction alone.

This device not only delivers the required bias voltage but also has the same voltage-vs-temperature coefficient as the output transistors. As the temperature increases, the voltage across it reduces slightly to ensure that the correct bias is applied to the output transistors to ensure thermal stability.

As a result, the Jetliner (and sets with the same bias circuit design) deliver good audio performance until the batteries are almost dead flat. On test, the set easily delivered 50mW at under 10% distortion with "flat" batteries supplying just 3V, ie, half the nominated 6V supply voltage (4 x 1.5V cells).

The actual circuit specifies either of two bias transistors (AV-2 or OA675), depending on the actual output transistors used. The transistor is fitted with a "flag" heatsink that's riveted to those used for the two output transis-

tors. This gives tight thermal coupling so that the transistor-connected diode will respond to output transistor temperature variations. Even the best thermistors, separately mounted flat on a circuit board, cannot match this degree of bias voltage response.

Transistor manufacturing tolerances mean that some form of bias adjustment is needed. As a result, the Jetliner provides a jumper to select one of two bias values. This jumper either places resistor R28 in parallel with R29 or a series combination of R28 & R27 in parallel with R29.

Finally, emitter resistors R25 & R26 provide some local feedback and help balance differing gains in the two output transistors.

Getting it going

As it came to me, the set was almost dead. A common problem with old transistor sets is no output at all due to corroded/tarnished contacts on headphone jacks and power switches. By contrast, this set worked but its performance was extremely weak.

What was strange was that the signal meter indicated a "strong signal", with the pointer stuck at the righthand end of its travel. That just had to be wrong but it was also a clue as to the fault.

It didn't take long to find the cause—a bad solder joint between resistor R7 and the meter. And since R7 is transistor TR2's emitter resistor, this upset the operation of the first IF amplifier stage.

Once this joint had been resoldered, the set leapt into action. However, I was unhappy with the performance of the output transistors, so I raided my junkbox and replaced them. I then tested the set and found that I was able to tune stations from one end of the broadcast band to the other. Considering my country location, it was a good result and the Pye Jetliner seemed to be a pretty sensitive set.

A note on circuit board removal and replacement: the two dial pointers sit in a channel moulding behind the dial inserts and cannot be removed unless they are set to the top end of the band, so that they align with a couple of slots in the case. Similarly, on replacement, the two pointers must be lined up with these slots, as shown on one of the photos.

A bit about noise figures

It was time to pop the set onto the test bench to find out just how sensi-

Freq (kHz)	Signal ($\mu\text{V}/\text{metre}$)
1400	100 150 750
600	300 500 2500



This photo shows the needle positions on the 'Radicator' for various signal strengths at 1400kHz & 600kHz.

tive it really was and take a few noise measurements. Before doing that though, I applied contact cleaner to the switches and volume pot and then gave it a quick alignment check.

I measure sensitivity for a 20dB signal-to-noise ratio at 50mW output and at 30% modulation. To meet this 20dB requirement, I first set the input signal for 50mW output. I then turn the modulation off and (hopefully) get only 0.5mW of output. This gives me a S/N power ratio of 20dB.

If the noise-only signal is above 0.5mW, the volume control is turned down until the output reaches this level. I then turn the modulation back on and increase the input signal to get the 50mW standard output. In practice, it's common to juggle the volume control and signal generator output to get 50mW output at 20dB S/N ratio.

You may wonder why I don't simply detune the signal generator or turn it off, as this would give less noise. The reason is that the 20dB figure must be the "on signal" ratio, i.e. the ratio of the audio output to the noise in the received signal.

How good is it?

The frequency response of this set from the volume control to the loud-speaker is 140Hz to 25kHz ± 3 dB. So the high end is pretty "snappy" but a few more henries in the transformer windings would have given a better bottom end. Unfortunately, the IF channel (as in most broadcast-band AM radios) is the bottleneck. From antenna to speaker, the frequency response is 140Hz to about 2.8kHz, confirmed by an IF selectivity of -3dB at ± 2.8 kHz. At 60dB down, the selectivity is about ± 15 kHz.

