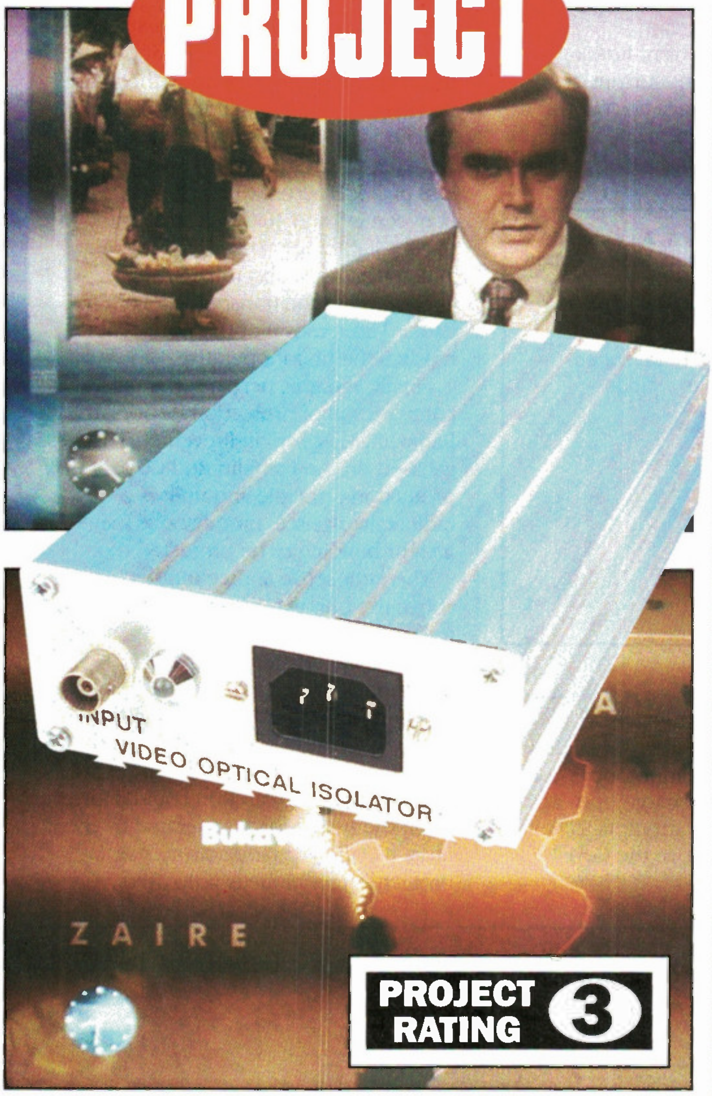
PROJECT



Video OPTICAL ISOLATOR

by Ian Berry

There are all kinds of interference signals which can appear on audio and video signals to distort them in one way or another. One of the most common is hum, at either 50 or 100Hz.

You will probably have encountered hum while working with audio and Hi-Fi equipment, and the methods of combating such are fairly well known. When hum appears in video equipment, it is just as annoying but usually much more difficult to get rid of. It can normally be seen as horizontal bands of alternate darkening and lightening of the monitor screen – see photographs. By and large, hum is introduced into a system, whether audio or video, through the interconnections between the system components. If hum is produced by an actual piece of equipment, the cause is much more likely to be a fault of some sort within the equipment itself.

Hum is usually 50 or 100Hz sine waves induced from nearby mains wiring or mains transformers. No one is immune from this problem. A few years ago, a large Broadcasting organisation were covering the snooker from the Guild Hall in Preston. The circus of OB trucks, VTR trucks, Graphics trucks and so on are connected by miles of video and audio cable. When all was connected, it was found that hum was present on just about every video circuit. After a great deal of running about, it was found that the spare mains cable from the lighting circuits had been coiled and shoved under a VTR truck out of the way. This made the biggest transformer primary you can imagine. In this case, there were so many circuits, it was not going to be possible to use elimination equipment to get rid of hum, but for only one or two circuits, methods are available.

Aspects of Hum

There are two different aspects to hum picked up by interconnecting circuits. These are common mode, where the hum is induced equally in both signal and ground wires, and single-ended, where hum is present in only one of the wires, usually the ground or braid of the coax. It would seem that if hum is present only in the ground wire, it would be shorted out at each end of the cable.

