Component video to RGB converter

Want the best possible picture quality from your DVD player? The component video outputs are the ones to use. But what if your TV can only accept "RGB" video signals? This easy-to-build converter solves the problem, with no discernible picture degradation.

By JIM ROWE

THE PICTURE AND sound quality available from DVD video discs is streets ahead of what's available from VHS tapes. That's no doubt why sales of DVD players, widescreen TVs and surround sound systems have rocketed ahead in the last couple of years. DVDs have also generated tremendous interest in setting up home theatres, so enthusiasts can watch movies at home with a presentation almost as good as that in their local cinema.

At the same time, the very high picture and sound quality available from the best movie DVDs has raised consumer expectations. And it has motivated enthusiasts to find out how they can achieve the best possible results from their home theatre set-ups.

For example, most people are now aware that the highest picture quality from a DVD can be achieved only by using a player fitted with "component video" outputs, connected in turn to the corresponding inputs of a widescreen TV or video projector. This is because the video is actually recorded on DVDs in digital component format, so component video output signals have undergone less processing than those from S-video or composite video outputs.

As a result, component video signals provide cleaner and sharper pictures than the other signal formats. However, some widescreen TVs (particularly those of European

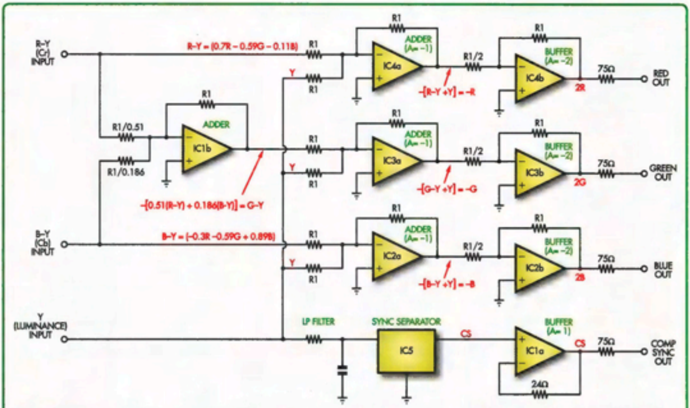


Fig.1: block diagram of the Component Video To RGB Converter. IC1b is used to produce the G-Y colour difference signal, while IC2a, IC3a & IC4a produce inverted RGB signals which are then buffered and fed to the outputs.

origin) and some projectors don't have component video inputs. Instead, they may be fitted with "RGB" (red, green, blue) video inputs, made either via RCA connectors or a European-style SCART connector – these in addition to the usual composite video and S-video inputs

And that's where problems can arise – RGB inputs are not compatible with component video signals (and most DVD players don't have RGB outputs). This means that you need a converter box to change the signal format if you want to drive your TV's RGB inputs from the component video outputs on your DVD player.

And that's exactly what this low-cost project is designed to do. As shown in the photos, it's housed in a small instrument case and has three RCA sockets on the front panel to accept component video signals from a DVD player. The circuitry inside then processes these signals to produce the corresponding RGB video and sync signals, which are provided via four RCA sockets on the rear panel.

These output signals can then be fed to the RGB video inputs of a TV set or video projector, either via RCA-to-RCA cables or via a SCART adaptor cable if necessary.

The complete converter is easy to build and runs from a 9V AC plugpack supply, drawing less than 150mA (1.3W).

How it works

To understand how the converter works, you need to know that the component video format used on DVDs consists of three video signals or "components". These are the "Y" or luminance signal and two other signals called "R-Y" (or "Cr" or "Pr") and "B-Y" (or "Cb" or "Pb"). The Y signal is basically the high-bandwidth black and white picture information, while the R-Y and B-Y signals are described as the **colour difference** signals (these have a lower bandwidth than the Y signal).

As the R-Y and B-Y labels suggest, these two colour difference signals actually correspond to the red (R) and blue (B) colour signals from the colour TV camera (or film scanner) that's used to produce the video signals in the first place, but with the Y luminance signal subtracted from them.

The RGB output signals are accessible via RCA sockets at the rear of the unit, along with a composite sync output signal (see text). Also accessible from the rear is the power socket.

