View ANY program – even digital TV – on a Vintage TV Set with this

Analog TV audio/ video modulator

1950s' and 1960s' TVs are now old enough (and rare enough) to be regarded as collectable. But how do you enjoy them? You certainly can't use off-air signals – they're now all digital. And the output from a modern VCR or set-top box can be far from optimal for driving these old TV sets. This design will process that signal to provide optimum picture and sound quality.

Television first appeared in Australia in 1956 and was a great boon for the Australian electronics industry.

As with a vintage radio, you can restore a 1950/60s TV to working order and an increasing band of collectors and enthusiasts are doing just that.

But unlike AM radio (where analog and digital signals still happily co-exist), vintage TVs can no longer be used as originally intended because of the shut-down of analog TV transmissions.

Of course, it is not only vintage TV collectors who may need a good signal for displaying on an old TV set.

Every time you see a TV series which might happen to show a working TV set of the era means that there is a need for an optimal signal.

Museums face this problem too and it is sometimes apparent that their display is far from optimum. After all, back in the days of black & white TV, people did not habitually watch poor quality pictures.

So what is the use of a beautifully restored TV if you can't watch anything on it?

The obvious approach is to use a commercial VHF TV RF modulator or the modulator in a VCR.

Either of these will accept a composite video signal and audio, which can come from a digital TV set-top box (allowing you to watch current TV channels), a digital media player or a DVD player.

By Ian Robertson

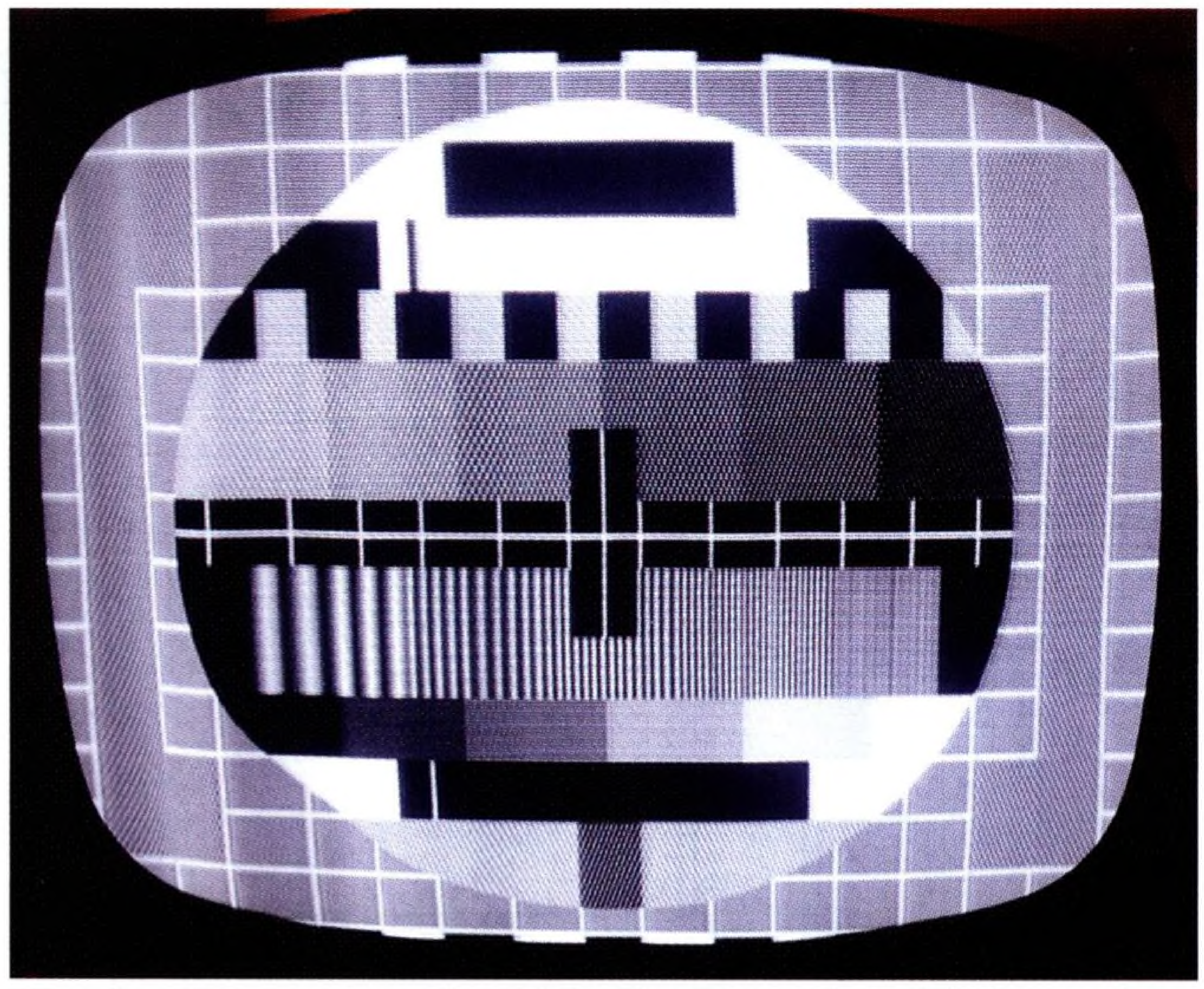
In most cases, provided your TV can tune to a channel your modulator can generate, you may get an acceptable picture and sound on your vintage TV this way. But chances are that the results will be disappointing.

Depending on the TV and the material you are playing, you may notice symptoms such as diagonal white lines and buzzing interference in the sound, spoiling your enjoyment of that classic movie or TV show. (See adjacent photo.)

Why does this happen?

Well, the short answer is that modern analog TV signals are different to those that were broadcast in the 1950s and 1960s.

The diagonal white lines often seen on older sets are retrace lines, which are normally hidden but can manifest themselves due to the VBI not being fully blanked. By the way, the blue cast on these screens is quite typical for sets of the day.



Here's a "test pattern" which displays a lot of information about the signal (in this case, after being processed by our new Video/Audio Modulator). The moiré pattern is caused by an interaction between screen and camera.

Firstly, in the late 1960s, in readiness for colour, the transmitted sound carrier power was quietly reduced from 25% of peak vision power to 10%.

The main effect at the time was that many older TVs became more critical to tune for good sound quality. That could be tricky because the tuning for best picture (with minimum snow) could result in poor sound.

The second change was the "discovery" in the mid-1970s of the Vertical Blanking Interval (VBI) in the TV signal.

The VBI is effectively the time that was included in the TV signal to allow the scanning beam in the receiver's CRT time to return from the bottom to the top of the screen (vertical retrace).

Prior to the mid-1970s, the VBI contained no information, just a black signal; actually, it was below the black signal level.

Then John Adams at Philips in the UK came up with the idea of transmitting text data in this otherwise wasted interval and Teletext was born.

Other uses soon appeared for the VBI. Amongst these were Vertical Interval Test Signal, Time Code and once home video recorders appeared, a number of copy protection schemes, notably Macrovision.

All these systems have three main attributes: They became embedded in the recorded video, they were virtually ubiquitous and the VBI portion of the signal was no longer below "black".

Why should this be a problem, since even vintage TVs have vertical retrace blanking circuits?

The answer is, it turns out to be almost impossible to fully blank peak white signals that occur in the VBI using available internal signals in the TV with passive circuits.

Because such VBI manipulation hadn't been thought of, early TV designs simply didn't do it. Even some early colour TV designs were embarrassed by signals in the VBI and required field modifications.

VBI signals cause another problem. When fed to most RF modulators, the peak white excursions of the data in the VBI completely cut off the AM vision carrier.

This action "punches holes" in the FM sound carrier, causing an annoying buzz in the sound. You might remember this buzz from the days when you operated your TV through the VCR.

So what can be done about it?

You could modify the TV to bypass the entire RF section and feed vision and sound directly to the video and audio amplifiers.

When done properly, this can work very well but it does require specific modifications to each TV and arguably ruins the originality and authenticity of the set.

And since most vintage TVs used the AGC to provide contrast control, you will usually lose this control.

This is actually the rear panel of the Modulator – you'd normally bring all cables in here so it would be hidden.