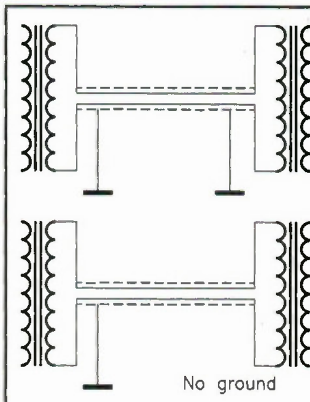


Figure 1. Balanced audio circuit. Note that one side of the braid may be disconnected without affecting the audio circuit, thus eliminating the hum loop shown in the next Figure.

If cables are very short, this is usually the case, but for longer cables, it is not so. It depends how you look at it. Relative to the wanted signal on the inner core of the cable, there is a hum on the braid or screen, it's going up and down in time with the hum. However, hold the screen at ground and relative to ground, the signal on the inner core of the cable is going up and down.

It's a bit like being on a boat. If you stand on the shore and watch the boat, it goes up and down with the waves. However, stand on the boat and it appears that the land is going up and down instead. So, the single-ended hum signal on the braid is effectively transferred to the input of the equipment.

If items of equipment are located some distance apart, hum loops are created by the two different paths of earths, one from the sending equipment to the power distribution system and then back to the receiving equipment, the other, the direct connection of the coax braid. The worst case is equipment located in different buildings, where the mains supply may not even be on the same phase.

With an audio installation, it is possible to reduce the incidence of hum by using balanced circuits (see Figure 1). Here, common mode induced hum is cancelled out at the transformer or balanced input

SPECIFICATION

Operating voltage:	230V AC mains
Overcurrent protection:	T500mA Fuse
Output voltage:	2V Pk-to-Pk, from twin BNC terminals
PCB dimensions:	159 × 100mm
Case dimensions (WHD):	108 × 47 × 168mm

Figure 2. Unbalanced input with single-ended hum on the screening braid. Within the equipment, the hum is transferred onto the input.

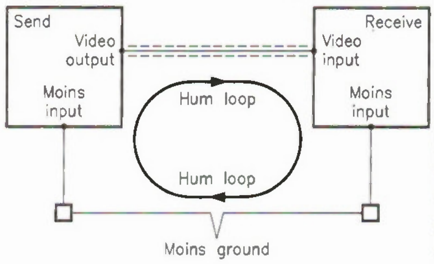


Figure 3. Earth hum loop formed by ground braid and mains earths. To eliminate this, it is necessary to break the loop. This is only possible at the braid. For safety reasons, the mains earths must remain connected.

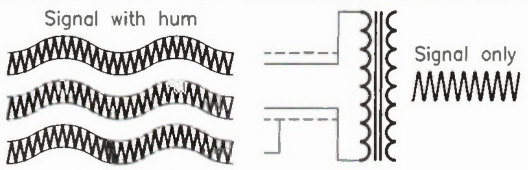


Figure 4. If signals appear in phase at each end of the transformer winding, there is no voltage difference, so no current will flow and no output will be induced in the secondary. Wanted signals will not be in phase, so will cause current to flow in the secondary and so will give an output.

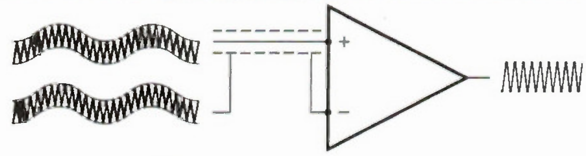


Figure 5. Differential amplifier for audio or video. The output is the difference between the two inputs. Output = ('+ve' input) − ('-ve' input). For in-phase signals, such as common mode hum, the output is zero, leaving the wanted signal only. The input socket must be insulated from ground.

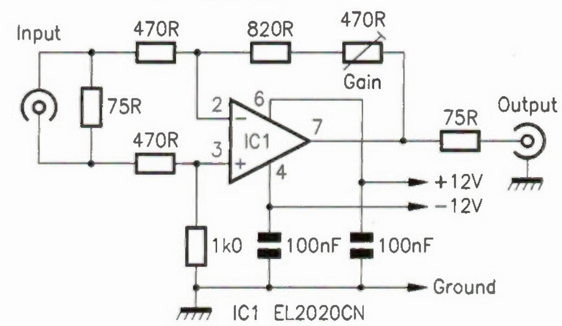


Figure 6. Differential input video buffer amplifier.