Parts List

1 PC board, code 02105041, 117 x 102mm (double sided)
1 plastic instrument case, 140 x 110 x 35mm
7 RCA sockets, 90° PC-mount (2 red, 2 black, 1 yellow, 1 green, 1 white)
1 2.5mm concentric power socket, PC-mount
8 4G x 6mm self-tapping screws
2 M3 x 6mm machine screws with nuts & lock washers
4 stick-on rubber feet

Semiconductors
4 MAX4451ESA dual wideband op amps, SOIC-8 (IC1-IC4)
1 LM1881 video sync separator (IC5)
1 7805 +5V regulator (REG1)
1 7905 -5V regulator (REG2)
1 3mm green LED (LED1)
2 1N4004 diodes (D1,D2)

Capacitors
2 2200µF 16V or 25V RB electrolytic
2 100µF 10V RB electrolytic
2 10µF tantalum
2 2.2µF tantalum
9 100nF multilayer monolithic
2 100nF MKT polyester
1 470pF disc ceramic

Resistors (0.25W, 1%)

1 680kΩ	19 510Ω
1 7.5kΩ	1 470Ω
1 4.3kΩ	1 180Ω
1 3.6kΩ	1 100Ω
1 2.7kΩ	1 91Ω
1 1kΩ	4 75Ω
1 620Ω	1 24Ω

If you're wondering where the green or "G" colour signal is hiding, it's inside the Y signal. That's because the Y signal is itself produced by processing or "matrixing" the three original colour camera signals, according to this standard formula:

(1). Y = 0.3R + 0.59G + 0.11B

So a more expanded way of expressing the R-Y and B-Y signals is:

(2). R-Y = 0.7R - 0.59G - 0.11B
(3). B-Y = -0.3R - 0.59G + 0.89B

Now since the two colour difference component signals simply consist of the Y "mixture" signal subtracted from the original R and B signals, it's not very difficult to convert them back again. All that needs to be done is to add the Y signal to them again; ie:

(4). R-Y + Y = R
(5). B-Y + Y = B

It's slightly harder to restore the original green signal, because this involves two steps. First we have to recreate the G-Y signal and this is done by dematrixing the R-Y and B-Y signals according to this expression:

(6). -(0.51(R-Y) + 0.186(B-Y)) = G-Y

You can check this out for yourself by expanding the lefthand side using the full expressions for R-Y and B-Y given in equations (2) and (3). The G signal can then be recovered by adding in the Y signal, as follows:

(7). G-Y + Y = G

Block diagram

Just how we do all of this is shown in the block diagram of Fig.1.

The first step is to reconstruct the G-Y signal, by combining 0.51 of the R-Y signal with 0.186 of the B-Y signal. This is done using a wideband inverting adder stage based on IC1b. We now have all three colour difference signals (the other two are fed in directly from the DVD player), so these are then added to the Y luminance signal using inverting adder stages IC4a, IC3a and IC2a.

The outputs of these stages are thus inverted versions of the R, G and B colour signals, so all we have to do after that is pass each one through an inverting output buffer. These output buffers – IC4b, IC3b & IC2b – then drive 75Ω video cables and the 75Ω inputs of a TV receiver (or video projector).

Note that each output buffer stage has a 75Ω "back termination" resistor in series with the output. Because of this, each buffer is given a voltage gain of two (+6dB), to compensate for the 6dB loss that is introduced by these resistors.

But why does the converter also have a sync separator stage using IC5? Well, we've included this because there's some variation in the way TVs and video projectors with RGB inputs handle the video sync signal. Some extract the sync signal from the green (G) video signal, a technique known as "sync out of green", while others expect to receive the video sync signal via a separate composite sync (CS) input line.

The green output from the converter automatically contains the sync signals (as do the red and blue signals), so there's no trouble driving a set with "sync out of green" circuitry. However, so that you can also drive a set which needs separate composite sync, we've included the sync separator as well.

This is derived by first feeding the Y signal to a low-pass filter to remove the colour information. The signal is then fed to a sync separator stage based on IC5 and the CS output from this stage then fed through unity gain buffer stage IC1a, so that the sync signal can be fed along a 75Ω cable.

