THE PW 'WINTON' Stereo Amplifier

Part 1

* E.A.RULE

The Winton amplifier has been designed primarily for the home constructor who would like a high fidelity amplifier equal to the best commercial design available, but at a price that enables it to be built within a sensible domestic budget, the total outlay being in the region of £110 for the complete project.

All the components are available and no special test equipment is needed for testing or setting up. The amplifier uses the very latest techniques and is capable of a standard of performance at least equal to the best commercial designs available with similar power ratings. In some aspects of its design it will outperform other amplifiers costing very much more.

Power f.e.t.s are used in the output stage and allow a wider power-bandwidth response with lower distortion than could be obtained if conventional bipolar output transistors were used. In the control unit section, bi-f.e.t. op.amps are used. These have an improved slew rate over the more common types, as well as much lower distortion. In the disc (magnetic) pre-amplifier, a three stage circuit using ultra low noise transistors enables noise figures of −68dB *unweighted* relative to 50W output to be obtained, with distortion so low that the input (normally 3mV) has to be increased to 140mV (+33dB) before the distortion even reaches 0·1%. A full circuit description will be given later.

On the front panel the Winton amplifier has controls for Volume, Balance, Bass, Treble and push buttons for selecting, Disc, Tuner, AUX 1, AUX 2, Tape monitor, Mono, h.f. and l.f. filters. Plus switches for mains on/off and loudspeaker or phones.

The headphone socket is also mounted on the front panel. DIN sockets are fitted on the rear panel for all inputs, terminals for the loudspeaker connections, an earth terminal, and fuse for the mains and each loudspeaker output. The heat sinks for the power f.e.t.s are also mounted on the rear panel.

Power f.e.t.s

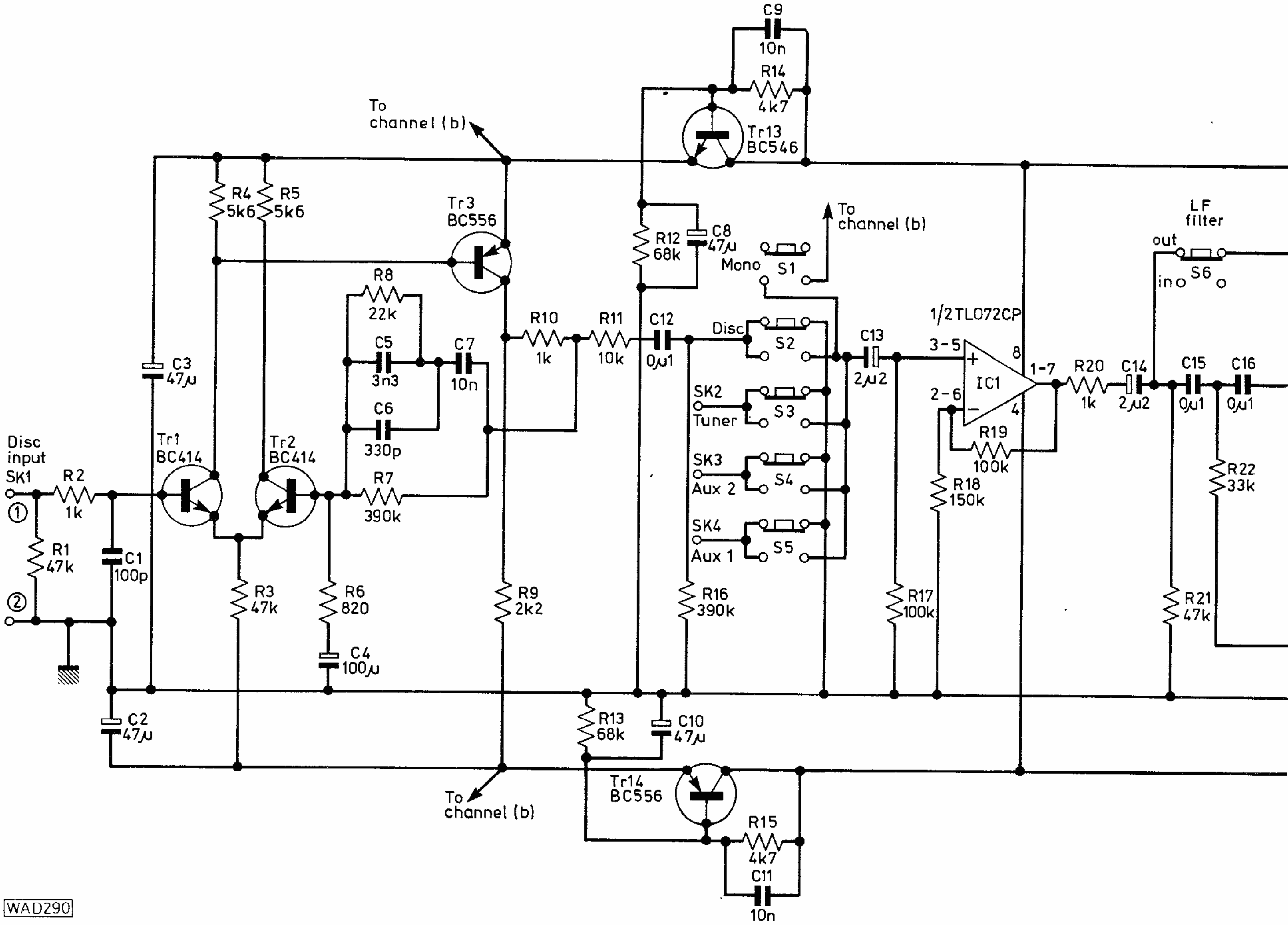
Until recently bipolar transistors have been used in almost every Hi-Fi available (the exceptions using valves). Bipolar transistors require a wide area of Safe Operation to achieve reliability and a large gain-bandwidth product so that large amounts of negative feedback can be used at the higher audio frequencies to reduce the distortion. They also have a positive temperature coefficient which means that any increase in transistor temperature causes an increase in transistor collector current which causes the temperature to increase further, and so on requiring careful design to avoid thermal runaway. Also, as bipolar transistors are minority carrier devices, they suffer from storage effects at high frequencies which can cause a most objectionable distortion, which may well account for the so called "transistor sound".