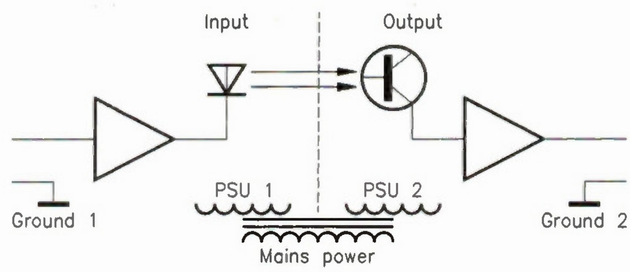


Figure 7. Within the optical isolator, there is no connection between input and output, so effectively breaking the hum loop.

to the equipment, since the hum signal is in the same phase at each end of the transformer winding or balanced input. Single-ended hum can be dealt with by disconnecting one end of the screening braid, thus breaking the loop. Since the braid is still connected at one end, its screen properties are retained more or less intact (see Figure 2). The other option, disconnecting one or both of the mains earths, naturally should not be considered, as this is very dangerous and foolhardy in the extreme.

This trick of disconnecting one end of the screening braid is rarely possible with video, the unbalanced nature of video interconnections made with 75Ω coaxial cable mean that one side of the transmission path is always connected to ground through the braid of the coax (refer to Figure 3). Disconnecting one end of the screening braid in this case will add far more problems in the form of mis-terminations, frequency response problems and reflections, and it probably would not get rid of the hum anyway. It is possible to transmit video by balanced circuits but much extra equipment is required in the form of sending and receiving interfaces and it is still not possible to completely isolate the sending equipment completely from the receiving equipment; there would still normally be a ground connection between the output and input. Video isolating transformers do exist (see Figure 4), but they are very expensive and require an equalisation amplifier after them to maintain the system frequency response.

Leaving aside the possibility of using a transformer, there are two methods of hum reduction. Number one will treat common mode hum and uses a differential input op-amp as a buffer at the input of the receiving equipment, as shown in Figure 5. In the same way as an electronically balanced audio input will have a 'common mode rejection', so will the differential video input. It will only buffer and pass on the difference between the two inputs. This is a very simple and cheap way to eradicate hum, but it will not break the earth loop between the equipment and is, therefore, not effective in eradicating single-ended hum. A circuit is included to show just how simple it is – see Figure 6. Method two will treat single-ended hum, as it gives gives true galvanic isolation between output and input by using an optical isolator – as shown in Figure 7.

Circuit Description

Refer to Figures 8 and 9, showing the block and circuit diagrams of the Video Optical Isolator.

The optical isolator used is very similar to normal chips found in all kinds of applications, but has a very large frequency response. It will handle up to 7-8MHz, contrasted with the ordinary opto isolator with a bandwidth of only a few kHz. Since there is no physical connection between the driving LED and the receiving phototransistor, it is possible to construct a unit which has no ground connection between input and output. To get around the problem of common power supply rails, two PSUs are used, one for send and one for receive, using separate windings on the same mains transformer. In this way, there is no connection between the two halves of the unit – refer again to Figure 7.

The unit is based on a HCPL 4562 Isolator (IC4), optimised for video use and made by Hewlett Packard. The input side of the unit is a simple current driver to vary the brightness of the LED in the package in response to changes in the video level. R16 applies the appropriate termination on the input cable and C1 blocks the DC bias voltage provided by R1 and R3 from appearing on the input socket. The bias voltage on the base of Q1 is chosen such that the video modulation is applied at the most linear part of the HCPL 4562 transfer characteristic. R4 and VR1 vary the gain of Q1 such that the video modulation is neither too low (where excessive amplification at the output would produce noise) or so high that signal clipping occurs. The gain of the amplifier in the output section is made such that VR1 can be used as an overall level control to ensure that the output from the unit matches the input.

In order to get the very wide bandwidth required for video, the detector part of the HCPL 4562 has a built-in buffer transistor with the base connection