Circuit details

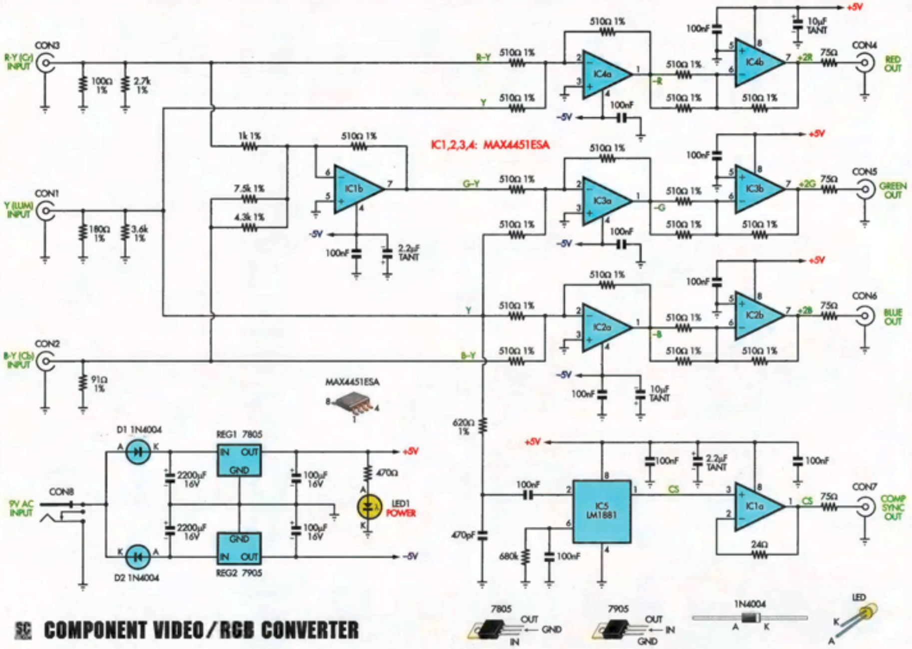
If you've followed the description so far from the block diagram, you shouldn't have any problems following the full circuit – see Fig.2. As shown, all the video adder and output buffer stages are designed around MAX4451ESA dual wideband (210MHz) op amp ICs from Maxim Integrated Products.

Despite its low cost, the MAX4451 is a very impressive device. Each of its two op amps has a -3dB bandwidth of 210MHz, a gain flat to 55MHz within 0.1dB, and an output slew rate of 485V/µs. This is in a device which comes in an 8-lead SOIC package, and draws a quiescent current of just 6.5mA per amplifier from a ±5V supply. In short, it is ideal for this type of video processing circuit.

The nominal resistor value shown as R1 in the block diagram becomes 510Ω in the full circuit, so this is the value of most of the resistors in the converter. The main resistors with different values are the input resistors for IC1b – which are values chosen to give the correct fractions of R-Y and B-Y to reconstruct G-Y – and the load resistors for the R-Y, Y and B-Y inputs. These may seem to have rather strange values but they've been chosen to bring each input resistance as close as possible to 75Ω (for good cable termination) while allowing for the inputs of the various adder circuits.

The back termination resistors for each of the four converter outputs are of course 75Ω, as shown in the block diagram. Note that although sync output buffer IC1a is a unity gain "voltage follower", the MAX4451 requires a 24Ω resistor in series with the link back to the negative input to ensure stability.

The low-pass filter that's used to remove the colour information (prior to the sync separator stage) consists of



COMPONENT VIDEO/RGB CONVERTER

Fig.2: the complete circuit if the Component Video To RGB Converter. The video adder and output buffer stages are all based on MAX4451 dual wideband op amps, while an LM1881 sync separator is used to provide the sync output (via buffer IC1a).

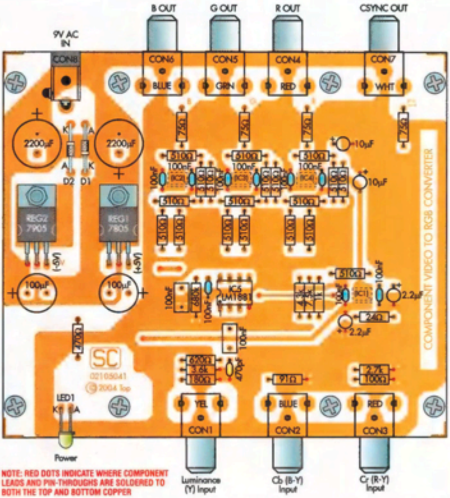


Fig.3: install the parts on the top of the PC board as shown here. The red dots indicate where component leads and "pin-throughs" have to be soldered on both sides of the board.

a 620Ω resistor and 470pF capacitor. From there, the signal is fed to pin 2 of the sync separator (IC5) via a 100nF capacitor. A standard LM1881 device is used for the sync separator and its output at pin 1 is fed to pin 3 of the unity-gain output buffer (IC1a).

Power supply

All the MAX4451 amplifiers run from +5V and -5V, while the LM1881 also runs from +5V. This allows the converter to be operated from a very simple power supply.