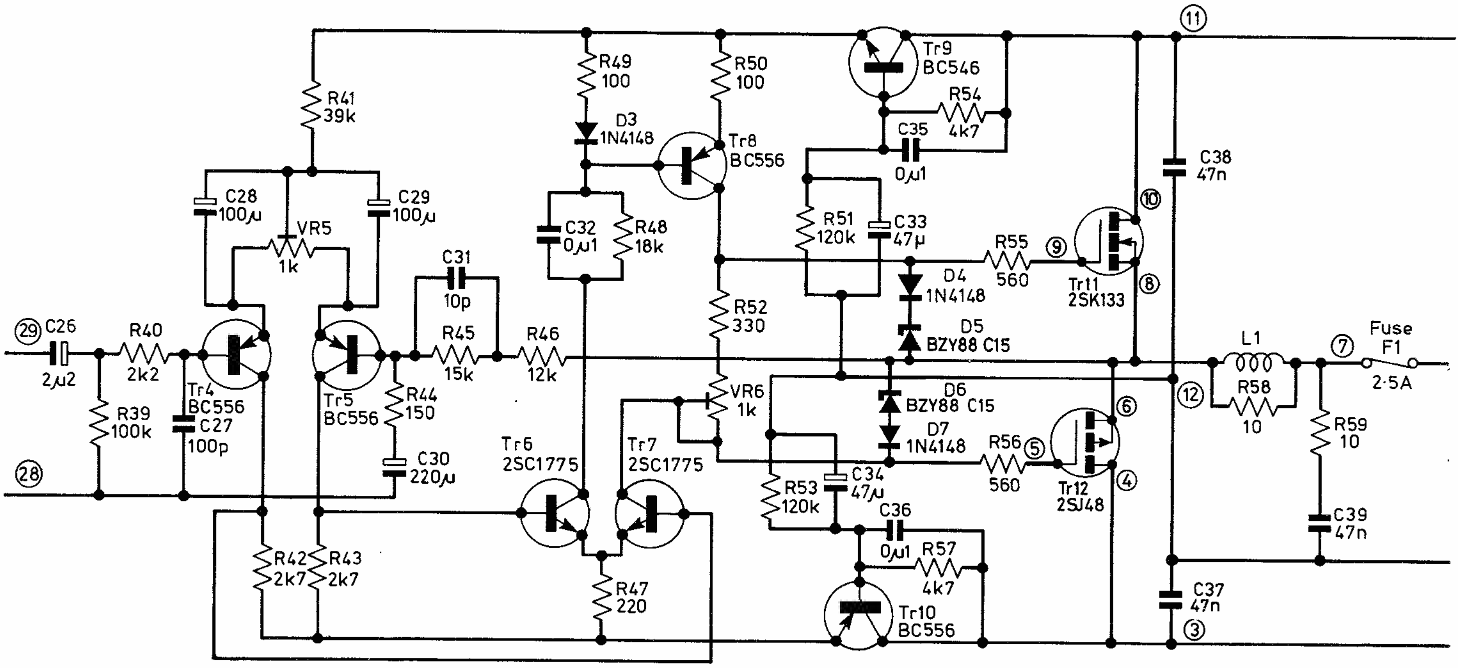
In the light of all these problems a considerable amount of money and research has gone into looking for a better device. One result of this has been the power f.e.t.s developed by Hitachi Ltd., of Tokyo, Japan. Some advantages over conventional transistors are:

