

control as shown is a total of 6 dB on either channel.

This second stage is preceded by the selector switch, and the gain control. The positioning of the gain control at this point is dictated by the need to avoid overloading of the second stage, which would occur if the control were placed after the second stage.

The selector switch connects the auxiliary, and radio inputs direct to the gain control, with a resultant sensitivity of approximately 20 mV for full output (with the 8- Ω version of the power amplifier) of 560 mV r.m.s. Overload occurs at approximately 2 V r.m.s., taking the form of almost symmetrical clipping. Any attenuators used to match this sensitivity to that of

the source should preferably not cause the gain control to be fed by a source of greater than 10 k Ω in order to preserve the very good noise level of the pre-amplifier.

The mono/stereo switch connects the inputs to the gain control in parallel when required.

The instability at first encountered with the CA3048, due to its very high gain-bandwidth product, was at first a problem in the second stage. A complete cure was found in connecting a 330-pF capacitor between slider and lower end of each gain control, together with the additional precaution of a screened lead at this point. The h.f. cut-off produced by this capacitor is well above the audio band, but is effective

in reducing the gain at r.f., and also acts as one arm of a capacitive attenuator to any pick-up on this second stage input.

Tone controls

The passive tone control of the original circuit not only degraded the noise figure of the pre-amplifier by 20 dB but also proved to be a difficult one with which to obtain consistent results, there being a considerable tendency for the cut-off frequencies to change with control settings.

The active 'Baxandall' circuit adopted does not suffer from any of these side effects. The nominal 'flat' gain of the circuit is unity since there is no need of further gain, especially as the gain of the second stage has already had to be reduced to account for the removal of the 20-dB gain loss of the passive tone control network.

An additional capacitor of 470 pF is added directly between base and collector of the tone-control stage in order to limit the gain at frequencies above the audio band. The value chosen gives a cut of -0.6 dB at 10 kHz, and -2 dB at 20 kHz, in the flat position of the controls. The purpose of the cut at h.f. is to help to ensure that the power amplifier does not get any appreciable input at frequencies where its power handling is restricted. With an input from discs only, this is not a likely problem, but with tape and radio inputs there are possibilities of higher levels of input above the audio range. Some readers may think the cut is at too low a frequency, and may desire to reduce this capacitor; a value reduction to 220 pF is certainly in order, but it should not be eliminated as it assists in ensuring h.f. stability of the whole pre-amplifier.

Some readers may prefer the use of switched tone controls in which case each of the 2-gang 100-k Ω controls may be

Fig. 2. Circuit of one section of CA3048 and layout of 16-pin package. All four amplifier sections are identical.