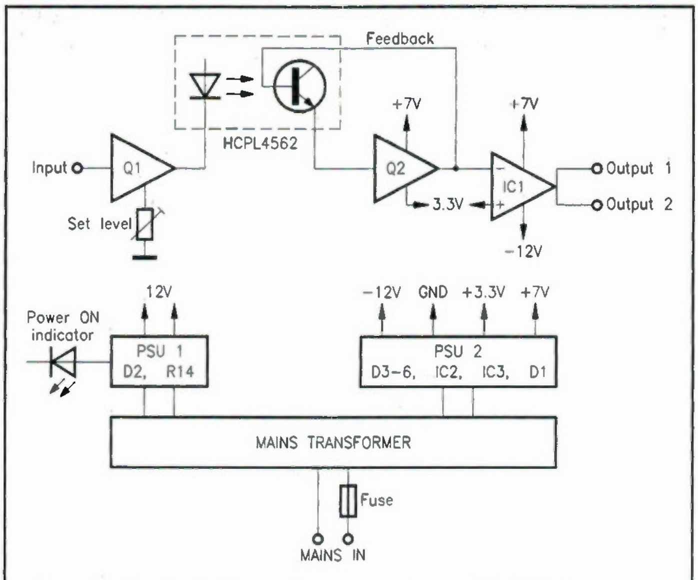


Figure 8. Block diagram of the Video Optical Isolator.

Power Supply Stage

At first glance, there would appear to be nearly as much power supply as actual signal processing. However, this breaks down into two or three chunks. There is the usual mains transformer, fuse, and input socket. This is obviously required to provide power to the unit. The transformer has two windings, each giving 18V AC. They are not connected together in any way, and so as one winding is used for the input current driver and one winding is used for the output buffer, there is isolation between the two sections of the unit.

As the input current driver takes very little current, around 20mA or so, a simple half-wave rectifier is used, with R14 acting as a dropper resistor to give a final voltage of about 12V. The LED power-on indicator is connected to this side of the power supply also.

Output Buffer Stage

The output buffer section is more complex. As the transformer has only one other winding, a virtual earth splitting system is used. The 18V AC is bridge rectified to give about 24V DC smoothed by C6. IC2 regulates this to 12V. This 12V rail is used as the ground rail for the output stage. This means, of course, that the negative end of C6 is at -12V with respect to the output ground rail and this is used as the negative supply for IC1. The unregulated 24V is also regulated by IC3, a variable

