THE 'TELEVISION' COLOUR RECEIVER PART 10 POWER SUPPLIES

Some of the design philosophy behind the power supply unit was mentioned in the first article of the series. Paramount is safety, and a mains transformer for the receiver has been specially commissioned. The main potentials used in the receiver are therefore all isolated and the receiver itself has a proper earth. We would emphasise immediately that although it is of course possible to operate the receiver by dispensing with the transformer and the earth facility we cannot advise this.

A number of varied factors must be taken into account in designing a power supply. First of course are the voltages required by the individual stages of the receiver, and the stability necessary for these different sections. It is also essential that the dropping resistors, rectifiers, etc. are all capable of withstanding the worst circuit conditions. Full circuit protection must in addition be provided.

The mains input is directly applied to the mains transformer primary with a 7A fuse in the line side. Coupled to the primary circuit, and on the fused side, are two feeds: one at 6F goes to the autodegaussing circuit, the second goes through the valve heater ballast circuitry. Coupled directly across the primary of the mains transformer is the standard mains filter capacitor C501. The voltage rating of this component should be particularly noted.

The heater chain ballast must take account of the current taken by the chain and the voltage drop necessary for operation of the valves used. It has become modern practice to provide a proportion of the voltage drop by using the "wattless" reduction in a diode (D501 here). This avoids the use of a large wattage dropper resistor with its associated heat dissipation problems—and cost!

It has also become the common practice in the last couple of years to dispense with thermistor switch-on protection in a receiver using only a few valves.

The voltage from the diode in the heater chain will be the *average* of the mains voltage. In arithmetical terms this will be $240 \div 2 = 120$V. At 300mA heater current the voltage drop across the three valves, PCF802, PL509 and PY500, will be 9.0, 40 and 42V respectively, a total drop of 91V. Thus a voltage drop of about 150V has to be provided by the ballast circuit and a dropper of about 100Ω is needed in series (R501). 100Ω at 300mA will dissipate 9W so the component is rated at 10W.

As the shadowmask tube is the most expensive component in the colour receiver it is obviously vital to protect it from failure such as might be caused by over-voltage on the heaters. The heaters for the three guns are connected in parallel and are rated individually at 6.3V, 300mA. The power requirement is therefore 6.3V, 900mA.

This is supplied from a 0-24V winding on the mains transformer. The same theory as with the heater chain applies: the diode (D505) provides a wattless voltage reduction, the average voltage being $24 \div 2 = 12$V. At 70°C the resistance of the switch-on protection thermistor (R517 VA1033) is about 1Ω. To get the required voltage drop of 12 − 6.3V (i.e. 5.7V) a 10Ω ballast resistor is fitted, giving allowance for a small variation in the c.r.t. heaters themselves. The rating of R516 must be greater than its 8.1W dissipation—10W is used.

By itself however this is not really sufficient to protect the tube heaters, particularly if a fault such as a short-circuited diode should occur. For this reason a 1A fuse is fitted on the c.r.t. base.

HT Supplies

From the 250-0-250V secondary of the transformer a full-wave rectifier using two BY133 diodes (D502 and D503) provides an average unsmoothed voltage of about 305V. The two diodes are provided with transient protection in the form of C502 and C503 and with a conventional series protection thermistor—the VA1104.

The high-voltage feeds necessary are: to the line timebase at 295V, taking a maximum of about 500mA; to the RGB output module at 230V, taking about 80mA; and to the sync separator at 220V with about 3mA current drain. This is a total possible current requirement of about 583mA.

The common dropper R504 plus R505 (50Ω) provide the 295V h.t. for the line timebase with smoothing provided by R505/C504. The line output stage is separately fused on the timebase board. Because it is a valve stage no excessive supply stability precautions need to be taken.

A 100mA fuse (FS502) protects the feeds to the RGB and sync separator stages, with R506 providing a common dropper resistance—its value is based on the assumption that the RGB module takes an average current of about 60mA rather than the peak 80mA possible. R506/C505 smooth the RGB feed while the spur R507 dropper feeds the sync separator point with additional smoothing from C506.