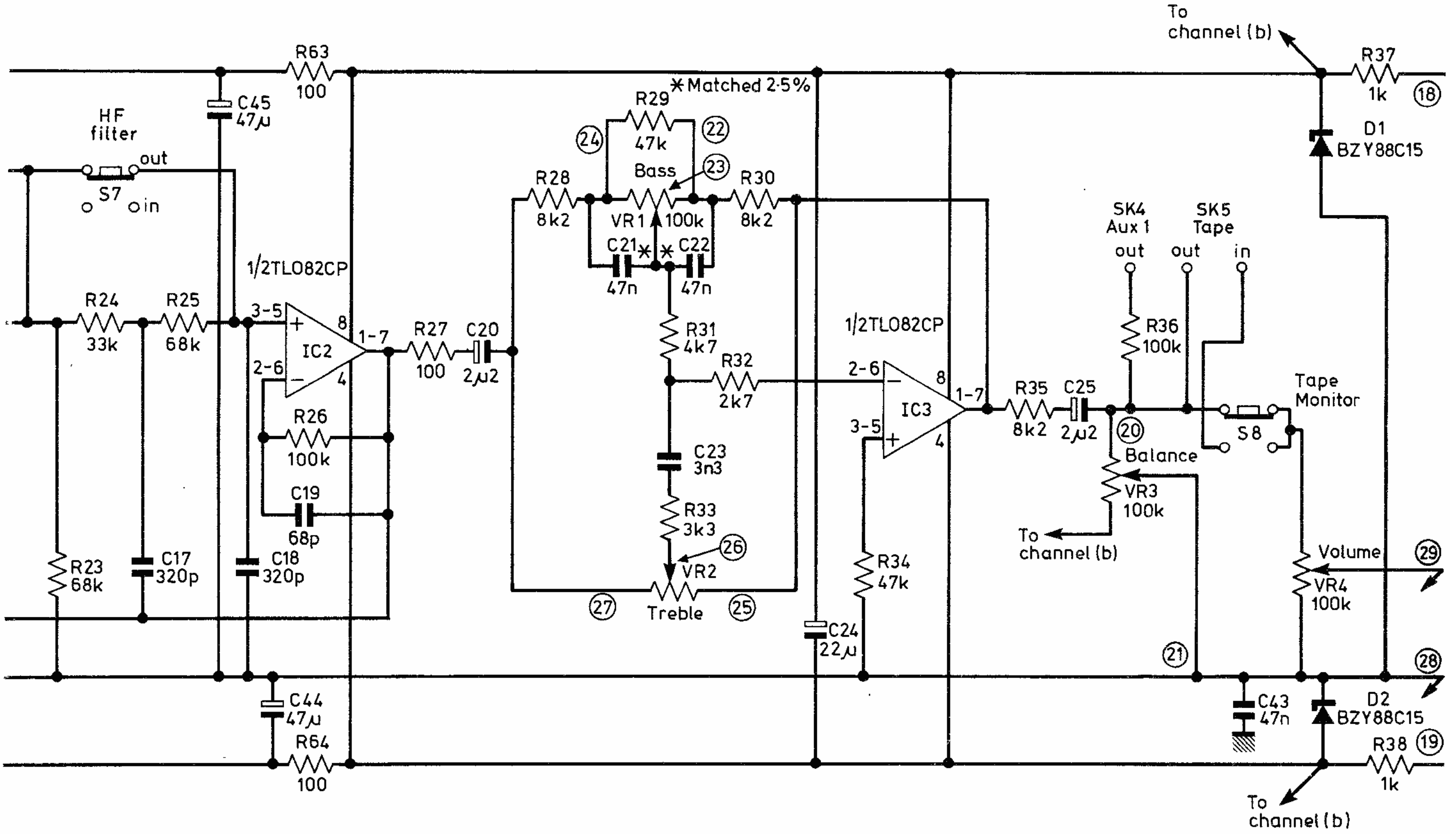
1) Good frequency response because of fast carrier speed.
2) No storage effect.
3) Negative temperature coefficients, so no risk of thermal runaway.
4) No secondary breakdown.
5) High input impedance and high gain.

