Vintage Radio

By Ian Batty

My kitchen radio . . .

Astor's M5/M6 5-transistor mantel sets

Despite using just five transistors, Astor's M5 & M6 radios are both good performers and make ideal kitchen "companions". The M5 is an all-PNP transistor design and the author's unit proved to be easy to repair and get going.

ASTOR RADIO Corporation began operation in 1926, based in South Melbourne. It quickly established a reputation for innovation because it offered radios in a variety of colours, compared to most other firms that offered standard timber cabinets only. The company later took over radio firms Eclipse and Essanay and went on to make a considerable contribution to the Australian radio industry.

Beginning, as many local makers did, with simple TRF sets, Astor soon progressed to producing superhet consoles, mantel sets and portables. The introduction of television and solid state devices saw Astor take up the opportunities offered by these new technologies, the company subsequently producing a wide range of TV sets and transistor radios. In fact, anyone who trained in "Radio and Television" at RMIT during the 1960s probably worked on the famous Astor SJ TV set.

It was during the 1960s that Astor was amalgamated with Pye which was then eventually absorbed into the giant Philips company.

Astor M5/M6: first look

Two interesting transistor sets produced by Astor during the 1960s were the M5 and M6 models, both featuring just five transistors. In my opinion, the M6's handsome plastic case puts it firmly into the so-called "Mid-Century Modern" school of design (from about 1940-1970). It's visually clean and unadorned, with none of the Art Deco scrolls or graceful rounded corners prominent in earlier times.

In addition, the M6's burnt-orange case, with white front insert, sits nicely in my kitchen. It's visually prominent without "shouting" its presence. On the other hand, the M5's red/black colour scheme is a bit too "loud" for my tastes.

Both sets feature direct-drive tuning which is operated by turning a large, clear plastic knob with a knurled edge. This allows stations to be quickly and accurately tuned. They are also both capable of producing a sound level that's easily heard throughout the room.

In short, clean design, good performance and ease of use make either an ideal mantel set.

M5 circuit details

Fig.1 shows the circuit details of the Astor M5. At first glance, it may appear somewhat confusing but the important thing to remember is that it uses PNP transistors throughout and has the negative DC supply rail connected to earth. Although this makes no difference to the circuit's operation, it does make some sections, especially the audio amplifier, a bit difficult to follow.

In addition, Astor simply numbered the components on its circuits in running order. However, this makes sense if you consider the assembly line workers. They didn't have to know whether a component was a resistor, a capacitor, a transistor or anything else. All

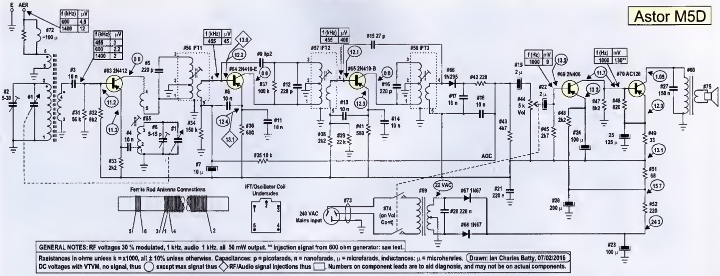


Fig.1: the Astor M5D's circuit uses five PNP transistors. Transistor #63 is the converter stage, #64 and #65 are IF amplifier stages, #69 is an audio driver stage and transistor #70 is a class-A audio output stage. Capacitors #9 and #15 are used to neutralise the two IF amplifiers, while the filtered output from diode demodulator #66 provides AGC to transistor #64.

they had to do was match the vacant component positions on the PCB they were assembling to the component bin numbers.

Rather than reinvent the wheel, I've preserved Astor's original component numbering on the redrawn circuit presented here.

As shown, the tuned RF signal is fed to the base of the 2N412 converter transistor (#63). This stage operates with fixed bias and uses collector-emitter feedback. This, together with a cut-plate tuning gang (and thus no padder), is pretty much a standard design. The only addition is an aerial coupling winding on the ferrite rod, which is useful if you need to connect an external aerial.