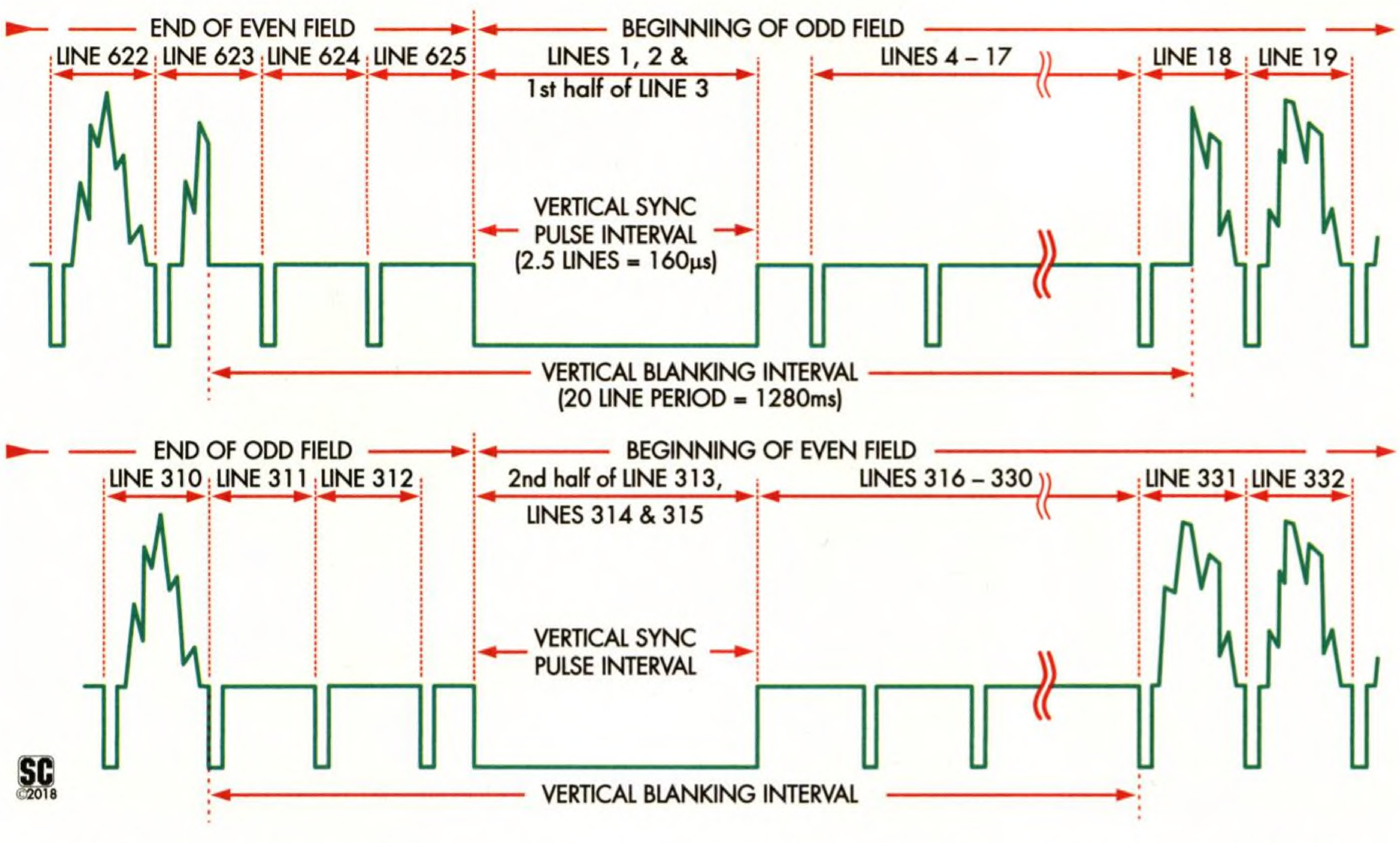


Fig.1: the structure of an analog video signal around the time of the vertical blanking interval (VBI), ie, the time between the transmission of each field (half of an interlaced image). This interval contains a negative sync pulse (much longer than the horizontal synchronisation pulses) plus a number of nominally blank lines. In many cases, they might not actually be blank and that can upset older TV sets.

What is really needed is a device that will convert modern video signals into a form suitable for any vintage TV.

To do so, we need to remove all signals during the VBI and return it to black, clip any peak white excursions above 1V peak, so they don't affect the sound, and generate a TV signal with a "B&W era" 25% sound carrier.

Then it should provide the best possible picture and sound quality. And ideally, it should be simple, inexpensive and easy to build!

Many possible design choices were evaluated. The video processor could have been implemented digitally but an analog solution was chosen because of the lower cost and complexity.

How it works

To reach the goals outlined just above, three main circuit sections are required: video processing, audio processing and RF modulation.

The video processing circuitry must detect the vertical synchronisation pulse and start a timer which lasts for the duration of the VBI (1.28ms) so that it can suppress any extraneous video signals during this time.

This is illustrated in Fig.1, which shows how the last two to three lines of each field are normally blank, containing only horizontal synchronisation pulses, which are negative excursions in the video signal, below the black level.

The vertical synchronisation pulse is essentially the same but much longer, lasting for 160µs, which is the time normally taken to scan 2.5 lines.

The remainder of the third line, plus lines 4 to 17 are blank and finally, the next field starts with line 18. So it's these blank lines which may contain unwanted signals that we need to suppress.

The rest of the time, during normal picture scanning, it needs to clamp the maximum signal level to the correct white level and by implication, it must also adjust the signal to achieve the correct black level.

Vintage TVs don't all display an accurate black level but it's needed anyway to ensure the minimum vision carrier level of 20% on peak white is observed, so that the sound is not affected.

Fig.2 shows the signal voltage during the scanning of one line. It starts with the horizontal blanking interval, during which time the CRT electron beam is being swept back to the start of the next line.

During this time, you can see there is a short pause (the front porch), followed by the short, negative horizontal synchronisation pulse, the back porch (which for colour signals, incorporates the PAL or NTSC colour burst), then the visible line interval, during which the video signal provides the brightness (luminance) information via its amplitude and, in the case of colour sets, the chrominance information via the phase information.

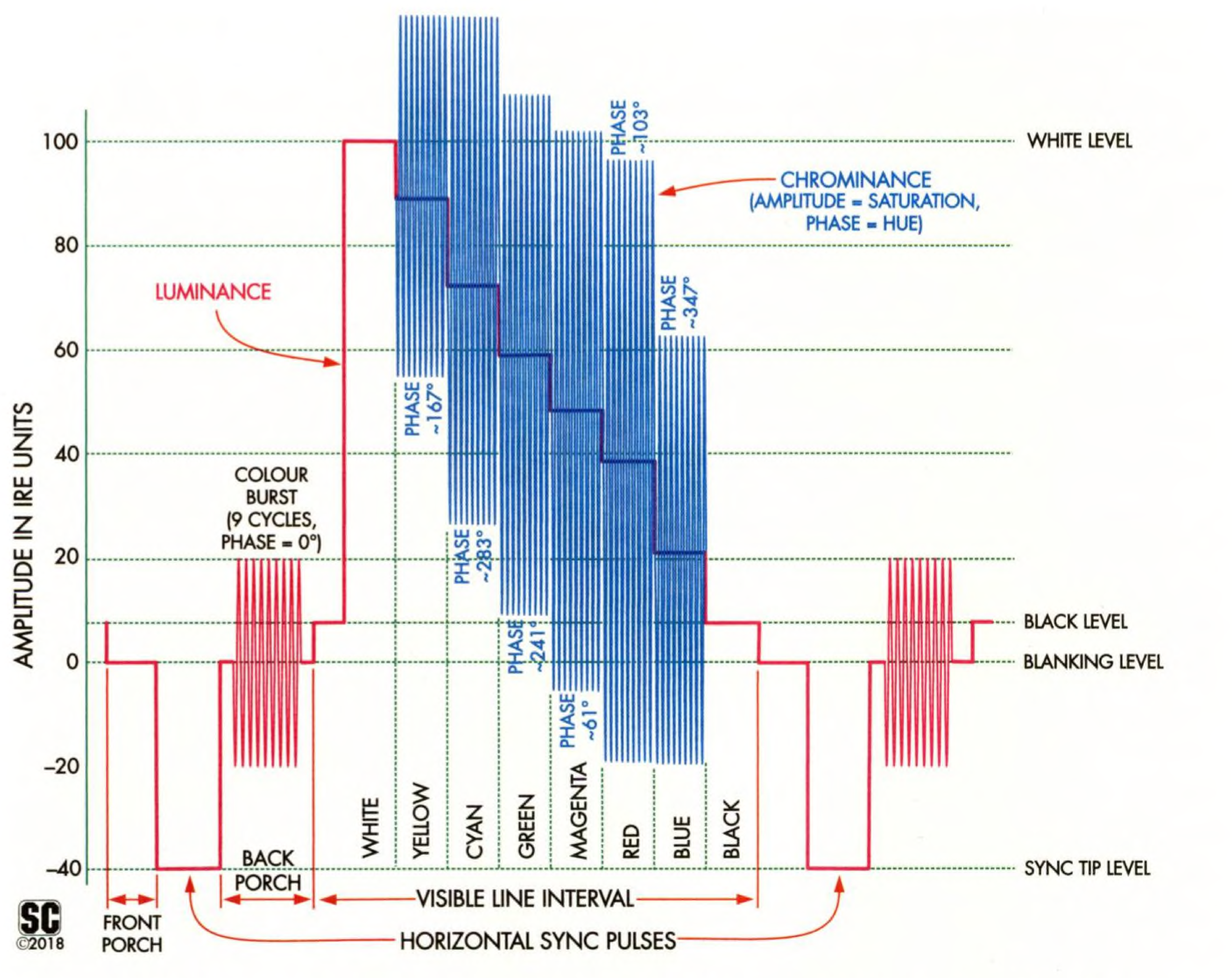


Fig.2: a PAL image contains 625 lines and each one is transmitted with a signal as shown here. The front porch and back porch provide a reference black level for the rest of the signal. The peak-to-peak amplitude, from the horizontal sync pulse to the white level, is normally 1V. Sometimes signals can exceed 1V; one of the jobs of the circuit described here is to prevent that as it can badly affect sound quality by blanking the audio FM carrier.