LT Supplies

An encapsulated full-wave rectifier (D504) supplies from the 0-35V winding the full range of low

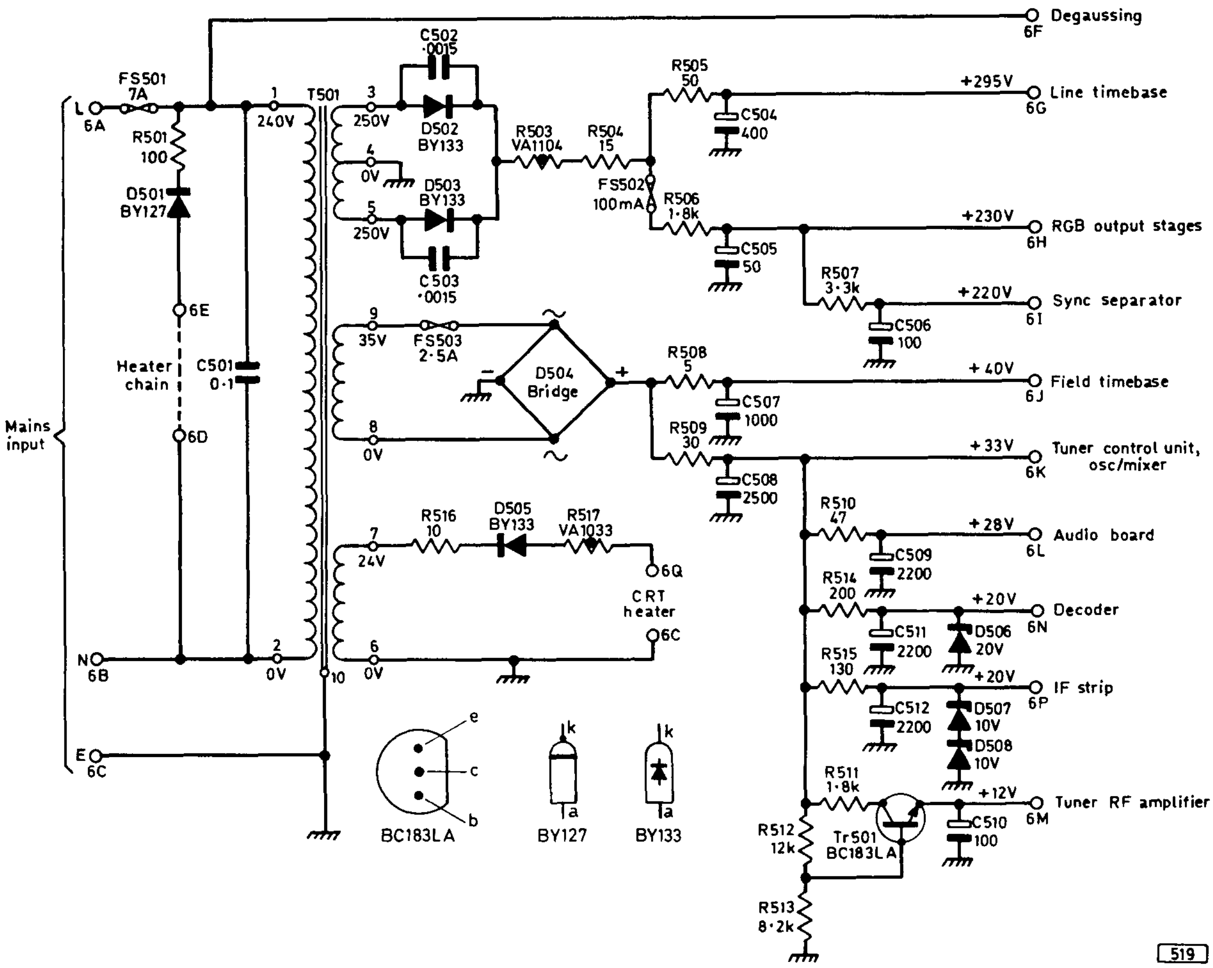


Fig. 1: The power supply circuits. The cathode end of the zeners is marked with a white ring.

voltages for the receiver. The feeds and their voltage/current requirements are:

Field timebase: 40V, approximately 1.25A maximum.

Tuner (control volts and oscillator/mixer): 33V, 0.75mA and 3.6mA.

Audio: 28V, 8mA quiescent, 100mA average peak.

Tuner r.f. amplifier: 12V, 6.5-16mA depending on gain and tuner type.

Decoder: 20V, 60mA approximately.

I.F. strip: 20V, 100mA approximately.

This is a total current requirement of about 1.53A although some transient and high-level signal conditions might raise it to about 1.8A. The secondary winding is fused at 2.5A, the bridge rectifier rating being 2A. A dropper resistance of 5Ω (R508) is required for the 40V field timebase supply, with smoothing provided by C507.

A 30Ω dropper (R509) and smoothing capacitor (C508) provide the 33V supply to the varactor tuner control unit and the tuner oscillator/mixer. Note that a different feed is used for the tuner r.f. amplifier stage which is gain controlled and has a fairly large possible range of current.