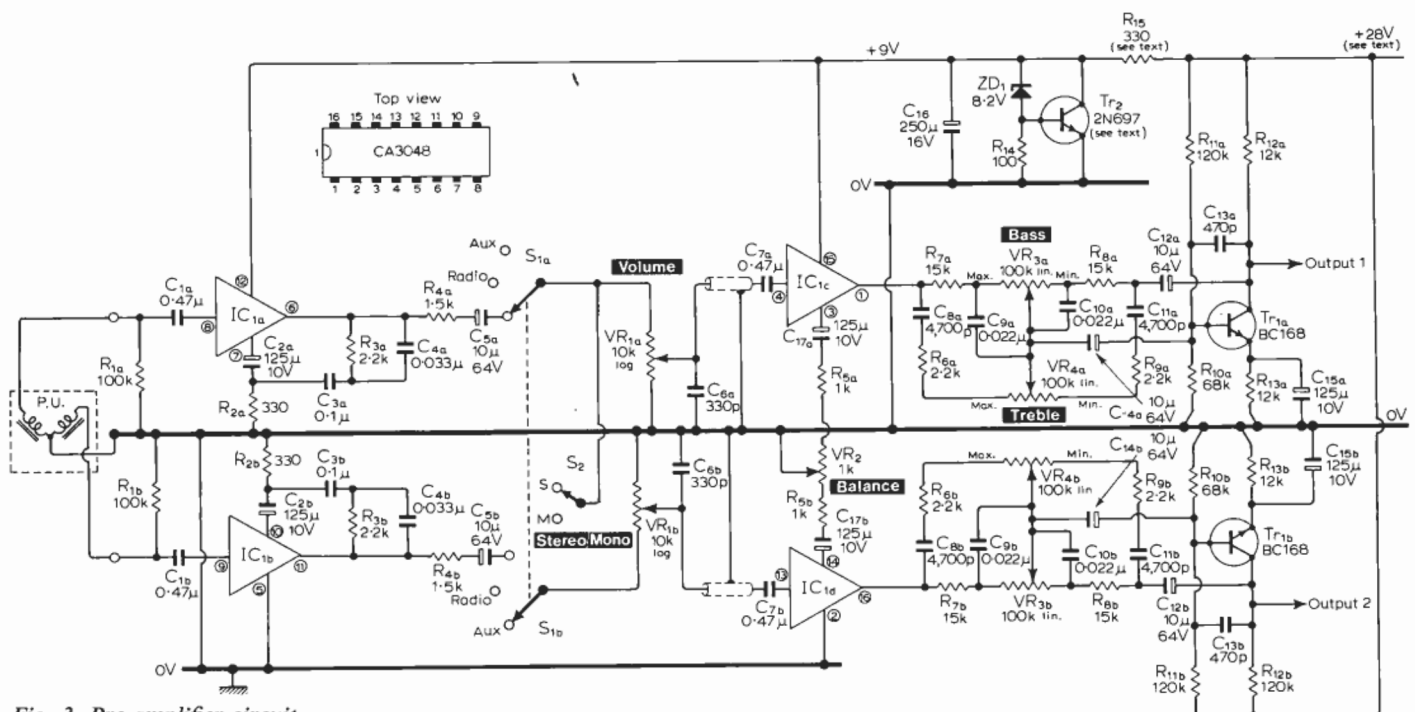
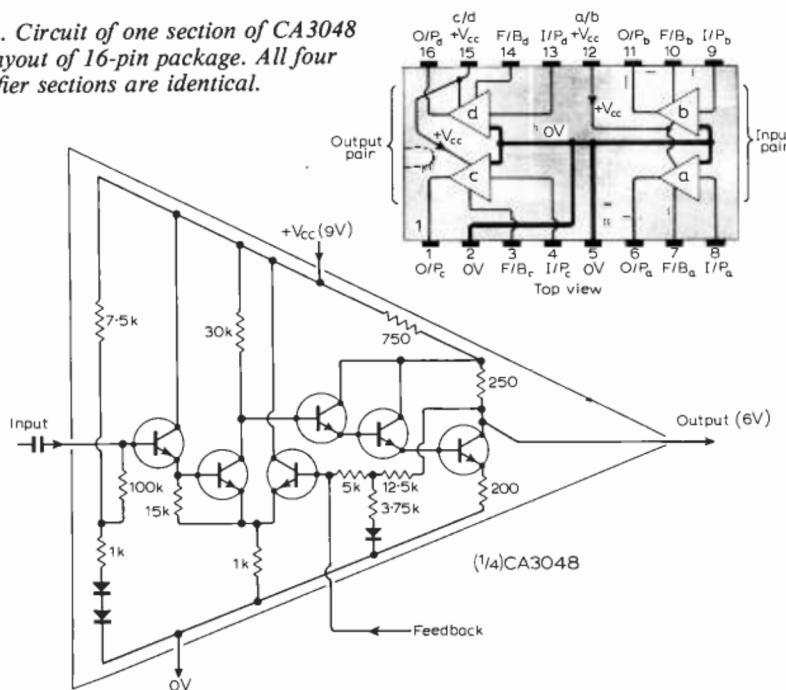


Fig. 3. Pre-amplifier circuit.