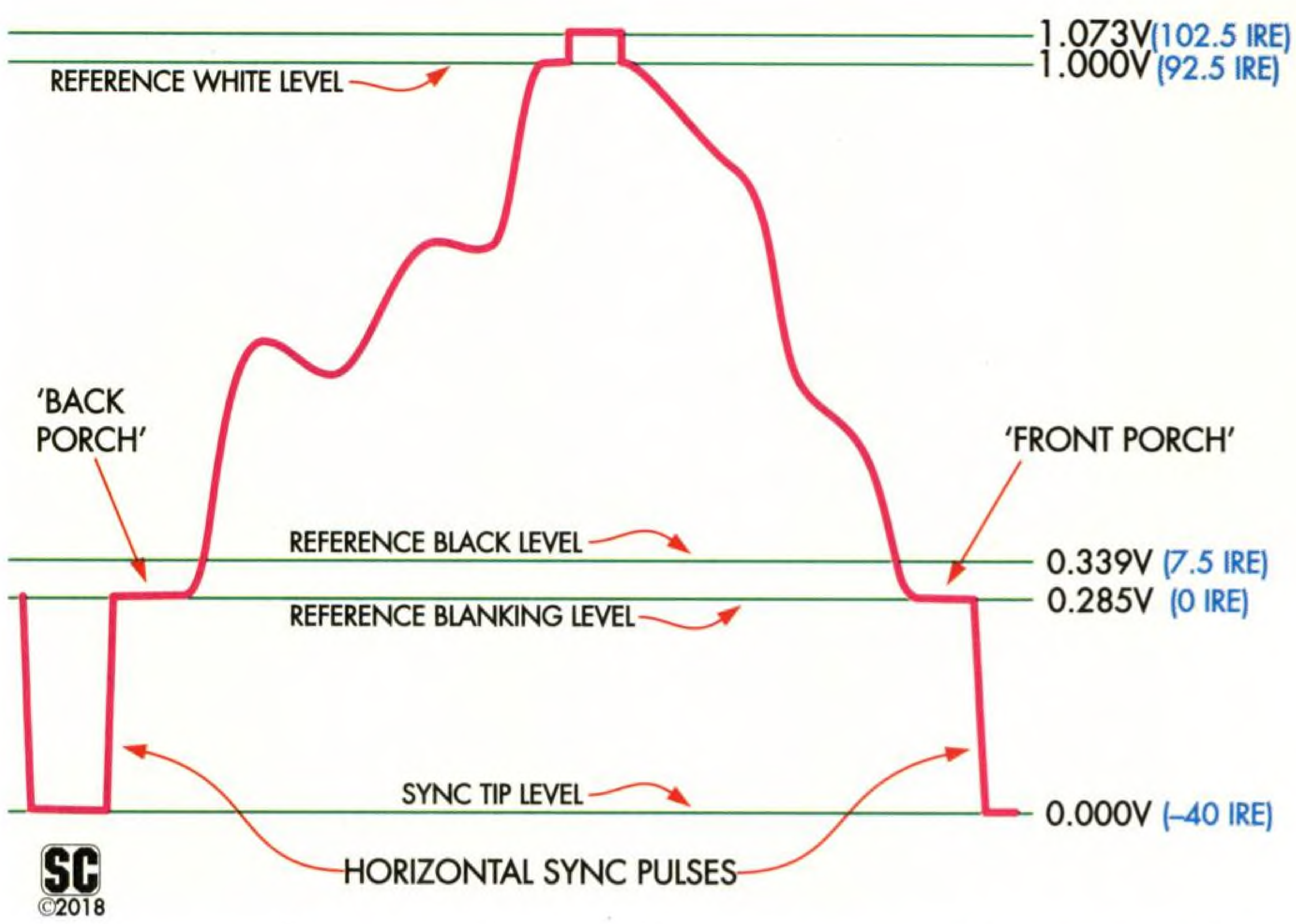


Fig.3: this waveform is a single video line showing the relationship between the various levels which can range between peak white (1.073V) and the sync tip level (0V).

The synchronisation pulses are nominally 285mV below the black level while the maximum white level should be about 715mV above the black level, giving a peak-to-peak voltage of around 1V.

The black level can be determined by monitoring the average signal level during either the front porch (just before the horizontal sync pulse) or the back porch (just after it). This design uses the back porch since it's easier to detect.

The overall design of the unit is shown in the block diagram, Fig.4. This shows how the vertical synchronisation pulse is detected by IC2 and then used to trigger pulse generator IC5a, which switches the video output between the version with the limited white level (clamped by diode D1) to the version with everything but the sync pulses removed (clamped by diode D2) during the VBI.

IC2 also detects the back porch period and this is fed to the circuit which normalises the black level so that the two clamps limit the video signal at the right levels.

The processed video and sound are then fed into audio/video modulator IC6. This includes an FM audio modulator with tunable carrier oscillator, RF oscillator for the video carrier and a double-balanced mixer. The two variable inductors, L1 and L2, allow the TV channel and FM sub-carrier to be tuned.

The sound is processed by applying an adjustable level of gain and then passing it through the correct pre-emphasis filter and this is then fed to the A/V modulator.

The RF modulated output passes through a low-pass filter and then to the RF output, which goes to the antenna input of the TV.

So now that we have discussed what processing must be done, let's look at the operation of the complete circuit, starting with the video processing section.

Circuit description

The full circuit is shown in Fig.5. The composite video and audio signals to be sent to the TV are fed into dual RCA socket CON1. A 75Ω termination resistor sets the load impedance correctly for the video signal, to eliminate reflections in the cable.

The video signal is then AC-coupled to non-inverting input pin 3 of IC1 via a 47µF capacitor and biased to 2.5V (half the 5V supply) by a pair of 10kΩ resistors.

IC1 is a video (wide-bandwidth) op amp which acts as a non-inverting buffer and also provides a gain of two, ie, doubling the signal amplitude.

The gain is set by the ratio of feedback resistors (1 + 4.7kΩ ÷ 4.7kΩ) and the 47µF capacitor at the bottom of this divider chain will charge up to the same bias level as applied to pin 3, so that the gain is not applied to the DC offset. That would cause output pin 1 of IC1 to be pegged to the +5V rail.

The signal at this output pin goes to two different sub-circuits; via a 100nF capacitor to IC2, the sync separator, and via a 4.7µF capacitor to emitter-follower buffer transistor Q1.

Let's look first at what happens to the signal buffered by Q1. As explained below, the base of Q1 is held at +1.5V during the back porch interval. This charges up the 4.7µF coupling capacitor.

Because the average voltage of the back porch is the black level, the black level of the signal at the base of Q1 becomes 1.5V.

Given the ~0.7V drop between its base and emitter, that sets the black level at its emitter to around 0.8V.

The signal at Q1's emitter passes through two 1kΩ resistors and then into inputs B0 and B1 of multiplexer IC3 (pins 1 & 2).

But there are also two dual schottky diodes, D1 and D2, connected to these pins. They are wired in parallel, so that they act like a single diode with a higher current rating and lower forward voltage.

Let's consider the signal at input pin

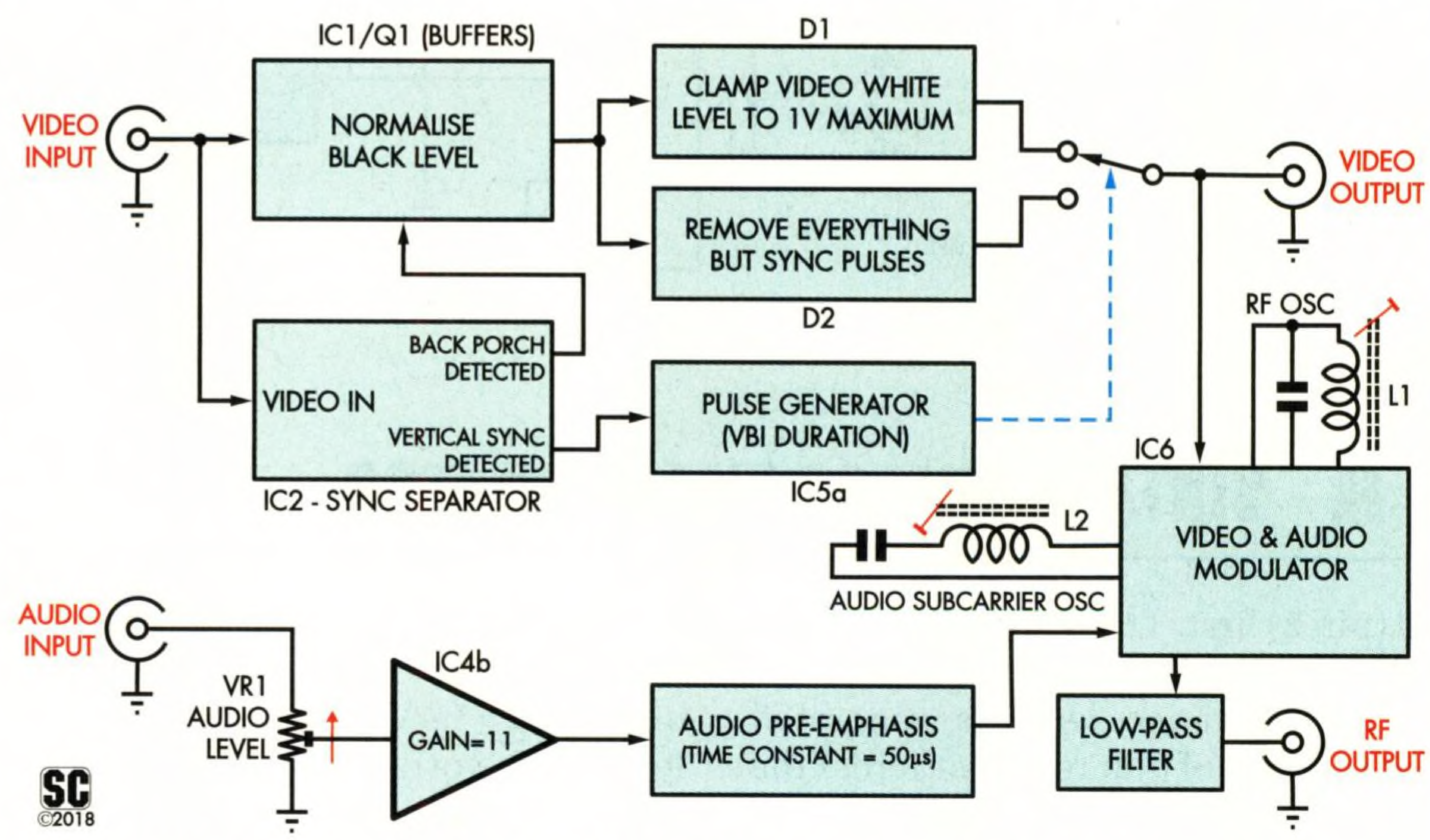
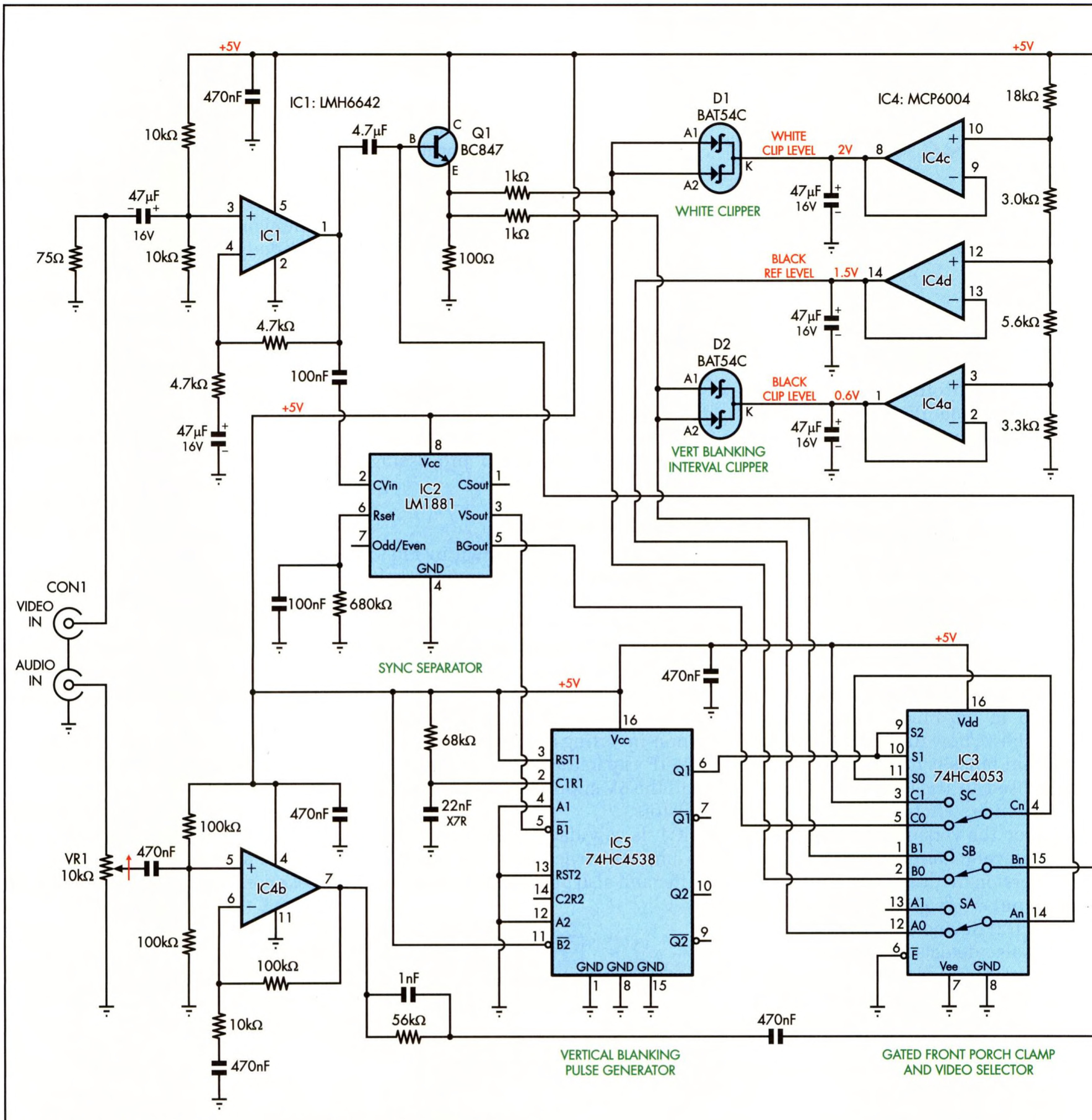