The Winton amplifier uses a complementary pair of Hitachi power f.e.t.s Type 2SJ48 (*p*-channel) and 2SK133 (*n*-channel). These devices have a maximum dissipation rating of 100W each, so when used in an amplifier of 50W output, each device is only dissipating about 25W, or just ticking over! In fact combined with a 120V drain to source breakdown voltage and a drain current of 7A they are almost indestructible when used in the Winton, which

* T & T Electronics


C9 10n
R14 4k7
Tr13 BC546
To channel (b)
R4 5k6
R5 5k6
Tr3 BC556
R12 68k
C8 47µ
To channel (b)
Mono
S1
LF filter
out
in
S6
R8 22k
R10 1k
R11 10k
C12 0µ1
Disc
S2
C13 2µ2
1/2TL072CP
3-5
8
1-7
R20 1k
C14 2µ2
C15 0µ1
C16 0µ1
C3 47µ
C5 3n3
C7 10n
IC1
2-6
4
C6 330p
SK2 Tuner
S3
R19 100k
Disc input SK1
Tr1 BC414
Tr2 BC414
R2 1k
R7 390k
SK3 Aux 2
S4
R18 150k
R22 33k
SK4 Aux 1
S5
R1 47k
C1 100p
R3 47k
R6 820
R9 2k2
R16 390k
R17 100k
R21 47k
C4 100µ
C2 47µ
R13 68k
C10 47µ
Tr14 BC556
To channel (b)
R15 4k7
C11 10n
WAD290


11
R49 100
R50 100
Tr9 BC546
R41 39k
D3 1N4148
R54 4k7
Tr8 BC556
C35 0µ1
C38 47n
C28 100µ
C29 100µ
VR5 1k
C32 0µ1
R48 18k
R51 120k
C33 47µ
R55 560
10
9
Tr11 2SK133
8
C31 10p
D4 1N4148
R52 330
D5 BZY88 C15
29
C26 2µ2
R40 2k2
R45 15k
R46 12k
L1
Fuse F1
7
2·5A
Tr4 BC556
Tr5 BC556
R44 150
VR6 1k
D6 BZY88 C15
12
R58 10
R39 100k
C27 100p
D7 1N4148
R56 560
6
5
R59 10
Tr6 2SC1775
Tr7 2SC1775
C30 220µ
R53 120k
C34 47µ
Tr12 2SJ48
4
28
C36 0µ1
R57 4k7
C39 47n
R42 2k7
R43 2k7
R47 220
Tr10 BC556
C37 47n
3



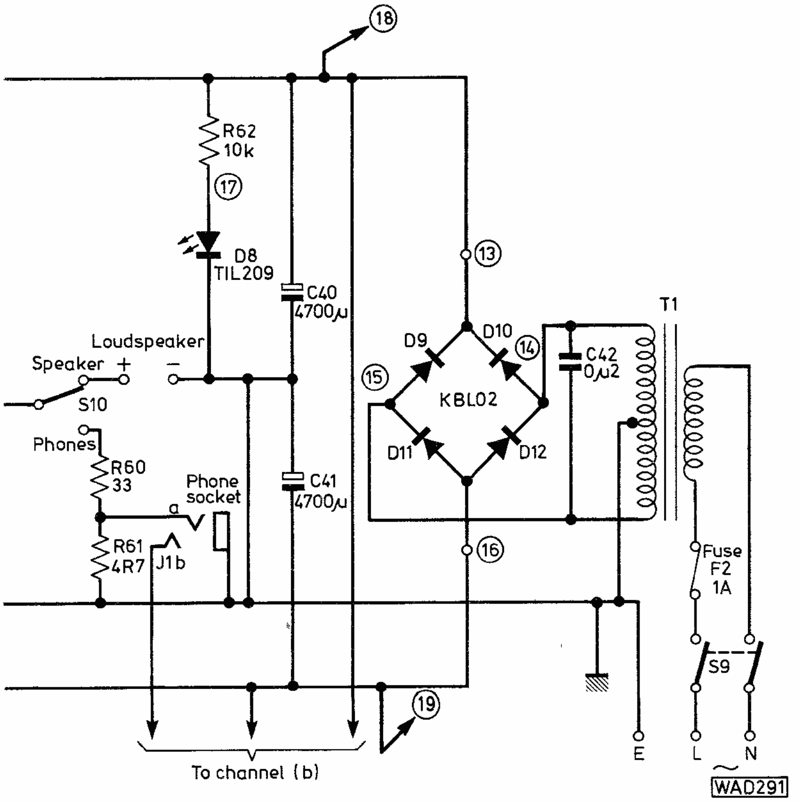


Fig. 1: Circuit diagram of the PW "Winton" stereo amplifier, showing Channel "a" (left) only. The following components are shared between the two channels: R12–15, 37, 38, 62–64; C2, 3, 8–11, 24, 40–45; Tr13, 14; IC1–3; D1, 2, 8–12; VR3; T1; F2; S9. The remainder are duplicated for the other channel

★ specification

Power Output
Continuous sine wave power, both channels driven
50 + 50W into 8Ω

Power Bandwidth *(power amp. only)*
−1dB 15Hz −100kHz

Frequency Response *(power amp. only)*
−0·5dB   10Hz – 40kHz
−3dB   5Hz – 150kHz

Harmonic Distortion *(50 + 50W)*
1kHz 0·013%
10kHz 0·015%
20kHz 0·018%
100Hz 0·011%
20Hz 0·019%
No significant increase at lower powers