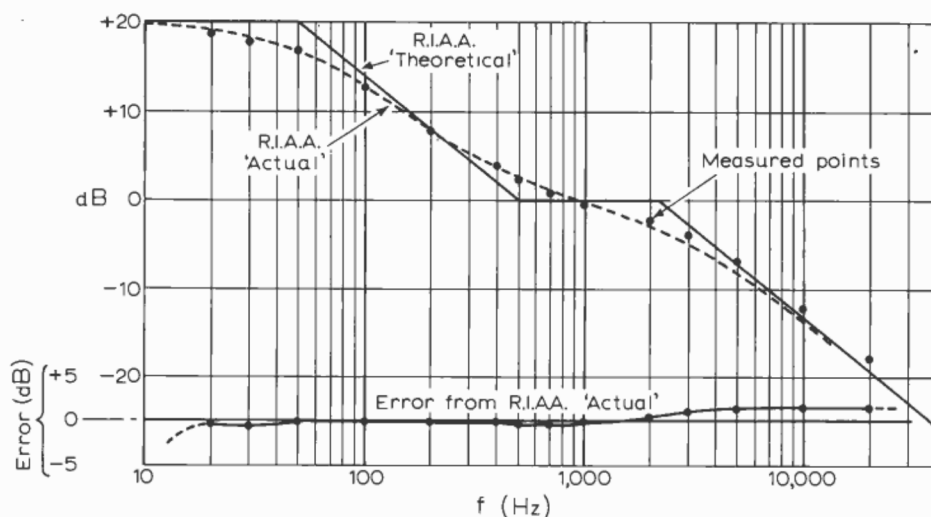


Fig. 4. Input stage R.I.A.A. equalization (tone controls flat).

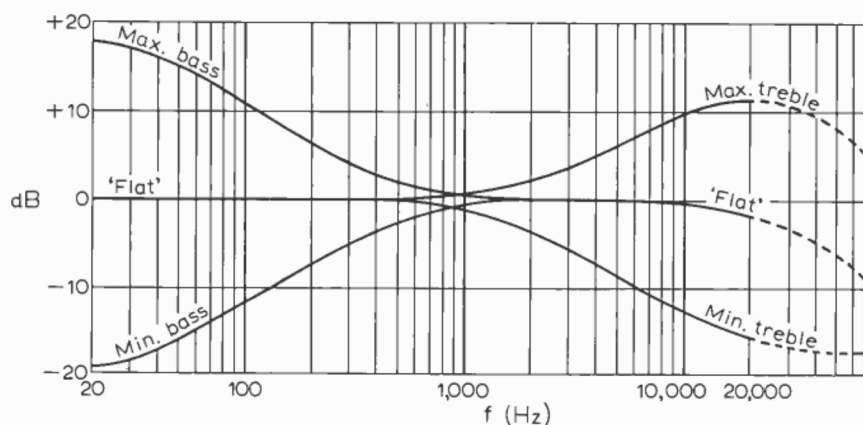


Fig. 5. Tone-control characteristics.

replaced by a 2-pole 7-way switch having six 16-k Ω resistors to each bank, or a 2-pole 9-way switch with eight 12-k Ω resistors.

Noise performance

The main source of wideband noise in the pre-amplifier is the second stage. The first stage contributes little as it has such a narrow bandwidth due to the R.I.A.A.

equalization network. The contribution of the input stage is almost entirely $1/f$ noise which is at a commendably low level and is in any case not particularly audible in practice.

In practice the result is a unit producing no audible hum or noise at any normal setting of the gain control or tone controls. With the gain control set so that peak power reaches 10 watts on a loud recording (5 cm/s at 1 kHz on disc) and with bass and

treble both at maximum (which is the worst case to be met in practice) there is still no audible noise 6 feet from both speakers (which are large units of good sensitivity), and only a very faint hum and hiss can be heard close to the speaker. These excellent results are confirmed by the measurements:

- (a) Unweighted hum and noise with gain set for 10W into 8 Ω (7 mV at 1 kHz from pickup) -63.5 dB, rel. 10W
- (b) Wideband noise alone (less hum and $1/f$) approx -80 dB, rel. 10W
- (c) Unweighted hum and noise at normal listening level (approx. 50 mW average power, 1-2 W peak) approx. -72.4 dB, rel. 10W

This last figure remains fairly constant for all lesser settings of the gain control, and represents the basic noise of the second stage and succeeding stages. The higher level of the first unweighted noise figure is largely due to hum from the windings of the pickup cartridge and $1/f$ noise from the first stage—both of which are of low audibility.

9-volt regulator

The integrated circuit requires a lower voltage supply than that available from the power amplifier. To protect the i.c. in the event of circuit failure, a simple shunt regulator was designed. This type of regulator also ensures freedom from voltage surges at switch-on, and switch-off. An incidental advantage of the use of such a regulator, together with its by-pass capacitor, is a very low cross talk figure for the pre-amplifier between channels. The original circuit² used decoupling for the supply to the first stage, but with the low level of ripple, and the low impedance of the supply from this regulator, a better performance is obtained without decoupling to this stage.

The TO-5 transistor of the regulator may be any type having a current gain of over 30 at 50mA, and it should be fitted with a heat-sink as the dissipation is approximately 500 mW.