Fig.4: block diagram of the Modulator. IC2 detects the vertical sync pulse and starts timer IC5a, which controls an analog switch that changes the video output to a version containing only sync pulses during the vertical blanking interval. The rest of the time, D1 and IC2 combine to prevent signal levels above the maximum white level from passing through to the modulator, which also receives the processed audio. Variable inductors L1 and L2 allow the two carriers to be tuned.



SC ©2018 **VINTAGE ANALOG TV MODULATOR**

B0 (pin 2) first. The cathodes of D1 are held at 2V by buffer op amp IC4c.

This reference level is generated from a string of four resistors across the regulated 5V rail. Given that schottky diode D1 will have a forward voltage of around 0.2V when conducting, this means that input pin B0 will be clamped at a maximum of around 2.2V.

This is 1.4V above the black level that we determined earlier would be present at the emitter of Q1 (ie, 2.2V - 0.8V).

Since we've applied a gain of two to the signal, that represents an increase of 700mV (1.4V ÷ 2) above the black level in the original signal; very close to the 715mV mentioned earlier for the correct white level. So D1 prevents the signal at pin 2 of IC3 from exceeding the desired white level.

During active line scanning, the signal at input pin 2 (B0) is fed through to output Bn (pin 15), which drives the base of PNP emitter-follower Q2.

Thus, Q2 buffers the video signal which is then fed through a 75Ω impedance-matching resistor and 470μF DC-blocking capacitor to the video output socket.

Note that the 75Ω resistor will form a voltage divider with the 75Ω cable impedance/input impedance of the TV.

Since IC1 already applied a gain of two to the video signal, the TV will receive a signal with the correct amplitude.

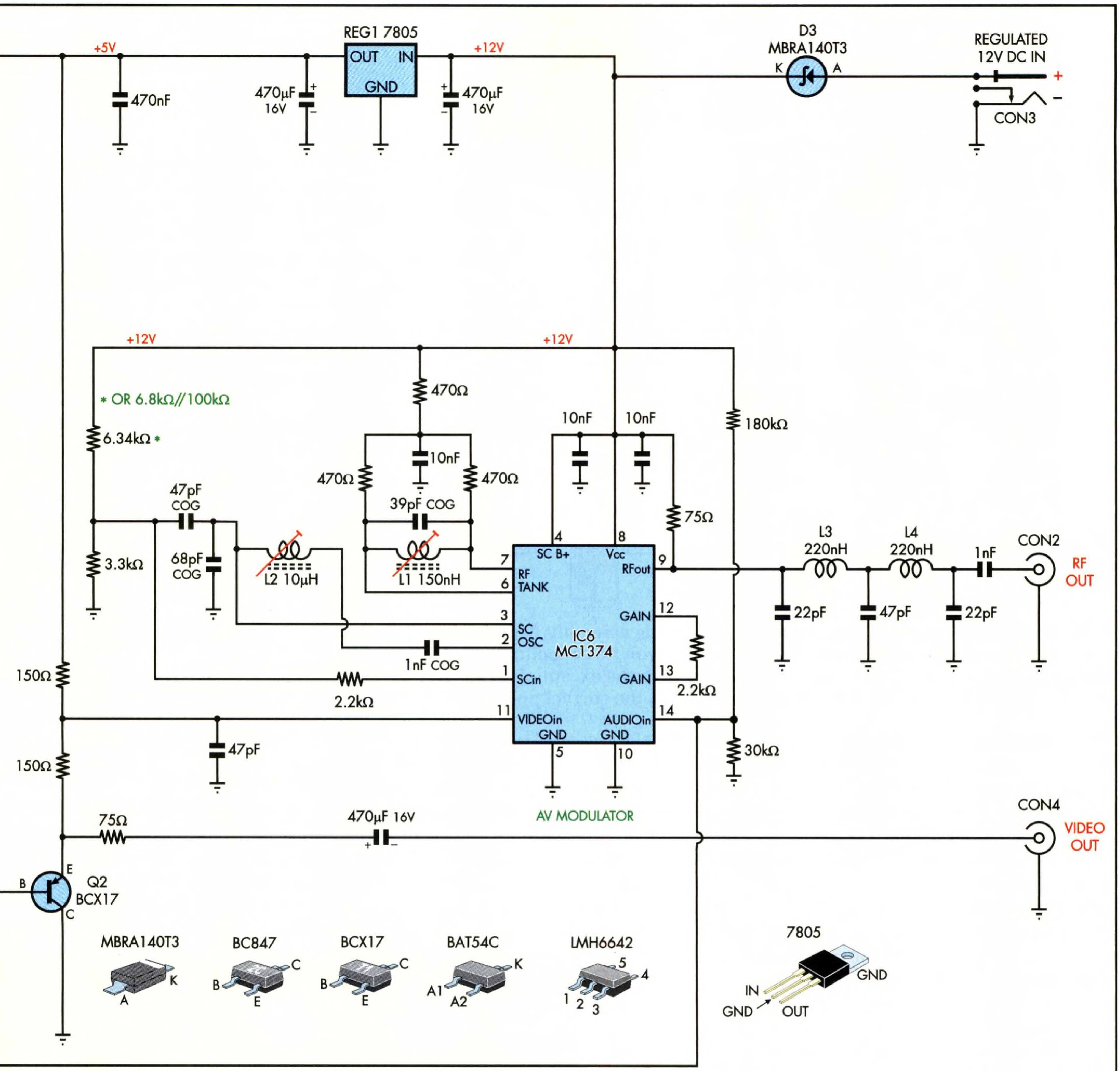


Fig.5: complete circuit of the Modulator. The video signal is buffered by IC1 (which also applies some gain), then buffered again by Q1 and clamped by diodes D1 & D2 before passing to analog multiplexer IC3. Its video output is then fed to another buffer transistor, Q2, and then onto the A/V modulator, IC6. It then generates a signal which is fed to the RF output, CON2, via a low-pass filter. The audio level is adjusted using VR1 and processed by IC4b before also being fed to modulator IC6.

Actually blanking the Vertical Blanking Interval

As mentioned earlier, the video signal from input buffer IC1 also passes through to IC2.