There's no immediate sign of an antenna screw terminal or socket on the case but the designers have pulled a neat trick. The aerial and earth connections are both made via two case screws on the underside of the cabinet, close to the front. Fortunately, they are clearly labelled.

IF stages

The output from the converter is fed to the tapped, tuned primary of the first IF transformer (#56) and this in turn feeds the first first IF amplifier stage, a 2N410-E (#64). This is the AGC-controlled stage. It uses combination bias (emitter resistor #36, base divider resistor #34), while the AGC control voltage is derived from the demodulator via resistor #35.

Because the 2N410 transistor is an alloyed-junction type, its high collector-base capacitance requires neutralisation (ie, from collector to base). That's done using capacitor #9.

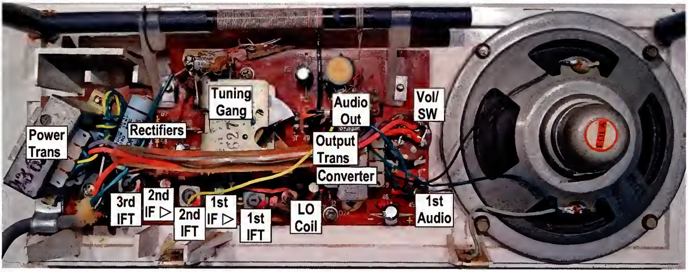
The second IF transformer (#57, IFT2) also has a tapped, tuned primary and feeds the signal to the second IF amplifier, in this case a 2N410-B (#65). This stage also operates with fixed combination bias. Note that IFT2's primary is shunted by a 100kΩ resistor (#37) to help broaden the IF bandwidth.

This second IF amplifier feeds a third IF transformer (#58, IFT3). Unlike IFT2, this last IF transformer is not shunted, as the loading of the following demodulator is sufficient to lower the primary winding's Q factor and broaden its bandwidth.

As with IFT1, the second IF amplifier (#65) is neutralised. That's done using capacitor #15 which is connected between IFT3's secondary and the transistor's base. This neutralisation capacitor has a value that's several times higher than that of capacitor #9 which is used to neutralise the first IF amplifier stage.

This is necessary due to its secondary IF connection; the signal is stepped-down which means that more

This photo shows the Astor M5 at left, while at right is the M6. They use the same cabinet but the colours and front panel details are different.



This photo shows the locations of the major components on the PCB. The parts are all easily accessible but be careful not to apply too much heat when desoldering parts from the board, as the copper pads are prone to separate from the laminate.

capacitance is needed for proper neutralisation.

The 1N295 diode demodulator (#66) is slightly forward biased by the first IF amplifier's bias resistor (#34). As the incoming signal strength increases, the diode produces a positive-going rectified signal current that partly opposes the current in this resistor. This in turn reduces the bias on the first IF amplifier stage and reduces its gain. Bypass capacitor #7 filters out audio signals to prevent them from affecting the AGC action.

Basically, it's a classic diode demodulator/AGC design, the only difference being the "upside-down" nature of the circuit due to the use of PNP transistors.

The demodulator drives the usual filter capacitors (#17 and #18), resistor (#42) and an audio load resistor #43. The recovered audio is then fed via capacitor #19 to volume control #44 and from there via capacitor #22 to the first audio amplifier stage (#69). This then drives the audio output stage (#70)

The audio section is direct-coupled, with DC-coupled feedback from the output transistor's emitter back to the driver transistor's base.

M5: simplified audio stage

The redrawn audio amplifier circuit shown in Fig.2 makes it somewhat easier to follow. Audio output transistor #70 (an AC128) gets its base current via resistor #47. At only 8.2kΩ and with around 11V across it, this could potentially provide almost 1.5mA of base current for transistor #70. That sounds like a lot and it would be except for the action of audio driver transistor #69 (a 2N406).