Intermodulation Distortion *(28V pk into 8Ω)*
$f_1 = 15$kHz $2f_1 - f_2$ 0·005%
$f_2 = 16$kHz $2f_2 - f_1$ 0·004%
$f_2 - f_1$ 0·003%

Damping Factor
20Hz — 1kHz   80
20kHz   20

Rise Time *(power amp. only)* 2μs

Slew Rate *(power amp. only)* 26V/μs

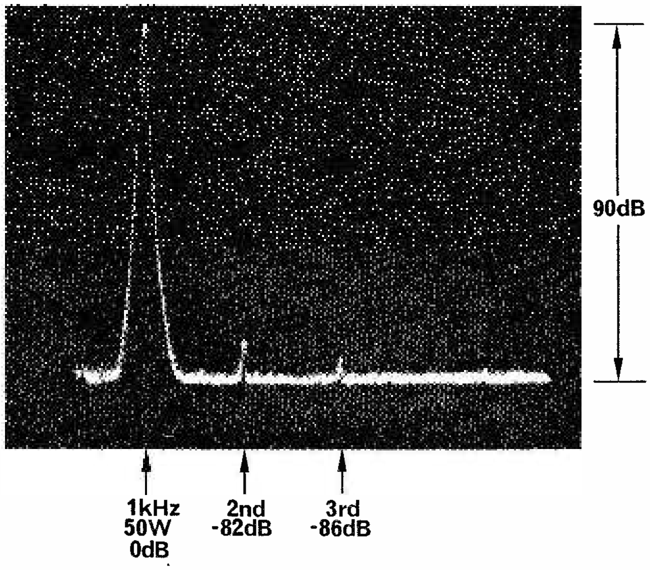
Stability – Unconditional

Sensitivity *for 50W*
Disc 3mV
Tuner 100mV
AUX 100mV
Tape 100mV

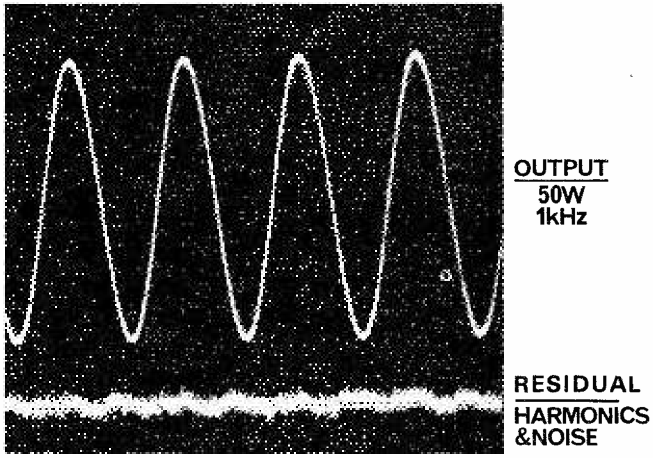
Input Impedance
Disc 47kΩ
Tuner 100kΩ
AUX 100kΩ
Tape 100kΩ

Maximum Input *for 0·1% t.h.d.*
Disc 140mV
Tuner 4V
AUX 4V

Frequency Response ±0·5dB
Disc RIAA
Tuner 20Hz–20kHz
AUX 20Hz–20kHz
Tape 10Hz–40kHz

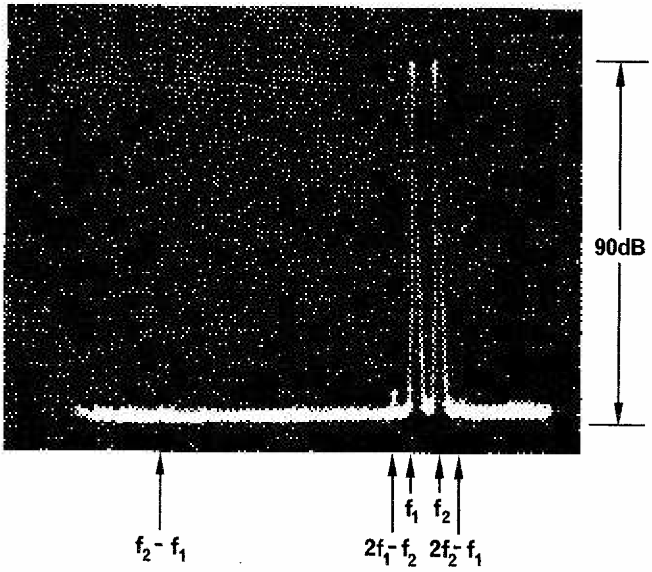


Plot of Harmonic Distortion components generated when handling a 1kHz signal dissipating 50W in an 8Ω load. The 2nd harmonic is at −82dB and the 3rd harmonic −86dB relative to the fundamental



The upper trace shows the *PW* "Winton" output when handling a 1kHz signal dissipating 50W in an 8Ω load. Note the complete absence of crossover distortion