A spur from the 33V rail provides the 28V for the audio output stage through a 47Ω dropper (R510). This assumes 100mA being taken. In quiescent conditions the audio rail voltage will rise to a value very close to the 33V rail but this will not harm the audio i.c. At the other end of the range of possibilities is a continuous current drain of more than 120mA—representing a *continuous* audio output of more than 1.5W. The voltage feed to the tuner control unit then falls below the range of the stabilising i.c. (details of this will be given with the tuner board) and the tuning changes. A fault condition in the i.c. or overdriving it therefore gives an instantly noticeable change in receiver tuning.

The decoder and i.f. strip feeds (20V) are both spurred off the same point on the 33V rail. The 60mA current drain of the decoder requires 200Ω ballast and this is smoothed by C511, whilst the 100mA drain of the i.f. strip requires 130Ω and this is smoothed by C512. To reduce the effects of excessive voltage both rails are protected by zener diodes, the ratings giving over-voltage protection to the extent of a further 20V or so. This allows in particular for the possibility of over-voltage during some fault conditions—e.g. if one of the field output power transistors goes open-circuit lifting the voltage rail to about 45V.

Table 1: Components List

Component—Pack 18

R501 100Ω, 10W	R510 47Ω, 1W
R503 VA1104	R511 1.8kΩ, ½W
R504 15Ω, 6W	R512 12kΩ, ¼W
R505 50Ω, 10W	R513 8.2kΩ, ¼W
R506 1.8kΩ, 15W	R514 200Ω, 2.5W
R507 3.3kΩ, 1W	R515 130Ω, 2W
R508 5Ω, 10W	R516 10Ω, 10W
R509 30Ω, 5W	R517 VA1033
C501 0.1μF, 900V	C508 2500μF, 40V
C502 1.5nF, 1kV	C509 2200μF, 35V
C503 1.5nF, 1kV	C510 100μF, 25V
C504 400μF, 350V	C511 2200μF, 35V
C505 50μF, 350V	C512 2200μF, 35V
C506 100μF, 275V	All above except C501,
C507 1000μF, 50V	C502 and C503 are electrolytics.
D501 BY127	
D502 BY133	D507 10V, 1.3W zener
D503 BY133	D508 10V, 1.3W zener
D504 2A, 100V bridge	Tr501 BC183LA
D505 BY133	FS501 7A } "00"
D506 20V, 1.3W zener	FS502 100mA } "00"
	FS503 2. 5A } "00"

Mains Transformer:	Primary	0-240V
	Secondaries	250-0-250V
		35-0V
		24-0V

Printed-circuit mounting fuseholders supplied in earlier packs.

Suppliers

No. 18 Electrokit, 12 Lauderdale Road, London, W9.
Cost: £12.50 including postage.

Printed Circuit Board (⅛in.):

E. J. Papworth & Son Ltd., 80 Merton High Street, London, SW19.
Cost: £2 including postage.

The feed to the varactor tuner r.f. stage must allow for the possible range of quiescent current demand without resulting in excessive voltage. The arrangement uses a BC183LA transistor as a simple series stabiliser. The 13.4V base potential is set up from the 33V rail by the potential divider R512/R513. If the supply voltage to the r.f. amplifier rises above 13.4V—as it will when the stage draws less than 6.5mA—the transistor conducts less thereby limiting the rise.

Constructional Details

It was decided that in order to make the power supply as compact as possible and to minimise the interconnection difficulties between the transformer and the circuit board the board should in fact sit above the transformer itself. The board layout is shown in Fig. 2, where the transformer tag connections indicated on the circuit diagram can also be seen. The system of interconnections between the transformer and the board is by means of 14 or 16 s.w.g. tinned wire. The wire is soldered to the copper side of the circuit board and also to the tags of the transformer. By keeping the leads short a mechanically rigid system will be achieved: we suggest in fact a spacing of about ½in.

The printed circuit drilling is probably the most complicated so far because of the tag connections on the larger electrolytics. Holes should not be drilled to the maximum dimension of the tags because this will make the capacitor mounting mechanically unsure. In the majority of cases it is better to make slits in the board to take the tags. These can usually be formed from $\frac{1}{16}$in. holes drilled in line to the width of the tag, the intervening matter being cleaned out using a needle file.

As far as possible the larger component weights have been centralised over the transformer but in some instances—e.g. C506—the weight falls on the overhang. This makes the actual mounting of the board on the transformer a little tedious. Undoubtedly the best method is to attach the ten lengths of 16 or 14 gauge wire to the transformer tags and then feed them through the board holes. If the wire lengths are made rather longer than is actually required it will be found that the board can be "settled" down towards the transformer and the necessary solder connections made looking up under the circuit board. The excess wire protruding above the board can then be snipped off.