As shown, this supply uses an external 9V AC plugpack and this feeds two half-wave rectifiers (D1 & D2) and two 2200µF capacitors to give ±13.5V DC rails. Regulators REG1 and REG2 are then used to provide stable ±5V rails for the converter circuitry. In addition, the +5V rail is used to power the green pilot LED via a 470Ω current-limiting resistor.

Construction

All the video converter circuitry is built on a double-sided PC board coded 02105041 and measuring 117 x 102mm. This in turn is housed in a small instrument case measuring 140 x 110 x 35mm, to produce a very compact and neat unit.

There's no off-board wiring at all, because all the input and output connectors are mounted directly on the PC board along the front and rear edges. As a result, they are all accessed through holes in the front and rear panels, when the case is assembled.

Note, however, that although the PC board is double-sided, the board supplied in kits will probably not have plated-through holes (unless one of the kit suppliers decides to provide it in this more expensive form). As a result, you'll need to solder many of the component leads to the copper on the top of the board, as well as underneath. You'll also need to solder short lengths of tinned copper wire (such as resistor lead offcuts) through a small

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	680kΩ	blue grey yellow brown	blue grey black orange brown
❑	1	7.5kΩ	violet green red brown	violet green black brown brown
❑	1	4.3kΩ	yellow orange red brown	yellow orange black brown brown
❑	1	3.6kΩ	orange blue red brown	orange blue black brown brown
❑	1	2.7kΩ	red violet red brown	red violet black brown brown
❑	1	1kΩ	brown black red brown	brown black black brown brown
❑	1	620Ω	blue red brown brown	blue red black black brown
❑	19	510Ω	green brown brown brown	green brown black black brown
❑	1	470Ω	yellow violet brown brown	yellow violet black black brown
❑	1	180Ω	brown grey brown brown	brown grey black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown
❑	1	91Ω	white brown black brown	white brown black gold brown
❑	4	75Ω	violet green black brown	violet green black gold brown
❑	1	24Ω	red yellow black brown	red yellow black gold brown

Will It Work Backwards?

Can this circuit be made to work backwards – ie, convert RGB video to component video?

Unfortunately, the answer to this question is "no". RGB to component video conversion requires a PAL encoding circuit, which is much more complicated than the relatively simple unit described here.

number of "via" holes, to make connections between some of the top and bottom tracks.

These points are all indicated on the "top-side" PC board overlay diagram (Fig.3) with red dots.

As shown in Fig.3, most of the components fit on the top of the board in the usual way. The only exceptions are the four MAX4451ESA broadband op amps (IC1-IC4), which are in surface-mount SOIC packages and must be mounted on the bottom of the board.

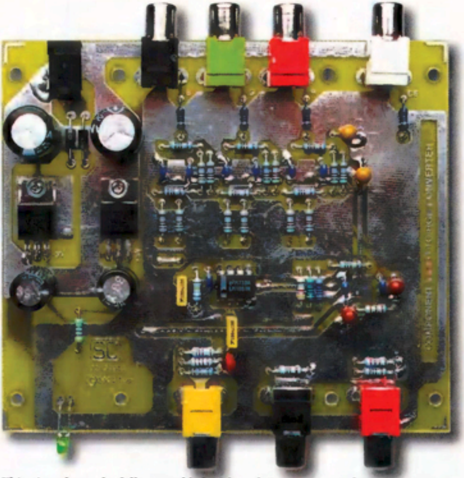
Begin the board assembly by fitting the short wire links which form "vias" between some of the top and bottom copper tracks. There are only five of these, all in the central area of the board around IC5. Fitting these first will ensure you don't forget them!

Next, fit the resistors, making sure you solder their "earthy" leads on both sides of the board where indicated. That done, install the RCA sockets and the 9V AC input socket, using a small drill to enlarge their mounting holes if necessary.

The small monolithic and MKT capacitors, plus the solitary 470pF disc ceramic, can go in next, followed by the four TAG tantalum capacitors and the larger electrolytics. Make sure that the polarised components are all orientated correctly, as shown on Fig.3, and don't forget to solder their leads to the top copper as well where this is indicated.

Next, fit the two diodes in the power supply (D1 & D2), again watching their polarity. Follow these with the two regulators, making sure that you fit each one in the correct position. REG2 is the 7905 and goes on the lefthand side; REG1 is the 7805 and mounts to the right of REG2.