As the AC128's collector current builds (potentially to some 75mA or more), it also draws emitter current. This emitter current flows through emitter resistors #49 and #51.

As shown on Fig.2, the top of resistor #51 is connected via resistor #45 (2.7kΩ) back to the driver transistor's base. The resulting base bias causes collector current to flow in this transistor. As its collector current increases, the voltage across resistor #47 also increases and so transistor #69's collector voltage approaches its emitter voltage.

However, since transistor #69's collector voltage is also transistor #70's base voltage, the base bias applied to the latter falls. It's a classic DC feedback circuit, which will stabilise at a designated value; in this case, at a collector current of around 30mA in output transistor #70.

Emitter resistors #46 and #49 and base-emitter resistor #48 "trim" the DC conditions, while capacitors #24 and #25 provide emitter bypassing to prevent degenerative feedback from cutting the gain. Capacitor #27 rolls off the high-frequency response. This slightly reduces the distortion and helps to reduce the noise in weak signals.

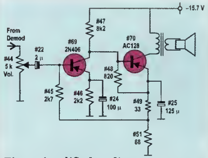


Fig.2: simplified audio output stage for the M5. It's a classic DC feedback circuit with output transistor #70 operating in class-A mode.

The AC128 (#70) operates as a Class-A stage. It drives output transformer #60 which in turn couples the amplified audio to a 5-inch (125mm) loudspeaker (#75). The set's power consumption is around 390mW, with around 330mW dissipated in the output transistor itself.

Note that although the AC128's maximum power rating is 1W, this rating only applies with adequate heatsinking. The AC128's thermal resistance from junction to ambient air (with no added heatsinking) is 290°C/W. Left with no heatsinking at all, a 1W power output at 25°C air temperature would send the transistor's junction to over 300°C and the device would quickly fail!

Astor's solution was simple: the transistor was fastened to a heatsink clip that was soldered to the output transformer's frame. That way, the output transformer also acted as a large heatsink for the output transistor.

The power supply uses transformer #59 to supply 22VAC (44VAC centre-tapped) to a full-wave rectifier based on diodes #67 and #68. Capacitors #23 and #26 and resistor #52 filter the output, while capacitor #21 provides RF filtering.

M6 circuit details

Astor's M6 "twin" is quite similar to the M5. Once again, it's a 5-transistor design and its RF/IF section differs only as follows: (1) it uses NPN silicon transistors without neutralisation; (2) damping resistors are connected across the first and second IF transformer primaries; (3) different bias resistors are used to provide the higher base bias voltage needed by silicon transistors; (4) the first IF amplifier's emitter voltage drops from 0.6V to 0.2V on strong signals; and (5) there are no external aerial/earth connections.

The Astor circuit diagram indicates the use of an AT325 transistor for the converter, followed by three AT319s for the IF amplifiers and audio driver stage. An AX1167 is specified for the output stage. By contrast, my set uses Philips "lockfit" (SO-25) BF194/195 types and an OC9264 output transistor.

Another set that I've worked on used the specified AT-series transistors for the first four stages and a Fairchild AX1157 TO5 ceramic/epoxy device in the output stage. All sets used germanium demodulator diodes.

So why were the extra damping resistors used? The reason is that the silicon AT/BF series transistors have high output impedances – about five times that of the germanium 2N-series devices. So while the M5 was able to capitalise on the lower output impedances of its 2N-series transistors to help broaden the IF bandwidth, the M6 required damping resistors to achieve the same effect.

Simplified M6 audio stage

Fig.3 shows the Astor M6's audio stage. As with the M5, it's direct-coupled but the circuit is quite different. In this case, the driver transistor (#74) is an NPN device, while the output transistor (#75) is again a PNP device.