Component Mounting

It is not possible to give a more accurate guide to the board drilling process: the constructor should mark off the hole positions on the etched board using the centre points given as guides. The only component for which these are not given is C506: this is because at the time of publication any one of a number of different components may have to be supplied, the drilling centres of which are all different. The constructor should check the type and the tag spacing on the item supplied.

When mounting the components the following should be particularly noted: the polarity of the electrolytics, the polarity of the diodes, the correct alignment of the bridge rectifier module D504 and the correct location of the BC183LA transistor. The higher dissipation resistors should be mounted about $\frac{3}{16}$in. off the board. When the board has been completed take care to fit the correct fuses in the various fuseholders.

The IF Strip

A number of queries about the stability of the i.f. strip have been raised by readers who have tried to align their own. This was noteworthy in view of the excellent stability of the prototype which although using a hand-made printed-circuit panel was laid out in an almost precisely identical manner. The coils used were hand-made but all the coils made by the suppliers have been tested by us in the prototype on a batch sample basis with no ill effects. We would add that this testing was at the request of the supplier so that he could be sure his standards were being maintained.

Our knowledge of the i.f. strip is rather more intimate than that of the majority of readers because

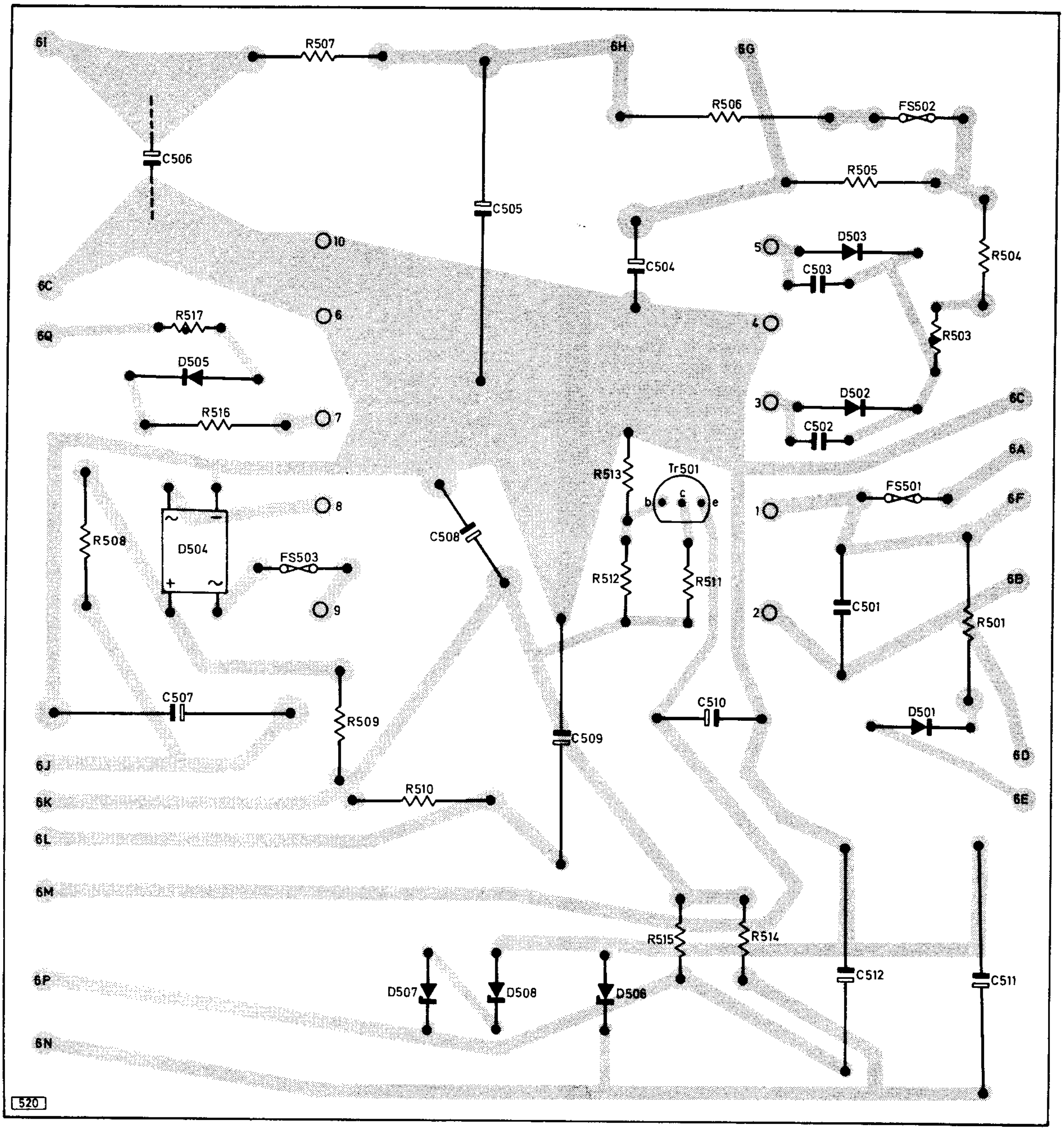


Fig. 2: Layout of the power supply board, viewed from the print side.