Note that both regulators are mounted horizontally on the top of the board, with all three leads bent downwards



This view shows the fully assembled PC board. Be sure to use the "correct-colour" RCA socket (or a near equivalent) at each location, so that you can easily identify their functions.

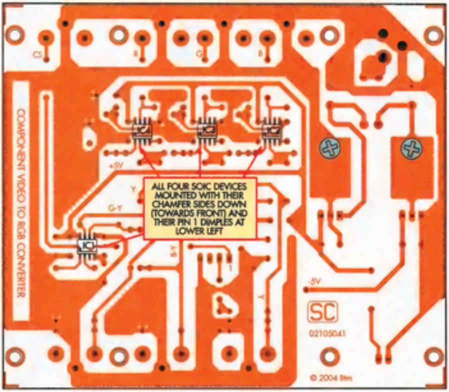
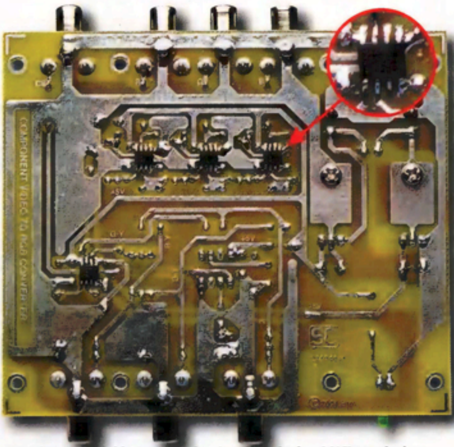


Fig.4: the four MAX4451 dual op amps are soldered to the underside of the PC board as shown here. Make sure you install them the correct way around.



Use a fine-tipped soldering iron when installing the four MAX4451 dual op amps on the underside of the board. Once they're in, check your work carefully using a magnifying glass, to ensure there are no solder bridges.

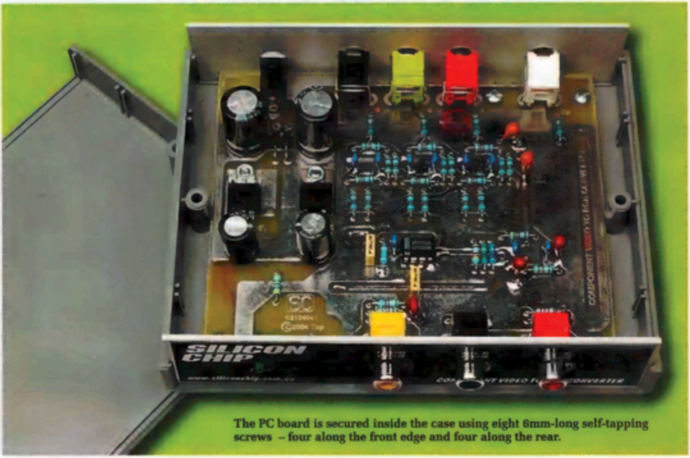
5mm from the body so that they pass down through the board holes. Their device tabs are then fastened against the board's top copper using 6mm x M3 machine screws and nuts.

Once the regulators have been fitted, the next step is to install IC5, the LM1881 sync separator chip. This comes in an 8-pin DIL package and mounts on the top of the board in the usual way. Take care with its orientation, though, and note that its earth pin (pin 4) is soldered to the copper on the top of the board as well as underneath.

Fitting the surface-mount ICs

You should now be ready to fit the four surface-mount ICs (IC1-IC4), which are the only parts mounted under the board. These are in an 8-lead SOIC package, with 1.25mm lead spacing – so they're not too small for manual handling and soldering, provided you're careful and use a soldering iron with a fine-tipped bit.

To fit these ICs, invert the board and find the four mounting locations using the underside diagram as a guide – see Fig.4. You'll find two sets of four small



The PC board is secured inside the case using eight 6mm-long self-tapping screws – four along the front edge and four along the rear.

rectangular pads in each position. That done, remove the four devices from their packaging and examine each one with a magnifying glass so that you can identify the small chamfer along one side – this is used to identify pins 1-4 of the device.

All four devices are mounted on the board with this chamfered side towards the front – ie, downwards in Fig.4.

Each device is installed by first placing it on its set of pads (with the correct orientation) and holding it there using a vacuum pick-up tool or toothpick while you press down gently on one of its eight leads with the tip of your soldering iron. This will usually make a weak solder joint between the lead and the tinning on the board copper – enough to hold the device in place while you solder the rest of its leads to their pads. That done, you can then go back and solder the first lead properly, to complete the job.