The lower trace shows the residual harmonic content of the above signal, after the fundamental had been removed by the distortion meter filter. The total harmonic distortion is about −78dB, but is masked by noise



Plot of Intermodulation Distortion components generated when driven to full power into an 8Ω load by two equal-amplitude signals, f_1 = 15kHz, f_2 = 16kHz. Component $2f_1 - f_2$ is at −86dB, $2f_2 - f_1$ at −88dB, and $f_2 - f_1$ estimated at about −90dB

This test, using these frequencies, is very critical of the power-bandwidth capability of an amplifier, and is seldom given in specifications due to the generally poor figures obtained

Hum & Noise
Unweighted with reference to rated sensitivity*
Disc −70dB
Tuner −75dB
AUX −75dB
Tape −75dB

Hum & Noise
Disc input with reference to 10mV input
Unweighted 80·5dB

Cross Talk** −48dB

Tape Output 100mV
AUX 1 100mV via 100kΩ

* *See comments regarding specifications.*
** *Important to note that cross talk residual is clean, i.e., does not introduce distortion into the other channel—a common failing in many amplifiers and seldom mentioned.*

Tone Controls
Bass ±10dB at 100Hz
Treble ±10dB at 10kHz

Balance Control
+0·5dB to zero, each channel

Channel Matching 0·5dB

Filters

l.f. −3dB 50Hz	12dB/Octave
h.f. −3dB 5kHz	12dB/Octave

Subsonic, disc only, non-switchable

(IEC 65) −3dB	20Hz
−8dB	10Hz
−17dB	5Hz

Ultrasonic, all inputs except tape, non-switchable

−3dB	60kHz
−7dB	100kHz

Before making any measurements, the amplifier was pre-conditioned for 1 hour at 30% full power with both channels driven. Measurements were made after a further 5 minutes at full power.
Unless otherwise stated, the volume control was at maximum, tone controls at centre and filters switched out.
The stability tests were made using various combinations of loads with capacitors up to 2μF and also with capacitors up to 2μF without additional load. Square wave signals were used over a frequency range of 20Hz to 20kHz.
The figures given are those obtained on the prototype amplifier.

Test Equipment
Hewlett Packard HP3580 spectrum analyser; *Kron-Hite* 4100 low distortion oscillator; *Sound Technology* 1700B distortion analyser, power output meter and low distortion oscillator; *Telequipment* D83 oscilloscope; *Polaroid* oscilloscope camera.
This equipment was kindly made available by *Armstrong Audio Ltd.*, at their research laboratory.

General Comment
Be very careful when comparing specifications of other amplifiers with the Winton. Many other published specifications use a weighted signal to noise figure. This would allow an extra 10dB or so to be added to their figures and tends to favour the poorer quality amplifiers at the expense of the really good amplifiers.

means that the circuit can be kept simple as no protection circuits are required, eliminating another source of distortion.

The Bi-f.e.t. Op.amps

The use of the Texas bi-f.e.t.s in the control unit section offers a number of advantages over the more usual 741 type of op.amp. The main ones being:

1) Wider bandwidth. 3MHz typical.
2) High slew rate 13V/µs.
3) Low distortion 0·01%.
4) High input impedance j.f.e.t. input stage.
5) Low noise 18nV/Hz (TL072CP).
6) 80dB supply ripple rejection.

When used in low or unity gain circuits using large amounts of negative feedback the noise and distortion from the device is almost unmeasurable. The Winton amplifier has a basic sensitivity at the AUX inputs of 100mV and this has to be increased to 4V before the distortion reaches 0·1%. At any normally used input level the distortion is below the noise and completely inaudible.

Circuit Description

Both channels are identical and are pre-fixed "a" for left and "b" for right. Only the "a" channel will be described. See Fig. 1.

The Disc Pre-Amplifier

The input from a magnetic cartridge is fed into the base of Tr1, a low noise BC414 via the input load R1, 47kΩ, and an r.f. filter R2 C1. The transistor Tr1 forms one half of a differential input pair. Operating at a low current, approximately 100µA each half, ensures the minimum amount of noise.

The output from Tr1 is coupled directly to Tr3 a BC556. This in turn is coupled to a subsonic filter (as recommended by IEC65) consisting of C12, R16 and R17. This subsonic filter has its −3dB point at 20Hz, Fig. 2. This response, coupled with the normal RIAA response provides a 12dB/octave filter at subsonic frequencies and prevents intermodulation at low frequencies caused by warped records, etc., from being produced and affecting the overall sound quality. The RIAA negative feedback equalising circuit consists of R7, R8, C5, C7 and is connected between the output of Tr3 and the base of Tr2.

In order to ensure further the low noise factor in the disc amplifier, electronic decoupling is used, Tr13 (BC546) Tr14 (BC556) in each supply rail to remove any ripple or noise from the power supply. This supply has already been decoupled and stabilised by the Zener diodes, D1, D2.