we have lived with it rather longer and because now of the "quality-control check" that we have through the Alignment Service. The first batch of i.f. boards received using the commercially made boards, the wound coils and the kit components were grossly unstable when powered. This caused concern and a great deal of time investigating the source of the trouble has been spent by the author and the alignment team—this time has unfortunately affected the author's output and has necessarily delayed the appearance of the tuner panel which was also promised for this month.

It was thought at first—as it has also been by a number of more experienced readers—that the instability was caused by the cascode stage going into self-oscillation, working as it does at high gain, and indeed screening the cascode stage can reduce and in some circumstances eradicate the instability—the latter occurring when the screening earths are correctly connected. Such additional screening would make nonsense however of the intention of the layout to be as uncritical as possible for the home constructor.

Investigation revealed however that the instability was in fact radiation *across* the i.f. strip from the a.f.c. coil tuned to the vision i.f. carrier. It was then found that the level of the signal driving the discriminator circuit was excessively high. Changing the value of R159 from 220Ω to 6.8kΩ reduces the drive sufficiently for the radiation to completely stop whilst the a.f.c. circuit still produces the required output range. This value change will be made to all boards passing through the Alignment Service. Readers not using the Service are advised to change the value themselves.

The a.g.c. circuit has also given trouble again and it has been found that the operation of the circuit is much smoother when C130 is removed from circuit completely. Again this will be done on boards passing through the Alignment Service.

It also seems possible that on many boards improved a.g.c. action can be obtained by using a slightly higher voltage range than on the prototype. In the majority of cases this means reducing the value of the main ballast resistor of the a.g.c. output stage—R130. Values of between 680Ω and 910Ω seem most suitable and an appropriate value will again be inserted on boards passing through the Alignment Service.

One remaining problem on most boards is causing concern. This is a general reduction in design gain particularly when used with earlier types of tuner. Work on this is continuing.

We hope the reader is aware of our concern to sort out these problems. The enormous amount of work that has already been done on the received boards will be continued but there are inevitably going to be some delays in the return of the first batches of i.f. boards. We hope that these delays can be quickly eradicated.

Mounting the Tuner Control Unit

A number of readers have queried the spacing between the vertical ties at the front of the cabinet in view of the dimensions of the push-button selector unit. The fact is that the cabinet was designed prior to the offer by Manor Supplies of the particular push-button unit suggested. If this unit was to be fitted directly between the ties the overall cabinet width would have had to be increased or the width of the ties reduced. Both these solutions were considered undesirable. So the ties were left as they were and to mount the unit a slot must be cut at each side. The small amount of cutting is easily achieved in the completed design of the cabinet. A small amount of wood slicing is also necessary to obtain a large enough aperture for the loudspeaker used in the cabinet. In both cases the small degree of cabinet weakening is more than matched by the mounting bracket used to support the push-button unit and the potentiometer controls. Full details will be given in the relevant article.

Timebase Pack

A few timebase component packs (Component Pack 10) were sent out with a 2W instead of a 6W resistor for R351, the incorrect amount of wire for L301 (15 metres is required) and incorrect heatsinks for the field output transistors. If readers ask Marshalls the correct items will be sent.

Blank boards: Blank $\frac{1}{8}$in. boards for the power supply circuit are available at 87p inc. post and packing from Servitronix Ltd., 26 Killarney Rd., London SW18.

THE 'TELEVISION' COLOUR RECEIVER PART 11
AUTOMATIC DEGAUSSING

THE shadowmask c.r.t. contains an area of steel—the shadowmask—which is quite large. Ignoring the holes in the mask the total area in for example a 22in. tube is about 1,500 sq. cm. Like all ferromagnetic materials the mask can be magnetised. Unfortunately the convergence and colour purity of a colour tube depend on the accuracy—and constancy—with which the three beams from the c.r.t. guns pass through the mask: even small effects on these beams will cause noticeable misregistration and loss of colour purity. The P-band (Rimguard) of a shadowmask tube is also ferromagnetic and in the same way this, if magnetised, can cause beam mislocation problems.

The shadowmask tube is thus extremely sensitive to external magnetic fields. A number of fields may be present in any domestic situation. Surprisingly one of these is the earth's own magnetic field. Other common objects such as metal-framed chairs, radiators, electric fires and so on are often slightly magnetised. The effect of these magnetic fields on a colour receiver picture would be to gradually pull the receiver out of convergence after installation; any further magnetic field created domestically—e.g. a vacuum cleaner operating close by—will worsen the situation. Additionally of course any movement of the receiver in the earth's magnetic field will cause changes.