Completing the PC board

The final component to fit is the power LED (LED1). This fits from the top of the board, with its longer anode lead towards the right (ie, towards CON1). Solder the leads in place with the body of the LED about 17mm above the top of the board (a strip of cardboard makes a handy spacer).

Bend both leads down together at right angles after soldering, at a point 9mm above the board (ie, 8mm from the LED body). The LED will then be pointing forward horizontally, ready to protrude through the matching hole in the front panel when it is fitted.

Drilling the panels

At this stage, your converter board assembly should be complete, so place it aside while you prepare the front and rear panels of the case. These each involve drilling and reaming a small number of holes for the various connectors and the LED, using a photocopy of the panel artwork as a drilling guide.

Additional photocopies of the artworks can then be cut out and attached to the outside of each panel, to make them look professional, as on the prototype.

The way to do this is to first make a copy of the artwork on adhesive-backed "A4 label sheet" paper. The labels are then trimmed, peeled off the backing and attached to the panels. A length of clear packaging tape (ie, wide adhesive tape) is then applied over each panel, to protect it from dirt and finger grease.

Finally, the excess tape can be trimmed off around the panels and the holes cut out using a sharp hobby knife.

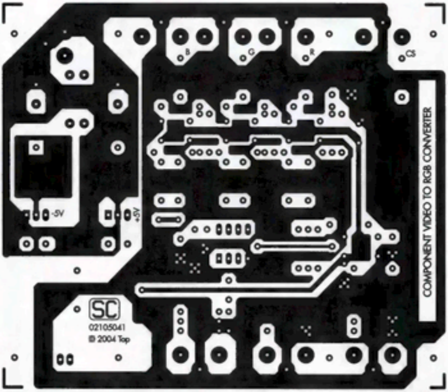


Fig.5: this is the full-size etching pattern for the top side of the PC board.

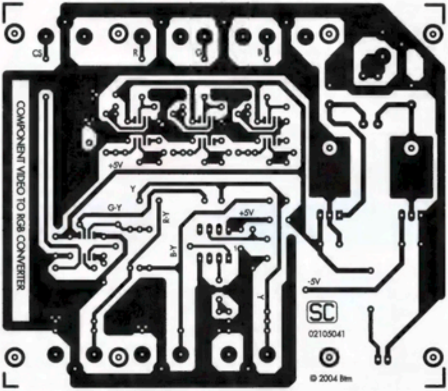


Fig.6: the full-size etching pattern for the bottom of the PC board. Check both sides of the PC board for etching defects before installing any parts.

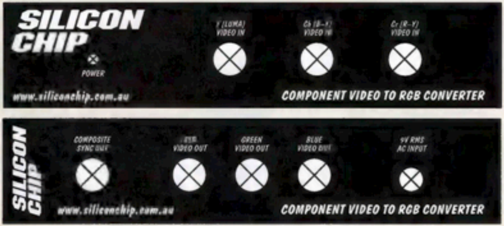


Fig.7: these full-size artworks can be used as drilling templates for the front and rear panels.

Of course, if you buy a complete kit, you probably won't have to do any of this. Instead, the panels will most likely be supplied pre-punched and with screened lettering for a really professional finish.

Now for the final assembly. This is done by first fitting the panels over the connectors on each side of the board (and over the LED in the case of the front panel) and then lowering this assembly into the bottom half of the case – ie, by sliding each panel into its mating slot. It's then simply a matter of fitting eight small 6mm long self-tapping screws (four along the front edge and four along the rear) to hold the PC board in place.

Finally, the top half of the case can be fitted and secured from the bottom using the two long countersink-head self-tappers provided.

Your Component Video To RGB Converter should now be complete and ready for use. There are no adjustments to make – all you have to do is connect a suitable 9V AC plugpack and it should spring to life.

Troubleshooting

If it doesn't work, the first step is to go back over your work and check that all components are correctly positioned and orientated. Check also for missed solder joints, especially where leads have to be soldered on both sides of the PC board.

Next, check the power supply rails. There should be +5V at the output of REG1 and -5V at the output of REG2. If you don't get this, check the two regulators and diodes D1 and D2.

You should also be able to measure +5V (with respect to ground) on pin 8 of all ICs and -5V on pin 4 of IC1-IC4.

Finally, if LED1 fails to light and the +5V rail is correct, check that the LED has been installed correctly. Check also that its 470Ω current limiting resistor is correct. **SC**