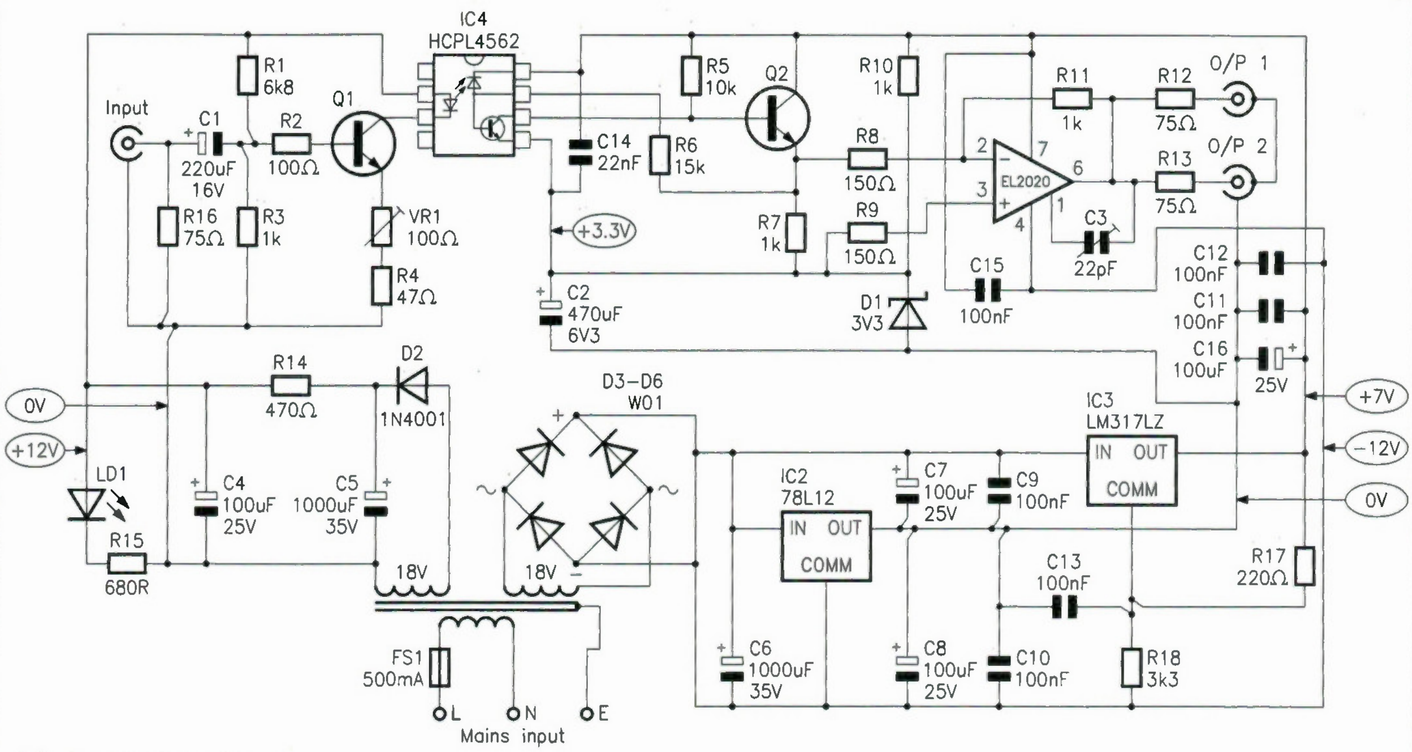
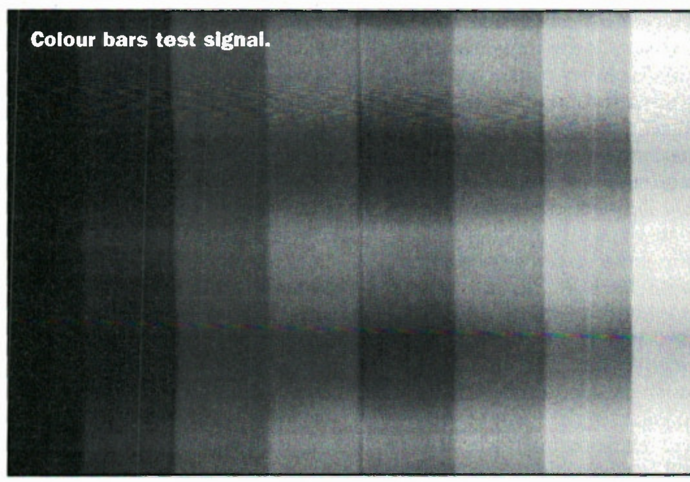
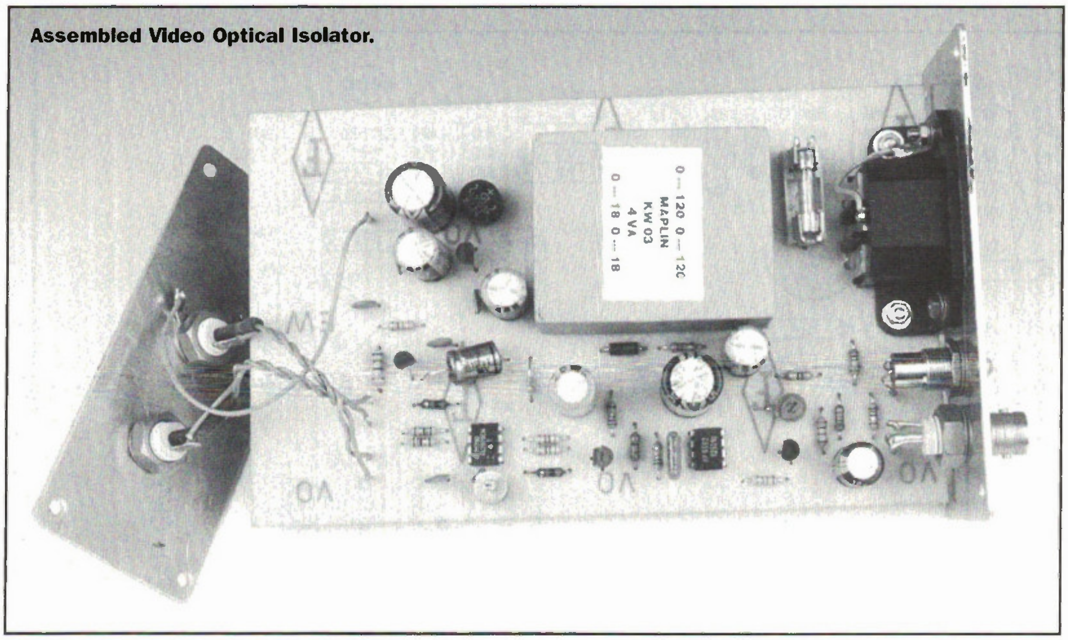


Figure 9. Circuit diagram of the Video Optical Isolator.

brought out so that the internal transistor may be included in a feedback path. Q2 acts as a buffer with R6 as a feedback resistor, which sets the output level at this point to about 1/3V Pk-to-Pk. At the emitter of Q2, the video signal is actually inverted.