Constructional details

The underside view of the prototype pre-amplifier is shown in Figs. 6 and 7. The CA3048 was mounted on a perforated bakelite 'pin-board' with fine tinned copper links soldered to 16 pins located in two rows on each side of the package. Layout should be kept simple, but is not critical provided reasonable precautions are taken to keep input and output leads separate. The whole assembly should be well screened, and mains leads, mains transformers, and the like kept as far away as possible, to minimize hum pick-up.

The two versions of the pre-amplifier built (one by the author, and one by one of his colleagues) have quite different layouts, yet give almost identical measured results.

Components

R_{1a}, R_{14} are $\frac{1}{4}$ W 10% carbon.
 R_{15} is 330 Ω 3W wirebound for 28V supply.
 (180 Ω 1W for 19.5V and 470 Ω 3W for 36V supply.)

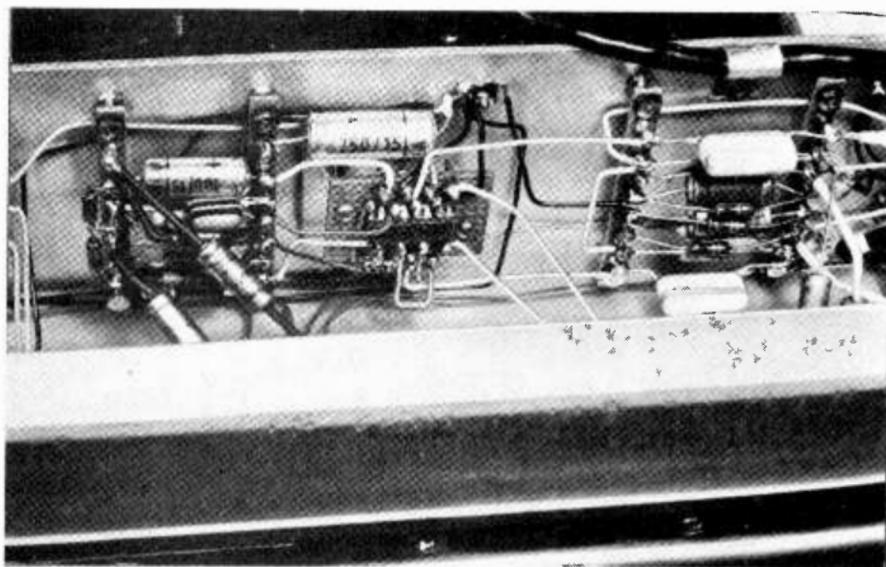


Fig. 6. Close view of the central region of the pre-amp showing the mounting of the i.c. The equalization network is to the left, the tone-control stage to the right, and the two transistors to the extreme right.

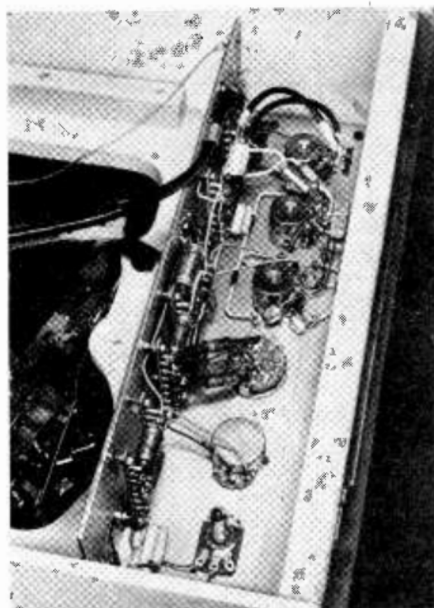


Fig. 7. View from the rear towards the front of the prototype pre-amplifier. The supply regulator is at the far end adjacent to the volume control. The tone control circuit is next, adjacent to its controls. The i.c. is at the centre, with the input stage equalization network nearest the camera.

All other resistors are $\frac{1}{4}$ W 5% 'Histab' carbon or 2% $\frac{1}{4}$ W metal oxide, the latter being preferable.

$C_{1a,b}, C_{3a,b}, C_{4a,b}, C_{7a,b}, C_{9a,b}, C_{10a,b}$ are all polyester types such as Mullard C280AE or C296AA/A. Capacitor 'a' should be matched to capacitor 'b' within 5% in each case.

(Matching is essential for C_3, C_4, C_9 & C_{10} , but not absolutely essential for C_1 & C_7 .)