The audio performance is pretty

good, with a total harmonic distortion of just 3.5% for a 1kHz signal at 10mW output. At 50mW output, the distortion is still just 4%. It rises to around 7% just as the amplifier begins to clip at 250mW output.

The transistor-diode's biasing superiority shows up with a low battery. At 3V (only 0.75V per cell), distortion is still only around 4.2% for 10mW output and is still under 5% at 50mW. Sets with resistor-biased output stages simply can't match this performance.

The Jetliner's RF sensitivity is outstanding and is under $3\mu\text{V}$ (ie, at the antenna terminal) for an output of 50mW. However, at this level, the signal-to-noise ratio is only 13dB at 1400kHz. The sensitivity falls to about $5.5\mu\text{V}$ if the gain is reduced to give the standard 20dB S/N ratio at this frequency. It's about the same at 600kHz, i.e. $5\mu\text{V}$ for 50mW output at 20dB S/N ratio.

In operation, this set produces a 50mW output at a field strength of $20\mu\text{V}/\text{m}$ at 1400kHz and $55\mu\text{V}/\text{m}$ at 600kHz (both at full gain). The required field strength rises to $50\mu\text{V}/\text{m}$ at 1400kHz to deliver a 20dB S/N ratio though.

Where the Jetliner shines is in the IF channel. In fact, its sensitivity is four times better than the Kriesler 41/47's when taken at the input to the first IF stage - about $50\mu\text{V}$ compared to $200\mu\text{V}$. Since both sets use the same transistors, it seems that the Jetliner's IF transformers and its improved coupling circuits are the secret.

AGC checks

Checking the AGC system revealed that the AGC control held the output to a 6dB rise for a signal increase of some 33dB. However, Mullard quoted 55dB with the specified AGC diode (D1), so what was going on?

Further checks showed that transistor TR2's collector voltage was only going to about 4V on full signal, during which the output was becoming distorted. Suspecting a fault in this stage, I tried shorting TR2's base to ground. This should have turned the transistor off and allowed its collector voltage to rise to at least 4.5V but this didn't happen.

Even with the set turned off, there was still some measurable resistance between TR2's collector and ground and the logical suspect was the .047 μF (47nF) bypass capacitor (C12). This

was one of those "red-tipped" high-value ceramics that's been notorious for leakage. On removal, it gave a resistance reading of about 10k Ω so it was effectively forming a voltage divider with the 3.9k Ω collector resistor (R8). And that in turn was preventing the AGC diode's cathode from rising high enough to obtain forward bias.

A new "greencap" capacitor fixed the problem. Shorting TR2's base to ground now resulted in its collector voltage rising to about 4.6V, as expected. More importantly, the AGC circuit was now working correctly with the set now handling a 60dB signal increase for an output power increase of just over 6dB (well in line with the original Mullard specification).

So leaky ceramic capacitors are a cause of trouble in low-voltage transistor radios. It's not just the electrolytic types that can cause problems.

Summary

The Jetliner is not a pocket set; instead its size and dual-speaker design make it a "picnic portable". Its sensitivity is one of its main features and the signal-strength indicator makes it possible to accurately tune stations.

It's a simpler set than the Bush TR82C and although the circuit is similar to that used in the Kriesler 41/47, its performance is much better.

In fact, its performance is excellent. It meets the manufacturer's impressive specifications for sensitivity and low-battery performance and my only reservation is the quoted output of 500mW, which I was unable to obtain. Some manufacturers do indicate up to 750mW output (with a 6V supply) for an OC74 push-pull output stage but the alternative 2N217 transistors appear to be lower-rated than the OC74s. It's possible that the 500mW figure quoted is for an OC74-equipped model.

Finally, note that the original circuit diagram for the Pye Jetliner shows TR7's base connected to its emitter. The base should in fact go to the collector (so that it correctly functions as a bias diode) and the circuit reproduced here has been corrected.

Further reading

If you've not already done so, take a look at Kevin Chant's excellent website at www.kevinchant.com It's a free resource for (mainly) Australian vintage radios and includes circuits, photos and parts information. **SC**