IC1 is a wide bandwidth op-amp, chosen for the fact that not only is it stable at video operating frequencies with gains up to 10 times, but it will also drive two normal 75Ω back-terminated video loads. Thus, the unit has two outputs, one as a main and another as a monitor output if required. The arrangement is a perfectly simple inverting amplifier with a gain of about six times. Thus, the 1/3V of video at the emitter of Q2 is amplified and inverted and appears at the output of IC1 on pin 6, at a level of 2V Pk-to-Pk. 2V is necessary, as the 75Ω resistors in series with the outputs would be connected to a 75Ω termination to ground, giving a potential divider and thus, 1V Pk-to-Pk at the input of the next piece of equipment, which is correct – see Figures 10 & 11.


Colour bars test signal.


Assembled Video Optical Isolator.

regulator whose output is set to +19V by R17 & R18. With respect to the output ground, this rail is effectively at +7V and this is the main positive supply for IC1 and the isolator chip and Q2. In order to produce a reasonable DC level from the buffer Q2 for IC1's input, a Zener diode, D1, is used to lift the ground for the isolator chip and Q2 to 3·3V above normal ground. The positive input of IC1 is also returned to this point to give the correct input DC conditions. The result of this 3·3V lift and the apparently odd choice of power rails means that the 0V DC level of the output video signal lies at just about blanking level. In turn, this means that DC coupling can be used at the output without the need for capacitors, which would degrade the low-frequency response. Capacitors C7-16 are used for low- and high-frequency decoupling of the various supply rails.

In use, it was found that there is a slight loss of HF through the isolator. This shows up as a slight loss of chroma information. Normally, this would not be a problem, especially if the following equipment is a display monitor, which will restore the level using the colour burst as a reference which is reduced by the same amount, but to bring the response back to normal, C3 is fitted to the balance system of IC1 and can be used to increase the HF response back to normal. If no test equipment is available, setting C3 to its minimum position will give a loss of about 2% of chroma, which is virtually unnoticeable.

Construction Details

PCB Assembly

Figure 12 shows the PCB legend and track, to suit the specified CCN-style box. It is possible that constructors may wish to redesign this layout to suit a smaller box, perhaps. There are a couple of things to bear in mind. Take care with mains voltages if the transformer is to be fitted on the board. The tracks should be nice and thick and well spaced apart, both from themselves and from the low voltage part of the circuit. Take care when testing the finished unit out of its box, since the mains voltages on the board can be lethal.

The input section of the circuit should be as far away from the output part of the circuit as is practical. The idea is for the input section to be on one edge of the board and the output section to be on the other.

The actual layout of the board is not critical, except that long tracks should be avoided if possible, as this will lead to instability in the output section. If it is found necessary to fit C3, beware attempting to increase the HF response too much as this will make any instability problems worse. If the unit is to be used with monitors or any other units with automatic chroma control, it is best not to fit this component. With Black and White video, this component is not required at all. Assemble the components in order of ascending component size, and finally, clean excess flux off the PCB using a suitable solvent.

Box Construction

This is fairly straightforward, although one or two things are quite important. The first is that obviously the input and output connections should not be near enough to each other that there is a possibility that they could be bridged by anything metallic (for example, the metal body of another connector), as this will defeat the object. The version shown in the article has its BNC input and output connectors at opposite ends of a quite large box. Secondly, although the PCB could be mounted in a plastic box, the use of a metal box is to be preferred. The metalwork of the box can be connected to the mains earth for safety. The unit shown is used in a television outside broadcast environment and the CCN-style metal box is ideally suited, both for screening and mains safety earthing. Another point is the extremely rugged construction which can be achieved. The CCN-style box also accepts standard sizes of PCB and the internal circuit is designed to fit on such a standard size board.

The mains input is by a PCB-mounted IEC-type connector. This has mounting holes both for fixing to the PCB, for added strength, and normal holes to fix to a panel. The panel holes are used to fix the connector to one of the end panels of the CCN box. This, together with the PCB mounting slots in the body of the box, are all the fixings required. The earth pin of the IEC connector is wired to a solder tag attached to one of the mounting bolts.

Using a metal box, of course, means that insulated BNC sockets are required. It is quite common nowadays for equipment to use RCA Phono style connectors for video inputs and outputs. If phono sockets are to be fitted, then an insulated version will be required (e.g. JZ05F).