The output from the disc pre-amplifier then goes to the selector switches S 1-5.

Control and Filter Section

From the selector switches S 1-5, each channel goes to one half of IC1 a bi-f.e.t. op.amp, Type TL072CP. This is used as a low noise buffer amplifier (with 4dB of gain) to provide a high impedance input, and a low impedance output suitable for driving the next stage, which also uses a bi-f.e.t. op.amp, Type TL082CP. This is used as an active high- (C15, C16, R22, R23) and low- (C17, C18, R24, R25) pass filter. Operating at unity gain, the filter is designed to provide a 12dB/octave cut-off with the −3dB points at 50Hz and 5kHz respectively, Fig 3. A slope of 12dB/octave is considered to be optimum for Hi-Fi use as a steeper slope could introduce ringing on transients, which would sound most objectionable.

The tone controls follow the filters, again using a bi-f.e.t. op.amp, Type TL082CP, and the circuit is a Baxandall negative feedback type.

This type of tone control circuit keeps distortion and noise to a much lower level than the passive type and also provides frequency response contours more acceptable to the ear, Fig. 4.

The amount of bass and treble boost and cut has been restricted to around + or − 10dB at 100Hz and 10kHz. Although it is possible to obtain up to 20dB boost and cut at these frequencies by removing R29 and reducing R33, extreme amounts of boost or cut are considered by the author to be bad design, as in practice large amounts can rarely be used. For example, suppose we have a signal requiring +10dB at 100Hz, with our circuit we can obtain this with only an extra dB or so at lower frequencies. If the unrestricted circuit was used, 10dB of boost at 100Hz would also produce 20dB of boost at 20Hz, as the response would continue to rise as shown in Fig. 4. The effect of this would be to increase all the rumble and other low frequencies a further 10dB over the required level at 100Hz. This would be in effect asking the amplifier for a considerable increase of power at low frequencies and as it cannot provide this, severe distortion would result. Note:

10dB of boost equals a voltage ratio of 3·16:1.

If our amplifier is already producing 50W into 8Ω, i.e., 20V, then 20V × 3·16 = 63·2V, power = $V^2 \div R$ = 3994 ÷ 8 = 499·28 watts!!

Even with the amount of boost restricted to + 10dB, if the bass control is at maximum and the amplifier is just reaching maximum power (50W) at say 20Hz then the maximum power at 1kHz must be limited to 5W (assuming a flat frequency response of the input signal). In practice, the tone controls are normally used to make up for the deficiency in the incoming signals, i.e., to restore the signal to an overall "flat" response, so the power restriction normally won't apply.

The output from the tone control circuit then passes to the balance control and the tape monitor switch S8. This switch selects either the output from the control unit section or the output from a tape recorder (connected to the tape socket) and feeds the signal via the volume control to the power amplifier. A tape output signal is permanently connected from the control unit output to both the tape socket and via 100kΩ resistors to the AUX 1 socket. This arrangement allows the use of either or both reel to reel and cassette recorders with the Winton. When using a reel to reel or cassette recorder fitted with a monitor head (plugged into the "tape" socket) tape monitoring can be achieved by simply pressing the "tape" button.