It is necessary therefore to demagnetise (degauss) a colour receiver regularly. This can be done manually using an external degaussing coil—such as the service technician will have; alternatively it can be done automatically. If degaussing is to be automatic and on a regular basis it should be done at receiver switch-on or switch-off—the logical condition is at switch-on so that the receiver performance is correct while it is actually working!

Automatic degaussing is done by a pair of coils which are inserted under the magnetic picture tube shield. The coils are in series aiding connection and a control circuit governs the current flowing through them from the instant of switch-on.

To demagnetise a metal completely the field created in the material must initially be enough to saturate it: the magnetic field must then be reduced to zero, increased negatively, reduced to zero, increased positively etc. with each swing being progressively smaller. The B-H loops created in this way will be such that when the field finally reaches zero the remanent magnetism will also be zero. The positive and negative field variations are provided by using a.c. as the energising current: the amplitude reduction must be provided by the control circuit.

To saturate the shadowmask, the P-band and the magnetic shield itself about 500AT (Ampere-turns) are required: this must not be exceeded by any proportion otherwise damage can result to the shadowmask through the magnetic force on it.

With the type of control circuit used in practice it is impossible to have at the end of degaussing a resultant zero flux. The flux must be reduced below 5AT to complete degaussing but it is known that a flux of less than 0.3AT is needed for minimal effect on registration. The difference between full current and minimum current for a given set of coils is therefore in the ratio 500:0.3, i.e. 1667:1, the ratio to be provided by the control circuit.

Circuit Operation

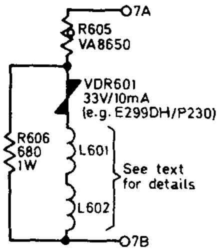
The heart of present degaussing circuits is the Mullard VA8650 (or equivalent) thermistor. This has a positive temperature coefficient, with a cold resistance of 80Ω ± 20%. As the thermistor heats up the resistance rises very considerably above this of course. When operated across a 240V mains supply the lower limit value (80 − 20% = 64Ω) necessitates a series resistance of 80Ω to limit the maximum peak current to 2.6A.

The network below R605 in the circuit (see Fig. 1) must therefore appear as 80Ω at switch-on. Thus with the shunt 680Ω (R606) in position the resistance of the v.d.r. (VDR601) plus the coil pairs must appear as about 90Ω. The actual coil current flowing will then be about 2.3A. The 33V/100mA v.d.r. (VDR601) with this current passing through it will have a resistance of about 43Ω so the coil resistance (total) must be about 50Ω.

At switch-on the thermistor is cold and the voltage across the network of the v.d.r., coils and R606 will be high (an r.m.s. voltage of about 240 ÷ 2 = 120V). The current through the v.d.r. and the coils is high (2.3A) therefore and the magnetic flux produced is sufficient to saturate the area to be degaussed.

The current flowing heats R605. As a result its resistance increases and the voltage across the lower network decreases. As the voltage decreases the current falls and the resistance of VDR601 increases to reduce still further the current through the coils. A permanent small current flows through the 680Ω resistor (R606) but a switch-on/stable current ratio through the coils of about 2,000:1 is obtained. The exact ratio depends on the ambient temperature conditions around the degaussing components.

The coils must have a resistance of about 25Ω



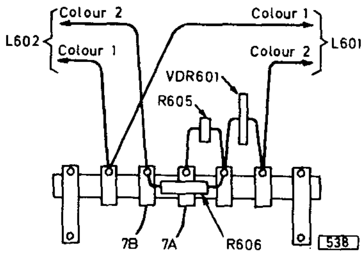


Fig. 1 (left): Automatic degaussing circuit. 7A and 7B connect to the a.c. mains on the power supply board—contacts 6F and 6B or 6D. Points 7A and 7B must not be earthed therefore.

Fig. 2 (right): Component layout on the tag strip, which should be mounted on the magnetic shield. Tag strips supplied in the component pack will be cut from standard RS 28-tagged strip.

each to meet the above total resistance requirement of 50Ω and they must have sufficient number of turns to give correct operation under the worst current conditions (which occur with the minimum possible mains voltage). When the current through the coils is 1.3A 385 turns (total) are required to give 500AT. As the diameter of the coils must be about 38cm. for 25 or 26in. tubes and about 29cm. for 19-22in. tubes it can be shown that *each* coil should consist of about 200 turns of 26 s.w.g. for the larger tubes and about 200 turns of 30 s.w.g. for the smaller sizes.