Setting-up Procedure

Setting-up of the unit only requires that VR1 is set such that the output signal matches the input. Ideally, this would be done with an oscilloscope using colour bars as a test signal. Setting may be approximately done simply by observing a monitor displaying first the input signal and then the output signal. For displaying on a monitor only, this would suffice, but for more demanding operation, a scope would need to be used.

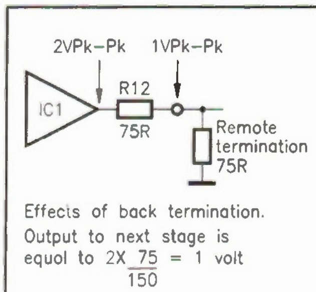


Figure 10. Effect of back termination. Output to next stage is equal to 2 × (75/100) = 1V.

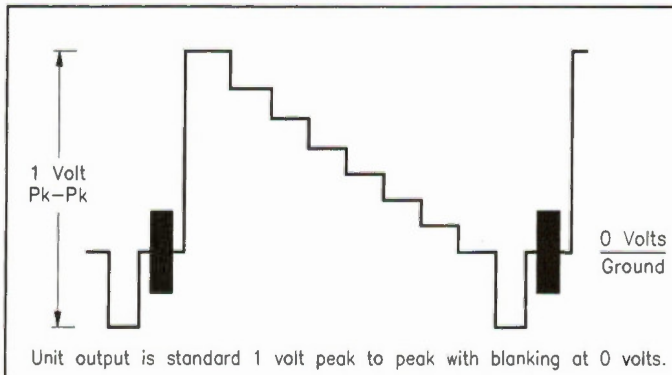
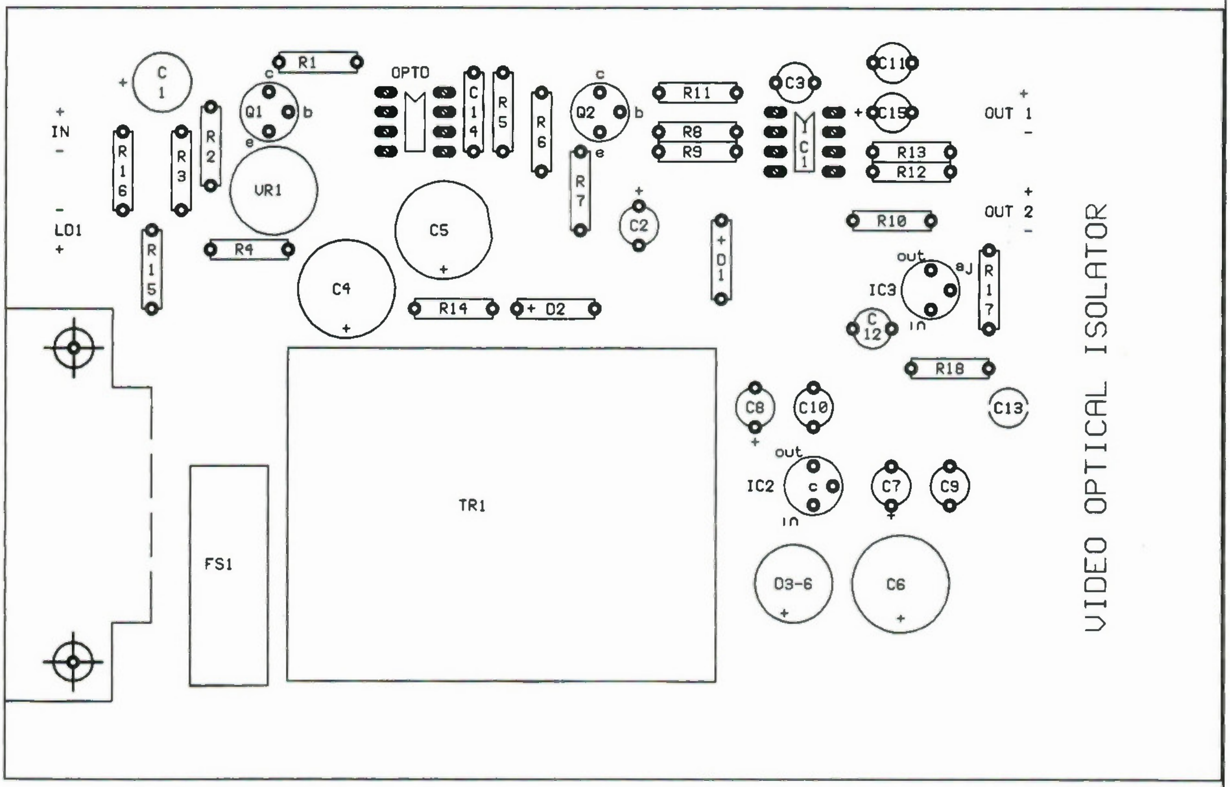


Figure 11. Unit output is standard 1V Pk-to-Pk with blanking at 0V.