This is an LM1881 sync separator and this detects two control signals: the vertical synchronisation pulses (shown in Fig.1) and the colour burst/back porch (shown in Fig.2).

Its pin 3 output goes low for a fixed period when a vertical synchronisation pulse is detected while the pin 5 output goes low during the back porch/colour burst period.

The vertical sync pulse output from pin 3 is stretched by IC5a, a 4538 retriggerable monostable multivibrator. The length of the output pulse is set by the combination of a 22nF capacitor and 68kΩ resistor and this time constant was chosen to be equal to the remainder of the VBI.

The signal from the Q output of IC5a (pin 6) is fed to logic input S1 of multiplexer IC3 (pin 10). This switches the source of the video fed to buffer transistor Q2 to be from input pin B1 (pin 1) rather than Y0 (pin 2) so that during the VBI, the video signal sent to the TV set contains only the horizontal synchronisation pulses and is otherwise black.

The signal fed to input B1 is similar to the signal described earlier at B0, except that it is clamped by diode D2

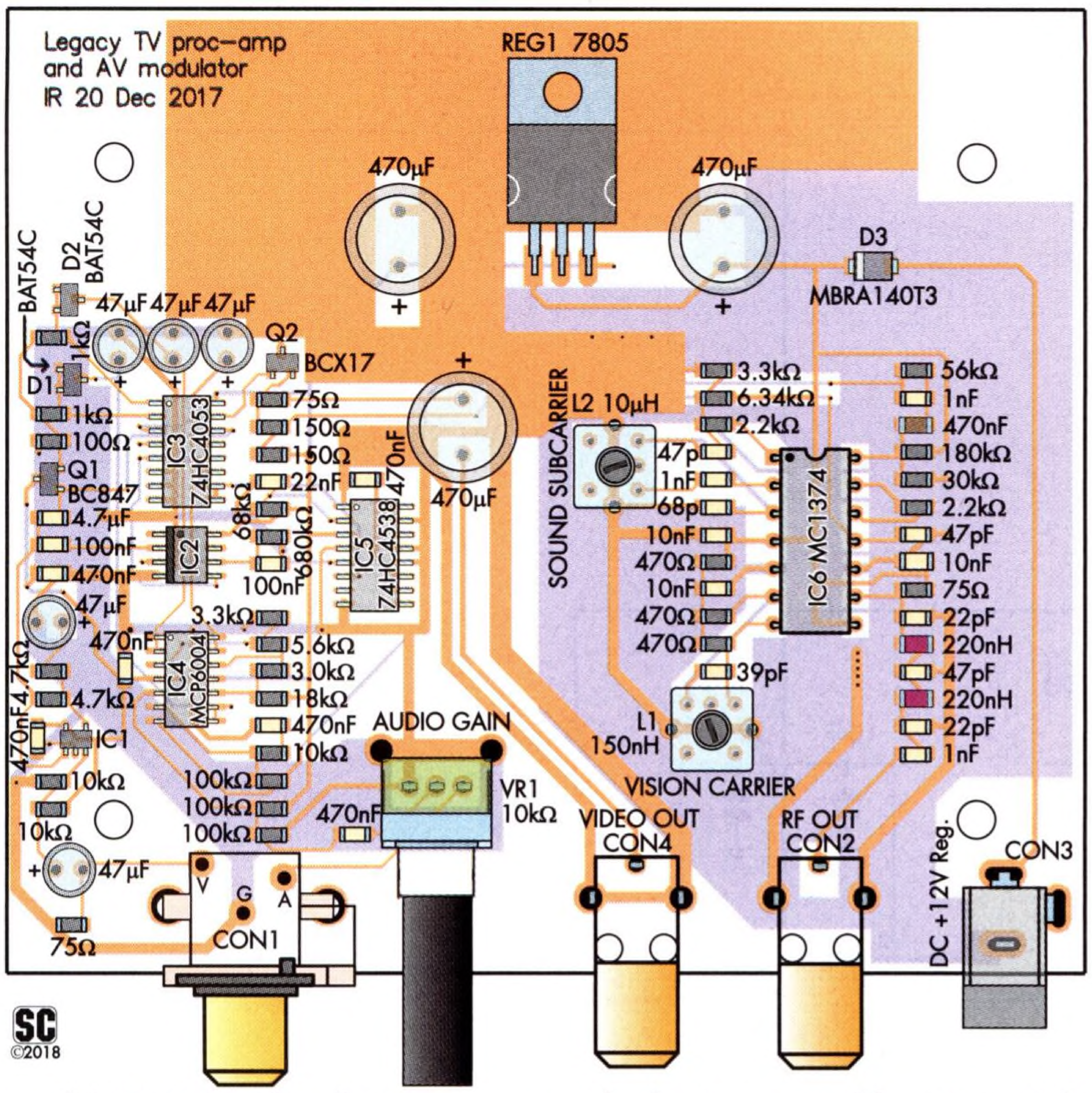


Fig.6: use this PCB overlay diagram as a guide during assembly. Most of the passive components, with the exception of the electrolytic capacitors, are surface-mounted, as are all the semiconductors, with the exception of IC6. Be careful to fit the ICs and electrolytic capacitors with the correct polarity.

rather than D1. D2's cathode is connected to a 0.6V reference level which is buffered by op amp IC4a (derived from the same divider string as the 2.0V reference mentioned earlier).

Since the black level of the video signal at the emitter of Q1 is around 0.8V, taking into account the ~0.2V forward voltage of D2, this diode will prevent any signal levels above the black level from passing through to input B1. Thus, the synchronisation pulses (which are negative) can get to input B1 but anything else during the VBI will be clipped off.

As a result, anything other than the sync pulse that may come from the video source during the VBI is not fed through to the TV.

By the way, because of the bias requirements of the vision modulator and the need to allow for diode drops, the reference voltages generated by the resistor chain are quite critical and inter-dependent.

A spreadsheet was used to calculate the best fit, using preferred-value resistors, to avoid the need for adjustments.

The back porch and black reference level

I explained earlier that the base of Q1 is held at +1.5V during the back porch to set the correct black reference level. This reference level comes from the output of op amp IC4d, which is in turn driven from the same four-resistor reference divider that produces the other two reference voltages.

The output of IC4d drives the base of Q1 when input A0 (pin 12) of analog multiplexer IC3 is connected to its respective An output (pin 14) when logic input S0 (pin 11) is low. This logic input is driven by the Cn output of the multiplexer, (pin 4). This part of the multiplexer is being used as a logic gate.

Since input C1 (pin 3) is tied high to +5V and input C0 (pin 5) is connected to the back porch/colour burst output of sync separator IC2, output Cn will only be low during the back porch period (ie, output pin 5 of IC2 is low) and when input S2 (pin 9) is low.

And input S2 is low most of the time but is driven high during the VBI, by the output of IC5a that was mentioned earlier.

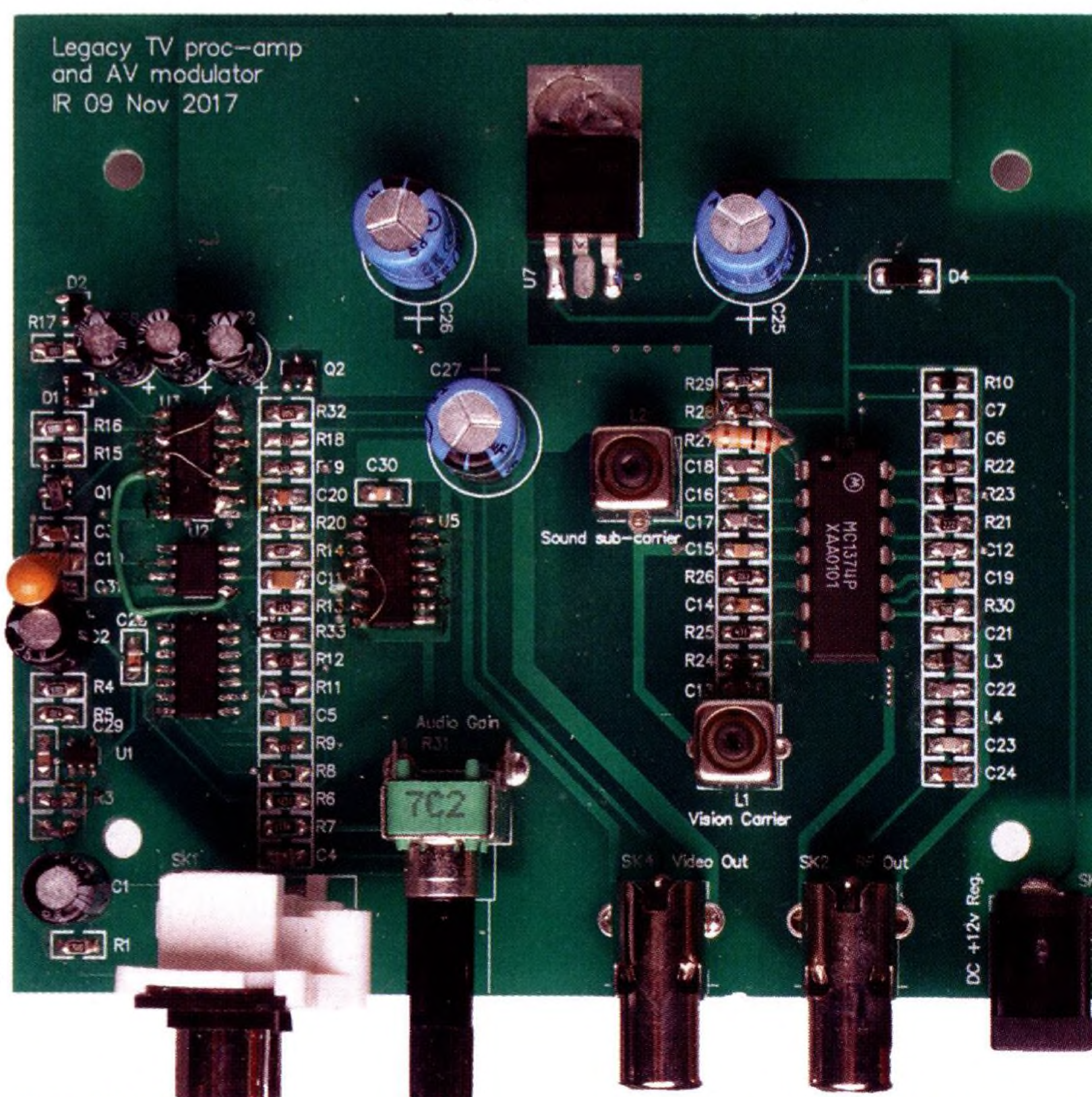
So basically, the base of Q1 is held at the +1.5V reference level during the back porch, except for during the VBI.