Resistors #46 and #45 form a voltage divider and this sets the bias on the driver transistor's base to 2V. Its emitter is connected to ground via resistors #52 and #54, while its collector current flows through resistor #49 and also through the base-emitter junction of the output transistor (#75). In fact, the driver stage could potentially pull over 1mA through transistor #75's emitter-base junction (resulting in a collector current of some 100mA or more through the output transistor) if not for resistor #54.

The voltage across this resistor increases as the output transistor's collector current builds (ie, the voltage at the top of the resistor is pulled closer to the 17.2V supply rail). This in turn reduces the voltage across resistor #52, thereby reducing the driver transistor's emitter-base voltage and thus its bias. As a result, the circuit stabilises with the output transistor collector current of around 30mA, as in the M5's circuit.

The 250μF bypass capacitor (#22) at the driver transistor's emitter removes any degenerative (gain-reducing) feedback in this stage. In addition, resistor #51 provides DC-coupled feedback, controlling the overall gain and effectively increasing the driver transistor's input impedance. This feedback also reduces audio distortion.

It's about as simple as you can get, yet it performs quite well. The only drawback, as with the M5, is the low efficiency of the Class-A output stage. However, in a mantel set which consumes just a few watts in total from the mains, it's a minor quibble.

Like the M5, output transistor #75 is fitted with a small flag heatsink that's attached to the power transformer.

M5 clean-up

My M5 was bought at a garage sale.

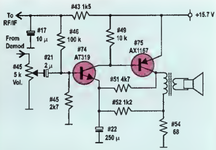


Fig.3: simplified audio output stage for the Astor M6. As with the M5, it's direct-coupled but, in this case, driver transistor #74 is an NPN device, while the output transistor (#75) is again a PNP device.

Unfortunately though, it wasn't working when I got it home; plugging it in and turning it on resulted in silence.

I turned on another set, tuned it to the top end of the broadcast band and was rewarded with a "swoosh" from its speaker as I varied the M5's tuning at the low end. This indicated that the M5's local oscillator (LO) was working and perhaps the rest of the RF/IF section as well.

I then opened the case and injected audio into various points in the audio stages. I found that I needed to inject some tens of millivolts into the output transistor's base in order to achieve a good output. However, I needed to feed even more into the volume control, so perhaps the driver transistor was dead?

The DC voltages around the driver stage subsequently checked out, so the transistor was OK. Instead, it turned out to be the usual suspects – dried-out coupling capacitors (#19 and #22). I ended up replacing all seven electrolytics in the set, just to make sure.

That done, I gave the set a quick alignment and a good clean, after

What To Watch Out For During Restoration

While changing the electrolytic capacitors in my M5 radio, I rather carelessly failed to completely desolder one of the circuit pads. When I subsequently wiggled the associated capacitor to remove it from the board, this pad lifted clear off the board.

Because of this, I suspect that the copper-to-board bonding is not especially good on these sets. My advice is to be careful and to take your time if doing repairs on M5 and M6 receivers.

Be aware also that the tuning knob is NOT a simple press-fit onto the tuning gang shaft, as it is with many other sets. Removing the tuning knob involves first prying off the centre gold/silver metal cap, then undoing three small screws that clamp the knob to a boss that's attached to the tuning gang's shaft.

Finally, note that the mains wiring in the M5/M6 is lacking in some respects. There's no grommet or strain relief where the mains cord enters the case and the mains wires inside the case are routed (through insulation) across the back of the metal tuning gang to the on/off switch on the back of the volume control. This volume control is fitted with a metal knob, while the metal boss in the centre of the tuning knob is in direct contact with the tuning gang.

For this reason, restorers are advised to check the mains wiring carefully, particularly the insulated tubing that carries the mains wires to the on/off switch. Make sure also that the circuit is correctly earthed.

Screw terminals for the external aerial and earth connections are hidden under the front edge of the cabinet. In most situations though, the set's internal ferrite rod antenna should provide adequate signal pick-up.

which it was right to go. By contrast, my recently-acquired Astor M6 model worked straight away and simply required a good clean and some alignment adjustments to optimise its performance.