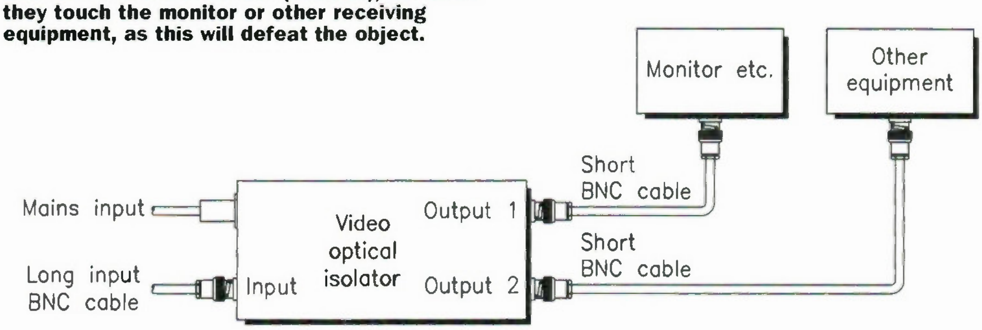
Figure 12. PCB legend and track.



Using the Isolator

In use, the unit is simply fitted in the coax circuit using a short BNC cable – refer to Figure 13, showing the wiring diagram. It is obviously important to ensure that the outer of the BNC plug on the input does not contact any metalwork associated with the receiving equipment, as this would restore the earth continuity and render the whole thing useless. This type of unit is invaluable for sending pictures around venues such as race tracks, football grounds, and anywhere where long cable runs exist. ELECTRONICS

Figure 13. Isolator in use. The two BNC plugs must not touch each other (difficult), nor must they touch the monitor or other receiving equipment, as this will defeat the object.



Isolator in use. The two BNC plugs must not touch each other (difficult) nor must they touch the monitor or other receiving equipment as this will defeat the object.

PROJECT PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless Stated)

R1	6K8	1	(M6K8)
R2,7,10,11	1k	4	(M1K)
R3	100Ω	1	(M100R)
R4	47Ω	1	(M47R)
R5	10k	1	(M10K)
R6	15k	1	(M15K)
R8,9	150Ω	2	(M150R)
R12,13,16	75Ω	3	(M75R)
R14	470Ω	1	(M470R)
R15	680Ω	1	(M680R)
R17	220Ω	1	(M220R)
R18	3k3	1	(M3K3)
VR1	100Ω Cermet Trimmer Potentiometer	1	(WR38R)

CAPACITORS

C1	220µF 16V Radial Electrolytic	1	(AT41U)
C2	470µF 16V Radial Electrolytic	1	(AT43W)
C3	22pF Trimmer	1	(WL70M)
C4,7,8,16	100µF 25V Radial Electrolytic	4	(AT48C)
C5,6	1,000µF 35V Radial Electrolytic	2	(AT63T)
C9-13,15	100nF Ceramic Disc	6	(YR75S)
C14	22nF Polyester	1	(BX72P)

SEMICONDUCTORS

D1	BZY88C 3V3 Zener Diode	1	(QH02C)
D2	1N4001	1	(QL73Q)
D3-6	W01 Bridge Rectifier	1	(AQ95D)
LD1	Panel-mounting Red LED	1	(YY60Q)
Q1,2	2N3904	2	(QR40T)
IC1	EL2020CN	1	(UR06G)
IC2	78L12	1	(WQ77J)
IC3	LM317LZ	1	(AV26D)
IC4	HCPL4562	1	

WOUND COMPONENTS

TR1	0-18V 0-18V 4VA Low Profile Transformer	1	(KW03D)

MISCELLANEOUS

	Video Input & Output Sockets	3	(CK05F)
	Mains Inlet Socket	1	(FE15R)
	Box CCN160	1	(YN51F)
	8-pin DIL Holder	2	(BL17T)
	Fuse Holder	1	(DA61R)
	T500mA 20mm Fuse	1	(CZ94C)
	PCB	1	

The Maplin 'Get-You-Working' Service is not available for this project.
The above items are not available as a kit.