This means that the black level of the signal is "reset" at the beginning of each horizontal scan line but it is left unaltered during the VBI since other signals that are present during the VBI can be falsely detected as the back porch and thus could result in incorrect biasing.

The 4.7µF capacitor at the base of Q1 has a high enough value to preserve the correct DC levels during the VBI.

Audio processing

The audio signal from CON1 is fed to audio gain/volume control pot VR1 and then AC-coupled to non-inverting input pin 5 of the remaining op amp, IC4b. The signal is biased to a half-supply (~2.5V) level using two 100kΩ



This same-size photo matches the above component overlay in most respects, but is of an early prototype and so has a number of patches and added components (particularly around IC3). The final PCB design above has these changes incorporated.

resistors. A fixed gain of 11 times is applied, set by the ratio of the 100kΩ and 10kΩ resistors. Again, the bottom end of the divider is connected to a capacitor to ground, so that the DC bias of the inverting input and the output will also settle at 2.5V.

A simple filter network comprising a parallel 1nF capacitor and 56kΩ resistor provide audio pre-emphasis with a time constant of 50μs (treble boost), as required for the following FM modulator. The audio signal is AC-coupled to the modulator via a 470nF series capacitor so that the signal can be biased to 1.7V, to suit the modulator; this level is derived from the 12V rail using 180kΩ and 30kΩ resistors.

RF modulator

IC6, the MC1374, is designed specifically for this sort of job. Along with the audio signal just mentioned, which is fed into pin 14, The video signal at CON4 is also fed into IC6, at input pin 11. A 47pF capacitor to ground filters out any RF which may be present in the video signal, preventing it from affecting the operation of the modulator.

The MC1374 contains an RF oscillator, RF modulator and a phase shift type FM modulator, arranged to permit good PC board layout of a complete TV modulation system. The RF oscillator can operate up to approximately 105MHz, which makes it suitable for Band 1 VHF. The video modulator is a balanced type.

The choice of the MC1374 may seem unwise as this part is no longer in production. However, it is readily available from many sources on the web at a reasonable price. This is a much better situation than most that TV restorers have experienced!

Silicon Chip will have a stock of this IC available in the Online Shop, so you can order it at the same time as the PCB.

The modulated sound carrier and composite video information are fed in separately, to pins 1 and 11 respectively, to minimise crosstalk. The RF output is a current sink which can drive a 75Ω load.

Note that the PNP video buffer transistor, Q2, is not just used to provide a low impedance drive for the output socket. It also allows us to shift the video signal DC bias level to around 3.9V, as is required by IC6, to set the correct black level. (Note that due to the way IC6 works, the same DC bias level is used for pin 1).

This shift is due partly to the ~0.7V base-emitter junction forward voltage and partly because of the voltage divider comprising two 150Ω resistors between Q2's emitter and the 5V rail. These two resistors also reduce the AC amplitude of the video signal by half, compensating for the gain of two that was applied earlier by IC1.

IC6 contains two internal oscillator amplifiers which drive the RF tank between pins 6 and 7, to generate the video carrier, and the FM carrier tank

Parts list – Audio/Video Modulator for Analog (Vintage) TV sets

1 130x100x50mm light grey ABS instrument case [Altronics H0371]
1 double-sided PCB, 100 x 88mm, code 02104181
1 150nH variable inductor (L1) [CoilCraft 7M2-151] ***OR*** 1 SBK-71K coil former pack (Silicon Chip Online Shop Cat SC2746) plus 100mm length of 0.25mm diameter enamelled copper wire
1 10μH variable inductor (L2) [CoilCraft 7M2-103] ***OR*** 1 SBK-71K coil former pack [Silicon Chip Online Shop Cat SC2746) plus 900mm length of 0.25mm diameter enamelled copper wire
2 220nH SMD inductors, 2012/0805 package
1 2-way PCB-mount RCA socket, red/white (CON1) [Altronics P0210]
2 black PCB-mount low-profile RCA sockets (CON2,CON4) [Altronics P0207]
1 2.1mm or 2.5mm ID PCB-mount DC socket (CON3)
1 12V DC regulated plugpack with plug to suit CON3
5 No.4 x 6mm self-tapping screws

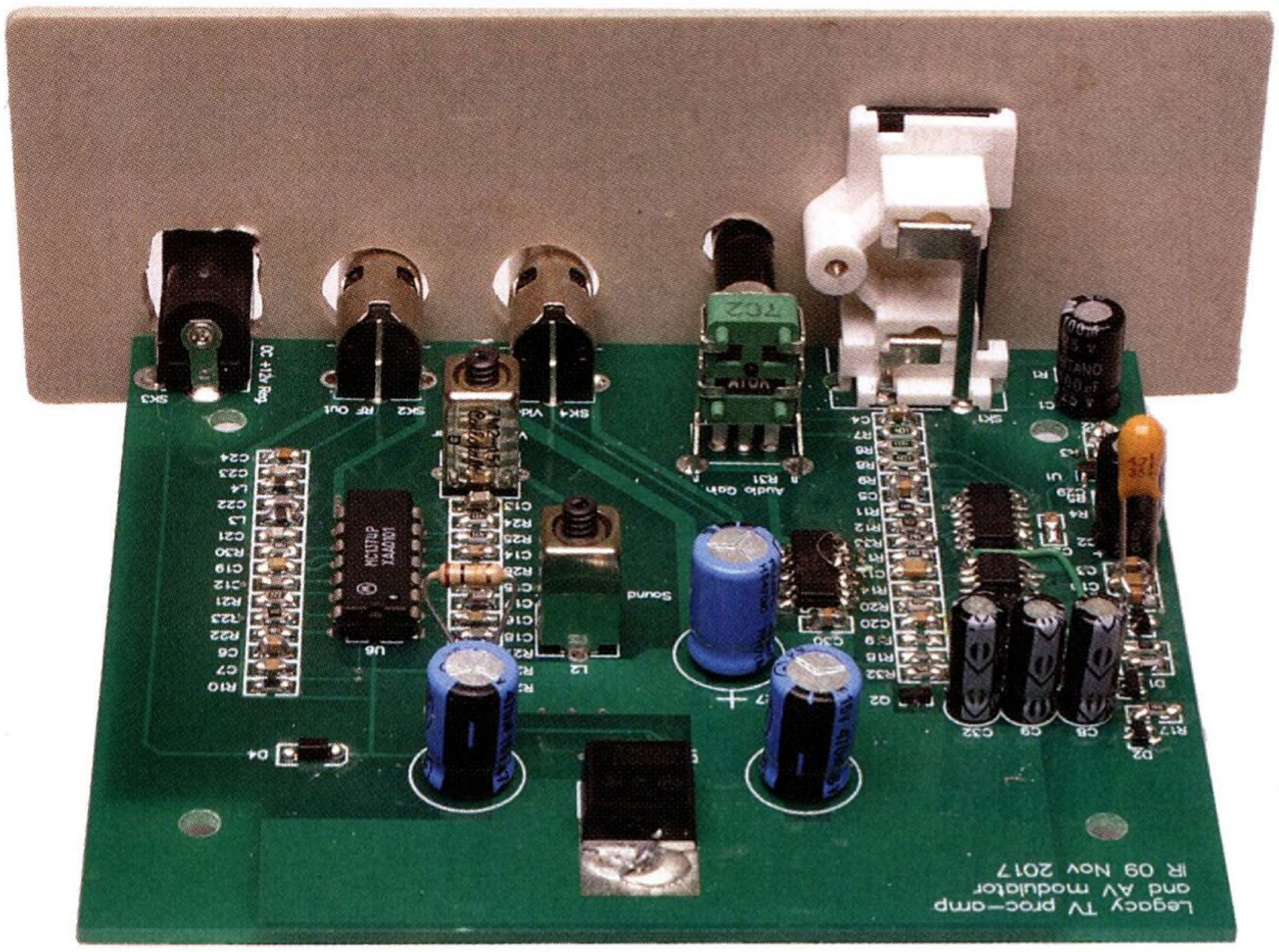
Semiconductors
1 LMH6642 high-bandwidth op amp, SOT-23-5 (IC1)
1 LM1881 sync separator, SOIC-8 (IC2)
1 74HC4053 triple two-channel analog multiplexer, SOIC-16 (IC3)
1 MCP6004 quad op amp, SOIC-14 (IC4)
1 74HC4538 dual monostable multivibrator, SOIC-16 (IC5)
1 MC1374P A/V modulator, DIP-14 (IC6) [SILICON CHIP Online Shop Cat SC4543]
1 LM7805S 5V 1A regulator, TO-263 (REG1) OR
1 7805 5V 1A regulator, TO-220, with leads cut short and bent to fit (see text)
1 BC847 NPN transistor, SOT-23 (Q1)
1 BCX17 PNP transistor, SOT-23 (Q2)
2 BAT54C dual schottky diodes, SOT-23 (D1,D2)
1 40V 1A SMD schottky diode, SMA package (D3) [MBRA140T3 or similar]

Capacitors (all SMD 2012/0805, 16V X7R unless otherwise stated)
3 470μF 16V radial electrolytic
5 47μF 16V radial electrolytic
1 4.7μF
6 470nF
2 100nF
1 22nF
3 10nF
3 1nF
1 68pF
3 47pF
1 39pF
1 22pF

Resistors (all SMD 2012/0805, 1%)

1 680kΩ	1 180kΩ	3 100kΩ	1 68kΩ	1 56kΩ
1 30kΩ	1 18kΩ	3 10kΩ	1 6.34kΩ	1 5.6kΩ
2 4.7kΩ	2 3.3kΩ	1 3.0kΩ	2 2.2kΩ	2 1kΩ
3 470Ω	2 150Ω	1 100Ω	3 75Ω	

1 10kΩ 9mm horizontal log pot with long 18-tooth spline shaft (VR1) [Altronics R1918]



The PCB attaches to the rear panel via a single screw on the input socket; the assembly is held in the case via four self-tapping screws while the rear panel slots into the vertical guides in the case. This holds the whole thing rigid.

between pins 2 and 3, to generate the audio carrier.