$C_{8a,b}, C_{11a,b}$ & $C_{13a,b}$ are polystyrene $2\frac{1}{2}$ % tolerance.

C_{16} is 250 μ F 16V Mullard C437AR/E/250 or similar.

All the remainder may be Mullard C426 types or similar.

$VR_{1a,b}$ is 10 k + 10 k log stereo potentiometer (2 dB match).

$VR_{3a,b}, VR_{4a,b}$ are 100 k + 100 k in stereo pots (2 dB match). All these twin gang pots. are Radiospares 'Tandem' types.

VR_2 is 1 k Ω in carbon or wirewound.

$S_{1a,b}$ is 3-way 2-pole (prototype uses Radiospares midjet wavechange switch 3-way 4-pole).

S_2 is miniature rotary type Radiospares 'Changeover SP'.

I.C.₁ is R.C.A. CA3048 (CA3052 may also be used with a slightly worse noise figure, but is cheaper).

$Tr_{1a,b}$ are BC108, BC168, etc. (for the 36-volt version BC107B or 167B would be advisable).

Tr_2 any good TO-5 n-p-n transistor such as 2N697, 2N1613, 2N3053, etc.

Tr_2 is fitted with a heat radiator Redpoint 5F.

ZD_1 is 8.2V, 250mW, zener diode. Mullard BZY 88-C8V2, Texas 1S2082A, Radiospares MZ-E8.2V etc.

Mainline Electronics Ltd., Thames Avenue, Windsor Berks, are suppliers of

the R.C.A. devices, and Electrovalue and Radiospares the majority of the other components.

Suitable Cartridges

The pre-amplifier has been designed with the use of a high compliance magnetic cartridge in mind. Most of the magnetic cartridges listed in the recent *Wireless World* summary³ are suitable. The sensitivity of the pre-amp. is sufficient to allow for the use of the least sensitive, and the overload limit is high enough to allow for the most sensitive in this range.

I am grateful to my colleague Mr. A. Cullen for the use of the results from

his version of this equipment which have been incorporated in this article, and for his co-operation throughout.

I am also grateful to R.C.A. (Gt. Britain) Ltd, for their help with the supply of very full data on the integrated circuit used.

REFERENCES

1. L. Nelson-Jones, "Ultra-low Distortion Class-A Amplifier", *Wireless World*, March 1970.
2. "Microelectronics at Paris Components Show", *Wireless World*, May 1969.
3. S. Kelly, "Stereo Gramophone Pickups", *Wireless World*, December 1969.

Computer Graphics

Recently the Univac Division of Sperry Rand Ltd produced several striking multicolour designs using their computers and graphic display consoles. Our front cover this month is an example of one of these. Shapes, which can be distinguished on the picture—squares, triangles, lines and points—were randomly programmed into the computer with no attempt to give them a definite pattern of movement. The tumbling shapes were shown on a graphic display and photographed through several different coloured filters—green and white in the case of our front cover.

A graphic display, one capable of showing engineering drawings, maps etc., is much more complex than the now familiar alphanumeric displays. According to Univac the development of graphic display terminals lags behind that of alphanumeric displays by between three to five years.

Cathode ray tubes are used for both types of display although these will probably be superseded by the laser, or one of the other competing devices, in about five years.

Drawings on graphic displays can be made by causing the c.r.t. electron beam to move between one previously defined point to another such point on the c.r.t. face in a straight line. Curves are simulated using a series of very short straight lines. A graphic display with a c.r.t. with a usable display area of 350 ×

350mm (12 × 12 inches) may have a million precisely defined points on which the beam can be positioned. The million points would be determined by electronics which allow the beam to be positioned at any of 1000 positions in the X direction and at any one of a 1000 positions in the Y direction. The electronics would also allow the beam to move in a straight line between a point on the screen defined by a certain value of X and Y to another point specified by a different value of X and Y.

In normal practice the values of X and Y are fed to the display in binary form from a suitable digital processing equipment.

Often, also under digital control, the brightness of the display can be altered to one of a number of predetermined values. Shapes which are often used can be held in a memory, as subsequent values of X and Y, for use when required.

The computer and the display electronics have to work together to handle the formidable amount of data needed to produce even a simple drawing on the screen and must be flexible enough to allow the drawing to be altered at will.

The recent rapid advances in m.o.s. integrated circuitry is having a marked effect on display design as apart from the control logic and character generation circuits, m.o.s. shift registers are replacing other forms of storage in display equipments.