How good is it?

Despite having just five transistors, the M5 is nearly as good as a conventional 6-transistor set with a push-pull output stage. Philips' marvellous Model 198 is better but the M5's provision of aerial and earth terminals (as was common with valve mantels) allowed it to also perform quite well in country areas.

The M5's sensitivity (50mW output) is 70µV/m at 600kHz and 45µV/m at 1400kHz for signal-to-noise (S/N) ratios of -10dB and -11dB respectively. A -20dB S/N ratio requires a signal strength of some 150µV/m at both frequencies.

At the aerial terminal, the sensitivity is 4.5µV at 600kHz and 12µV at 1400kHz for -10dB and -11dB S/N ratios respectively. The corresponding figures for a -20dB S/N ratio are 10µV and 38µV respectively. The loss of high-end gain is probably due to matching inductor #72 which has a value of 100µH.

The IF bandwidth measured ±2.3kHz at -3dB and ±31kHz at -60dB, which is reasonable. The AGC action is quite good, with the output rising by 6dB for a signal increase of some 22dB.

The audio response is 80-2600Hz from volume control to speaker and about 80-2200Hz from the antenna to the speaker. It gives 8% distortion at 50mW output, 3.5% at 10mW and 12% at 100mW with noticeable clipping. These distortion figures are consistent with single-ended Class-A output stages where (unlike push-pull output stages) odd-harmonic distortion is always present to some degree.

A note on testing

I've given signal injection voltages (as I do in all my testing) according to the generator output controls, as it's much easier than trying to measure the actual signal voltages in-circuit. However, this loses validity when injecting signals into the base of the AC128 audio output transistor.

In that case, the generator's 600Ω output impedance is attempting to drive the AC128's base impedance which may be only 100Ω. The result is a lower-than-indicated signal voltage being injected into the circuit.

The all-silicon M6

For the M6, we get similar sensitivities of 75µV/m at 600kHz and 33µV/m at 1400kHz for for 50mW output (S/N ratios of -12dB and -7dB respectively). Achieving a 20dB S/N ratio requires some 400µV/m at 600kHz and 150µV/m and 1400kHz.

The M6's IF bandwidth is ±2.6kHz at -3dB and ±27kHz at –60dB. Once again, the AGC action is quite good, with a signal increase of some 28dB necessary for an increase in output of 6dB.

The audio frequency response is 55-7300Hz from the volume control to speaker and around 50-2100Hz from the antenna to the speaker. The distortion is 1.5% at 10mW output, 2% at 50mW and 10% at about 120mW.

The lower distortion at lower output levels is testament to the use of negative feedback in the M6's amplifier stage.

In operation, the 5-inch loudspeaker, combined with a good-sized cabinet, gives acceptable low-frequency response down to about 100Hz.

"M" versions

Astor made other "M" version radios that were housed in the same case, eg, the look-alike M2 which was supplied with a separate remote speaker. This allowed normal radio listening (from the internal speaker), while the remote speaker allowed the unit to be used as an intercom or as a baby monitor. Radio listening via the remote speaker only was another option.

The M2 is a 7-transistor set, with four transistors used in the audio section to enable intercom operation. Two of these transistors were used in a push-pull audio output stage.

Would I buy another?

For the time being, I'm happy to stop with the M5 and M6 models I have, one of which is used as a kitchen radio. However, an M2 (preferably with its extension speaker) would be hard to pass up if any still exist. **SC**

Further Reading

(1) Special thanks to Kevin Chant for the original M5 and M6 circuits: www.kevinchant.com/astor.html

(2) Further information on the Astor M5 and M6 is on Ernst Erb's Radio Museum site: www.radiomuseum.org/r/astor_m5d.html

(3) For further information on direct-coupled bias circuits, refer to "Power Supplies and Biasing", Radio Waves, October 2015, pages 18-28.