Both of these tanks are based on variable inductors, to allow them to be tuned to the required frequencies, as well as capacitors, to make them resonant.

Since the video carrier, at 50-100MHz, is at a much higher frequency than the audio carrier (5.5MHz), the inductance value of L1 (0.15µH) is much lower than L2 (10µH).

This unit is not crystal locked but tuned to operate on channel 2 (64.25MHz), since this channel is now unused and able to be tuned by any TV. It is a simple matter to re-tune it to any band 1 channel (1, 2 or 3).

Note that it may be possible to tune to channels 0 or 4 but neither of these can be received by early TVs with 10-channel VHF tuners, so they would not be good choices. Later Australian sets had 13-channel tuners.

The design could have used a crystal for maximum stability but a suitable custom crystal would be expensive and the LC oscillator stability is excellent anyway. A PLL could also have been used but would have greatly increased complexity.

The configuration of the video RF tank (a parallel resonant circuit) is pretty much identical to the sample circuit in the MC1374 datasheet, with the exception being the 10nF capacitor; its suggested value was 1nF in the data sheet. Its purpose is to filter the applied supply voltage, so a larger value should be better.

Similarly, the FM carrier oscillator components (series resonant) are very similar to those specified in the MC1374 data sheet with the only real difference being the values of the 47pF and 68pF load capacitors, which have been tweaked to work better with the properties of inductor L2.

The balanced modulator gain resistor is the recommended value, at 2.2kΩ. This controls the modulation depth at the output.

The output is terminated with a 75Ω resistor from the 12V rail, which also supplies current to the modulator circuitry.

The output signal then passes through a double-pi low-pass LC filter (fifth order) to clean up the sidebands. It would have been better to use a proper "vestigial sideband filter" but these require tuning.

The downside of this simple approach is that it's possible to tune the TV to the opposite sideband. However, this will result in poor picture and sound quality which is easy to identify. In this respect, it's no different to typical VCR modulators.

The power supply is simple. We rely on the plugpack to supply a regulated 12V rail which is used to power the A/V modulator (IC6) more-or-less directly, via reverse polarity protection schottky diode D3.

A 470µF filter capacitor is provided, which also acts as the input bypass capacitor for 5V regulator REG1, which supplies the rest of the circuitry. It too has a 470µF output filter capacitor.

Construction

As all components mount on a single PCB, construction is relatively straightforward. The PCB then fits neatly into the plastic instrument case.

The PCB overlay diagram Fig.6 and photograph show where all the components go.

Most of the parts are SMDs (surface-mount devices) but there are some through-hole parts too, notably the connectors, electrolytic capacitors and IC6.

Because most of the SMDs have widely-spaced pins, you shouldn't have any difficulty soldering them in. IC1 is the one exception, with closely-spaced leads, but since it only has five pins (two on one side and three on the other), it shouldn't prove too difficult.

Soldering IC1 is a good place to start. Since it has a different number of pins on each side, its orientation is easy to figure. Tack-solder one of the corner pins (on the side with two pins) and then check that the other pins are correctly aligned over their pads using a magnifier.

If not, re-heat the solder and nudge it into place. Repeat until it's properly aligned, then solder the other four pins. This is easier if you apply a little flux paste to the pins first.

Don't worry about bridging the three that are close together; if this happens, simply apply a little flux paste and then apply some thin solder wick and heat and the bridges should disappear.

Add some flux paste and re-heat the initial pin that you tack soldered to ensure the joint is not cold.

Clean off any residue using alcohol or flux cleaner and check carefully under magnification (and with good light) that all five solder joints have good fillets. You can then move on to the other SMD ICs, IC2-IC5.

You can use a similar approach but you should find these considerably easier due to the larger pin spacings. Watch the polarity though; all the other ICs can be soldered in one of two orientations and only one is correct. Refer to the photo and the overlay diagram, Fig.6, to see the correct orientations. In each case, pin 1 should go towards the top edge of the board.

Pin 1 of the IC is normally indicated with a dot or divot in that corner, as well as the pin 1 side having a bevelled edge. Make sure the orientation matches that shown in Fig.6 before soldering all the pins.

Next, fit diodes D1 & D2 and transistors Q1 & Q2. These are all in 3-pin SOT-23 packages, similar to IC1 but since they have fewer pins, the spacings are larger, making them quite easy to solder.

Just don't get them mixed up since they look virtually identical. Use the same technique as before, tack soldering one pin and then soldering the rest before reflowing the first joint.

It's best to solder the passive SMDs next, ie, the resistors, ceramic capacitors and the two 0.22µH chip inductors, L3 & L4. The technique is essentially the same but this time you only need to make two solder joints per component.

In each case, make sure it is sitting straight and flat on the PCB before soldering the second pin.

Also, it's best to wait for a few seconds after making the first joint before attempting the second, since if it's still liquid, you will end up nudging the part out of place.

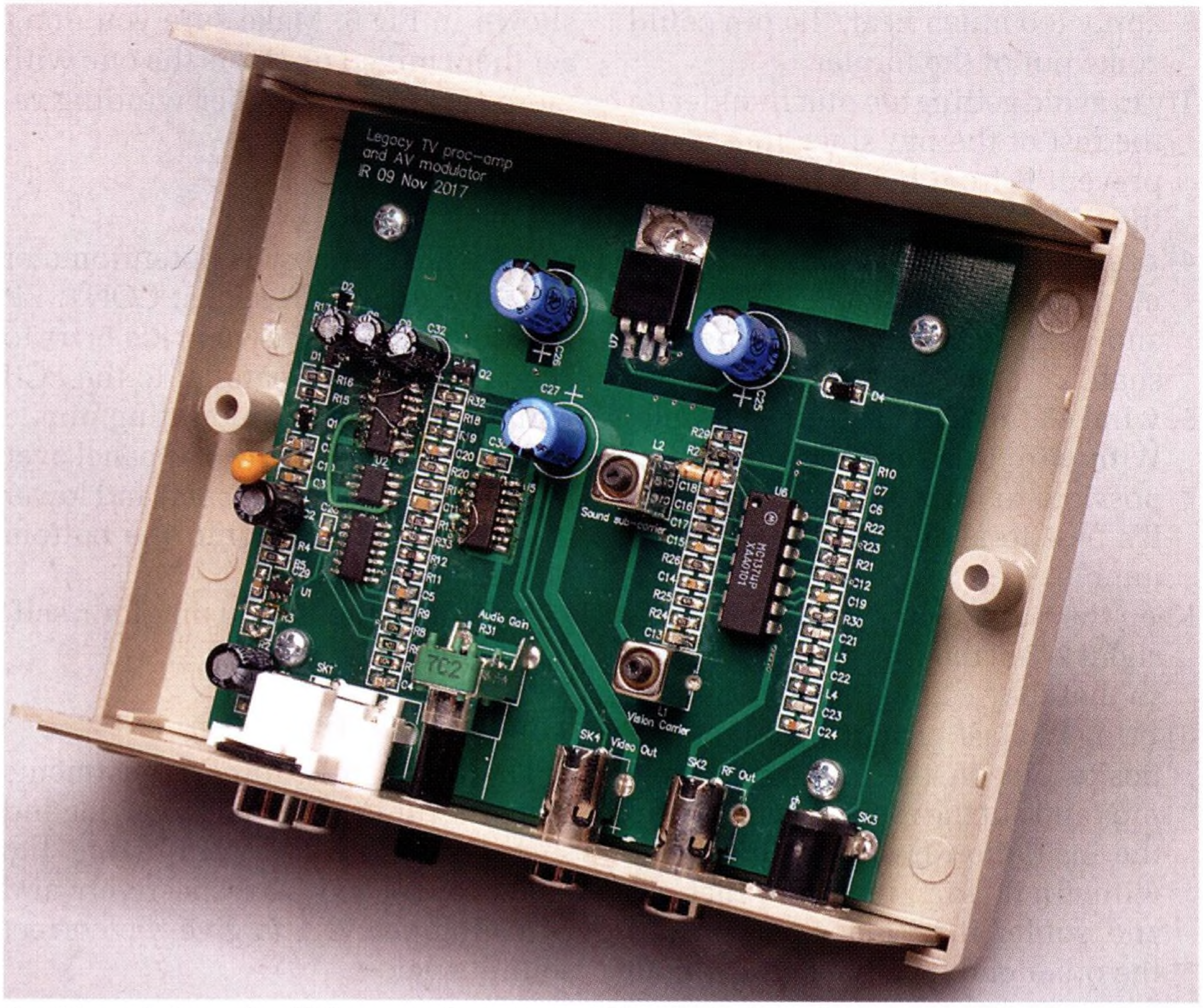
If the component moves when you go to make the second solder joint, even though you've waited a few seconds, that suggests the first joint hasn't adhered to the PCB pad properly.