Construction

The three degaussing components can be mounted on a tag strip centrally located on the bottom, back of the magnetic shield. Five insulated points are required so with the two mounting points a seven-way strip is required. This can be cut from a larger strip such as the 28-way standard strip marketed by RS Components.

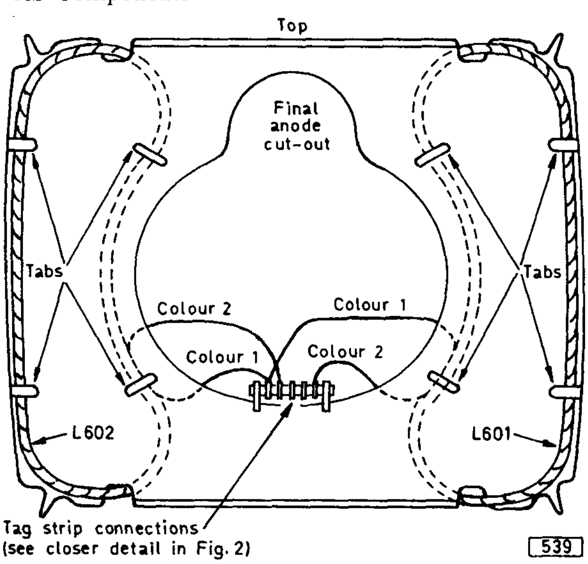


Fig. 3: Rear view showing the degaussing coils mounted on the c.r.t. magnetic shield.

Although the coils can be home-wound it is a fatiguing task and a mandrel of the right diameter for winding them has to be constructed. The wound sections then have to be wrapped in insulation and the end wires colour coded and sleeved.

The supplier listed can supply the coils, v.d.r., thermistor, resistor and tagstrip at reasonable cost. The colour coding used may differ with coils from different sources but one of the colours always indicates the start of the winding and the other the finish. The connections of the colours on the tag strip should be carefully noted: it is immaterial whether colour 1 is the start or the finish of a winding.

For series aiding coils the start (say colour 2) of the winding of L601 must finish as colour 1 and go straight to the *finish* of the winding of L602 (colour 1 again): the *start* of L602 is then the other terminal point. It might be thought that for series aiding coils the finish of one coil should connect to the start of the next. This however would only be so if both coils were on the same side of the tube: in our arrangement the coils are on opposite sides of the tube and the coils themselves must be "antiphase" connected to get series aiding effects.

In most colour receivers the magnetic shield is chassis connected—i.e. to the neutral of the mains supply. In our receiver we have a separate mains earth connection of course and *under no circumstances* should either 7A or 7B on the tag strip be earthed.

The coils are mounted partly inside and partly outside the magnetic shield: Fig. 3 shows the general arrangement quite clearly. Four metal tabs hold the coils securely in place on each side. Note that the top of the magnetic shield is where the final anode cut-out is shaped from the central hole.

The four tabs around the central aperture should be pushed through from the back using a screwdriver. The coils should then be slung over the corners of the shield so that the connecting leads fall inside near the bottom tabs. If all looks OK bend over the outer tabs to secure the vertical runs of the coils, straighten out the coils on the outer edges and then secure the inner runs behind the inner tabs. The shape of the inner sections should follow as closely as possible that shown in the diagram. The mounting is not difficult but you will probably find yourself a little ham-fisted if you have never mounted a set before. Don't press the tabs down excessively on the coils—finger pressure is quite sufficient. Be sure to mount the coils with the identification colours the right way round.

Not too much connecting lead length should be left hanging inside the magnetic shield: cut back to the coils as far as possible to make tidy connections to the tag strip. The samples of ready-wound coils that we have seen have all used self-fluxing enamel wire—this can be identified by its slightly redder colour than is normal with enamel wire. If the wire is self-fluxing it can be soldered directly to the tag strip by application of heat and solder. If the wire is normal enamel finished it must of course be cleaned off before tinning and soldering.

Finally we would like to have gone farther this month. The amount of other business to which the author has to devote time, a shortened production schedule this month because of the Christmas