The SMD resistors will have a code printed on them to indicate their resistance. For example, a 47kΩ resistor will be marked with either "473" (ie, 47 x 10^3) or "4702" (ie, 470 x 10^2).

However, SMD capacitors will probably not have any markings and the smaller inductors may not either. If your DMM has provision for it, measure them to confirm their value before placement.

The final SMD component is the regulator, REG1. We have specified an SMD version of the 7805 since that is what was used to build the prototype, however, it is possible to mount a standard 7805 regulator if you bend the leads so that they will sit against the PCB and then cut them short so that they don't protrude past the ends of the mounting pads.

Regardless of whether you use an SMD regulator or adapt a through-hole type, the tab has a lot of thermal inertia so we suggest that you spread a thin layer of flux paste on the large tab as well as the three smaller pads, turn up your soldering iron's temperature and then solder one of the smaller pins.



And here's how it all fits together, immediately before the case top is placed in position (it only fits one way) and the two case screws are inserted from underneath and tightened.

You can then check if the tab is properly located and start applying solder to the junction of the tab and the PCB.

You will probably have to hold the iron there for some time (10 seconds or more) to get the regulator and PCB hot enough for the solder to flow.

Once that happens, feed the solder in and then quickly remove the iron and you should get a nice fillet between the tab and PCB. You can then solder the remaining pins.

Alternatively, if you have a hot air rework station, you can apply solder paste and then carefully heat the regulator and surrounding PCB area with hot air until the solder melts.

Through-hole parts

There are just a few through-hole parts and most of them are easy to solder. Start with IC6, being careful to ensure it's correctly orientated before soldering it in place. We don't suggest that you use a socket; it's better to solder the IC directly to the PCB.

Follow with the electrolytic capacitors. They are different sizes so it should be obvious where each one goes but do pay careful attention to orientation. The longer lead goes into the hole marked + on the PCB and in Fig.6, while the opposite side (ie, negative end) of the can should be marked with a stripe.

Fit RCA connectors CON2 and CON4 next, followed by DC socket CON3. In each case, ensure the connector is pushed fully down onto the board before soldering the pins.

Inductors L1 and L2

While you can purchase these inductors from the CoilCraft website, if you're only buying two then the postage charge will be prohibitive.

Luckily though, the CoilCraft parts have an identical footprint to the SBK-71K coil formers that we already stock in the Silicon Chip Online Shop for other projects. These are supplied with a ferrite slug which can be adjusted for tuning the oscillators, just like the CoilCraft parts.

Wind inductors L1 and L2 using the following procedure:

1) cut a ~900mm length of 0.25mm diameter enamelled copper wire and strip the insulation off one end (by about 5mm) using a sharp hobby knife or emery paper.
2) tin the end of the wire and wrap it around one of the pins at either end of the side which has three pins (ie, not the middle pin).
3) push the wire as close to the base of the former as possible and solder it to the pin. Be quick since if you

apply too much heat, the pin could come out of the former.

Try to avoid getting too much solder on the rest of the pin since that could prevent it from being inserted into the PCB later.

4) pass the wire up the side of the former, through the notch in the base and wrap it around the cylindrical shaft.

5) wind 45 turns as neatly as possible. With wire this fine, it's almost impossible to do it layer-by-layer but it's best to avoid making it a total jumble.

Keep the turns below the collar that's about 2/3 of the way up the cylinder, so that they can't slip over the top.

6) bring the last turn down to the opposite pin on the side with three pins and cut the remainder off. Strip the insulation from the end of the wire, tin it, wrap it around that pin and solder it in place as you did the other end. See the below photo for an idea of what the finished coil should look like.

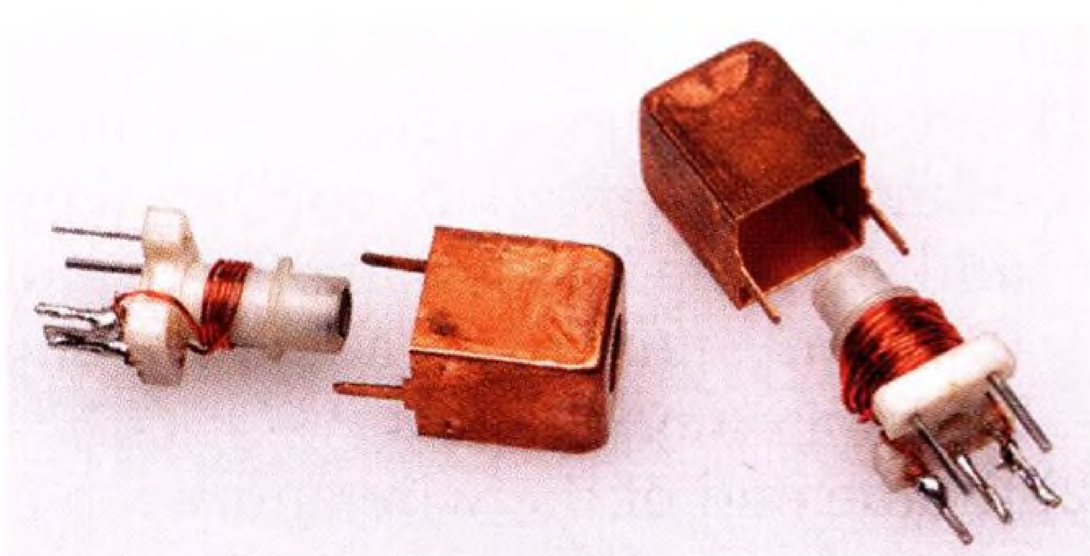
7) measure the resistance between the two pins. You should get a reading of 0.25-0.3Ω (remember that your multimeter leads will have some resistance so if possible, short them and null/zero it before making the measurements).

If you have an inductance meter, you can measure the coil now. It should be around 8μH.

8) screw the ferrite slug into the top of the former until it's fully inside and then place the shield can over the top, with its mounting flanges on the sides not occupied by pins.

9) L2 is now complete. Use the same procedure to wind L1, except that only five turns of wire are required. The resistance should be much lower – under 0.1Ω.

Having finished winding the two coils, solder them in place where shown in Fig.6. Make sure you don't get them mixed up. L2 is the one with more turns and a higher winding resistance.



You *can* buy L1 and L2 pre-made but winding them yourself, using SBK-71K coil formers from the Silicon Chip Online Shop, will prove much cheaper. L1, 150nH, (5 turns) is on the left, while L2, 10μH, (45 turns) is on the right.

Final assembly

All that's left now is potentiometer VR1 and dual RCA socket CON1. Fit these both where shown in Fig.6; try to keep the pot shaft parallel to the PCB while you solder its mounting pins.

You can then slip the rear panel over the connectors and pot shaft and lower the whole assembly into the bottom of the case.

Affix it to the base using four self-tapping screws.

Tuning and testing

There are only three adjustments to make: tuning the vision carrier and sound sub-carrier by adjusting the values of L1 and L2 respectively and adjusting pot VR1 to give the correct sound level.

Our prototype drew 42mA at 12V, so a good way of checking that you have assembled your unit correctly is to connect a DMM set to measure milliamps in series with the 12V power supply when you first power it up.

If you get a reading between about 30mA and 50mA then that suggests there are no serious faults and it's probably working correctly.

Having verified that the circuit is drawing an appropriate amount of current, the next step is to adjust the two oscillators by turning the tuning slugs in L1 and L2 with a plastic adjustment tool.

We've come up with three procedures for this, depending on what equipment you have.

The easiest one is if you have a spectrum analyser. Connect it to the RF output, power the unit up and adjust L1 so that the largest peak is centred on 64.25MHz. Adjust L2 so that the smaller peak is centred on 69.75MHz. You will likely see an image of the carrier 11MHz below this (ie, 5.5MHz below the main peak); ignore that one.

If you have a 100MHz+ oscilloscope, connect a tight loop of wire to the end of one of the probes and place it near the 39pF capacitor just above L1. Don't make a direct connection to the circuit or you may pull the oscillator off-frequency.

Adjust L1 to read 64.25MHz on the scope display. Then move the probe coil near the 68pF capacitor between L2 and IC6 and adjust L2 for a reading of 5.5MHz.

If you don't have equipment that can read these frequencies, the simplest approach is to hook the RF output of the unit up to the antenna input on an analog TV that you know works, tune the TV to channel 2 and feed some video into the input.

If TV has automatic fine-tuning (AFT), turn it off.

Adjust L1 so that image just breaks up at the edge of the sound carrier. Back it off until you have a clear image.

If you encounter significant ringing in the image while you are tuning, you are attempting to tune to the wrong sideband. Wind the core right out and start from the top position.

Once you have a clear picture, you'll need to tune the sound. It helps to display an image with a lot of white text, such as a DVD copyright message.

Tune L2 for minimum noise in the sound – the correct adjustment is a definite null, either side of which the noise increases.

Connect an audio signal to the unit's input and turn up VR1 (to about halfway) to verify that the sound is properly fed through.

If you adjusted L1 and L2 without using a TV, now is a good time to hook the unit up to a TV and tune in to channel 2.

With nothing connected to the video or audio inputs, you should get a black screen and silence. Then all you need to do is plug in a video and audio source and verify that you get a clean picture and sound.

As for setting VR1, which controls the audio modulation depth, basically, you just need to turn it up as high as possible before you notice any distortion in the sound, then back it off a little bit.

If you can't get the unit to work, feed the Video Out signal to the A/V input on a modern TV while feeding a video signal into the input and check that you get a good picture. That will verify that the video processing circuitry is working OK. If not, check the circuitry around ICs1-5.

If you can verify that the video output is working correctly but you still can't tune into a signal on your vintage TV, that suggests a problem with IC6 or one of its associated components, including L1 and L2.

Re-check that you have tuned the two oscillators correctly. SC