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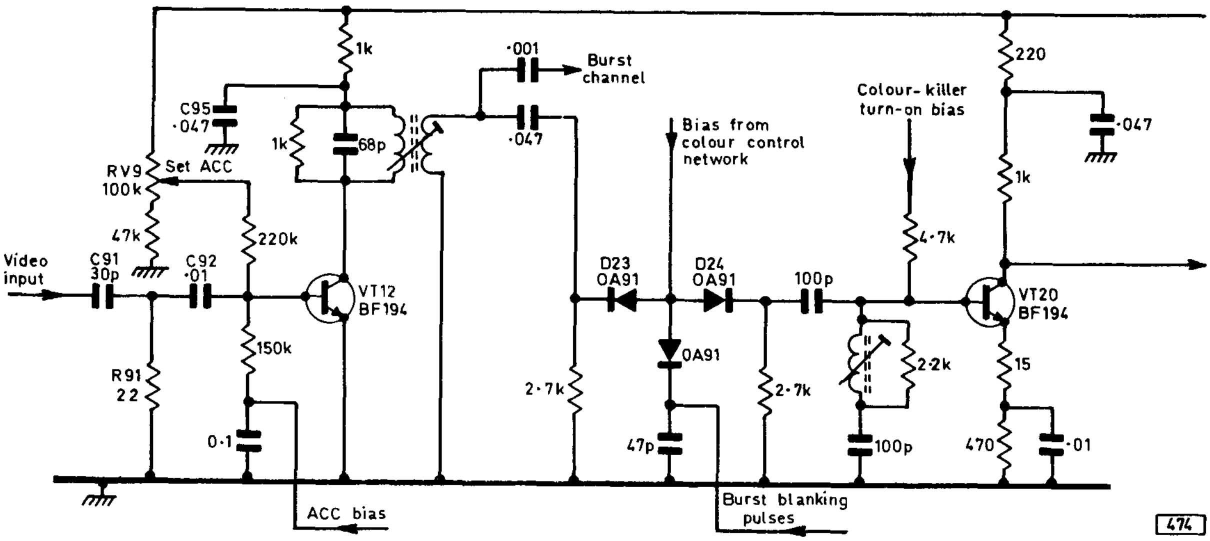

Fig. 1: First two stages in the chrominance channel, Pye group 691 chassis.

decided to check these diodes. Both proved to be OK. There are several other small diodes on the decoder panel, all concerned with providing biasing potentials or used for blanking purposes, so we decided to check them over: all had excellent forward/reverse resistance ratios.

There are three stages in the chrominance amplifier channel but in view of the occasional colour drop-out on BBC-1, likely to be due to inadequate bias on the first, gain-controlled stage (VT12), we decided to concentrate on this. The voltage readings obtained were markedly incorrect but all resistors in the stage were found to be well within tolerance. It appeared therefore that one of the capacitors must be practically open-circuit or of greatly changed value. As the emitter is connected direct to chassis our next move was to try the effect of shunting a replacement across the decoupler C95 in the collector circuit. This produced no improvement so it seemed that either C91, the 30pF high-pass (with R91) filter capacitor, or the 0.01μF coupler C92 in the base circuit was defective. On the basis that even a small reduction in the value of of C91 would have a more adverse effect than even a large reduction in the value of C92 we replaced C91 and obtained a really strong colour signal.

Occasional Field Slip

VERY good results were obtained with an old 17in. Invicta model fitted with a new tube—there are still plenty of "seventeens" in service—but the picture occasionally dropped a frame. This we found was due to the field hold control being at one end of its travel and still not in the centre of its locking position. A new ECC82 field oscillator valve shifted the locking position well away from the end so that it was possible to make the picture roll in both directions of control rotation. A week or so later however the same fault reappeared, the hold control once more having to be set to one extreme. Obviously a component in the field generator circuit was changing value and as it can generally be assumed that a resistor is the cause of such trouble we cleaned up all those surrounding the ECC82. We discovered that one, which proved to be the anode load resistor of one of the triodes, was very badly discoloured. It was impossible to decipher the colour coding and as we hadn't a manual for this old model we removed the resistor, placed the hold control in its centre position and tried various resistors until we obtained lock. After fitting the replacement resistor no further trouble was experienced.

COLOUR RECEIVER PROJECT

—*continued from page 175*

holiday and loss of editorial time in dealing with a number of non-recurring (we hope) problems have however made this impossible.

Component Pack 19

VA8650 thermistor, v.d.r., 680Ω resistor, tag strip and pair of 50Ω (total) degaussing coils (state tube size).

Supplier: Manor Supplies, 172 West End Lane, London, N.W.6. Price £2.30 including post and packing. Shop price to callers is reduced appropriately. Pack also available from Forgestone Components, Ketteringham, Wymondham, Norfolk.

Correction

Despite checking by several people the author's original convergence board drawings were incorrectly transposed on to the final drawings, one pair of mounting holes on reference line 2 being misplaced by 0.4in. Unfortunately movement of just one hole cannot be made because either 5U or 5X will be fouled. The answer is to move the hole on board 2 $\frac{7}{8}$in. away from its longer edge and that on board 3 $1\frac{1}{4}$in. away from its shorter edge. We do apologise for this error.

Power supply board size is $8\frac{1}{4}$in. × $8\frac{1}{4}$in.