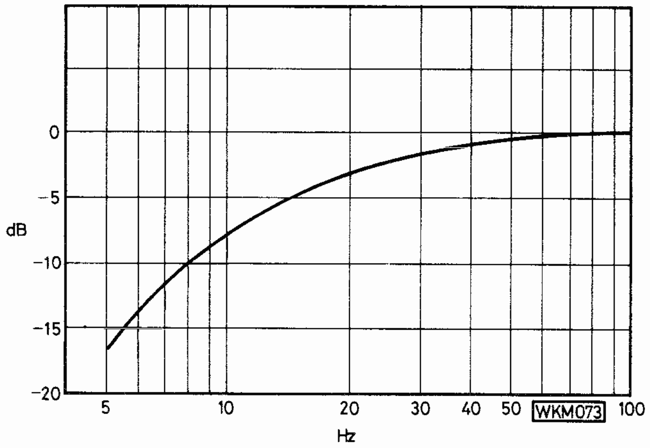


Fig. 2: Disc input — Subsonic filter response

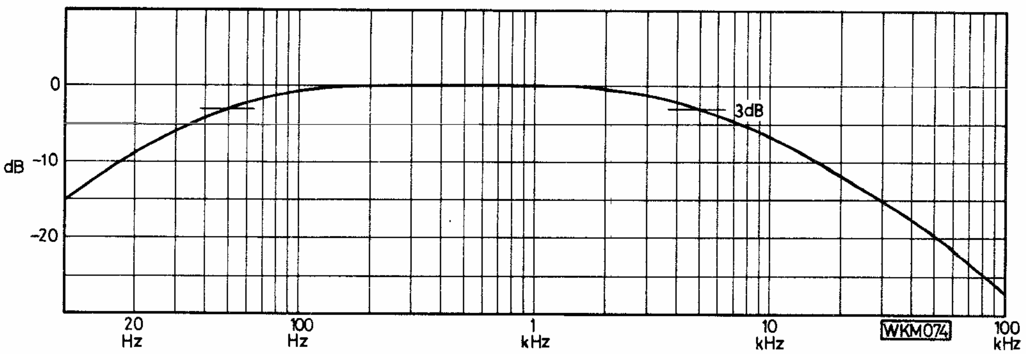


Fig. 3: Frequency response of l.f. and h.f. filters

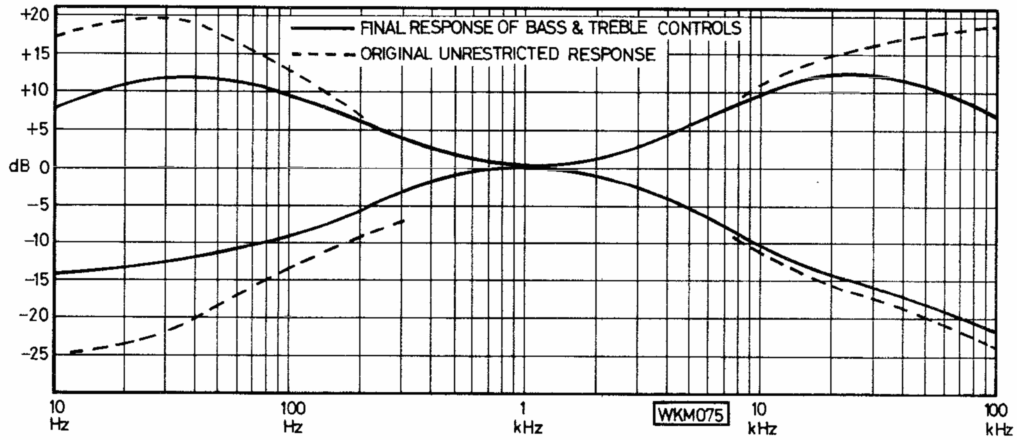


Fig. 4: Frequency response range of Bass and Treble controls

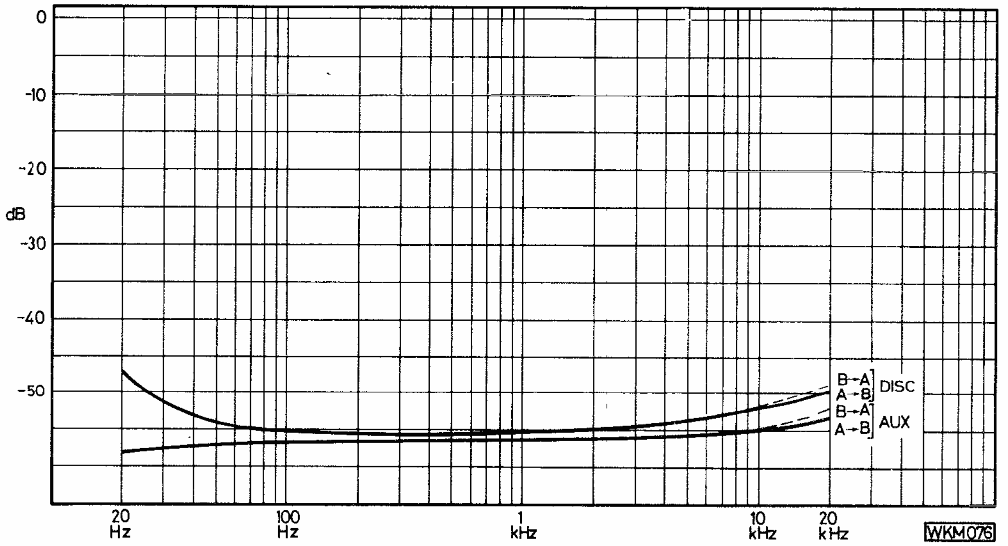


Fig. 5: Cross-talk between the two channels, for Disc and Auxiliary inputs

Power Amplifier

The circuit used for the power amplifier is based on a design produced by Hitachi for their power m.o.s.f.e.t.s. The original circuit has been modified by the author to suit the requirements of the Winton and electronic decoupling added to further improve the overall specification.

The signal from the volume control, VR4 is fed via an r.f. filter R40, C27 to the base of Tr4. This is one half of a differential pair Tr4, Tr5 using low noise transistors Type BC556. These in turn drive a second differential pair, Tr6, Tr7, Type 2SC1775, which has an active collector load (current mirror formed by Tr8 and D3), to maintain the pushpull action. The power m.o.s.f.e.t.s Tr11, Tr12 are driven directly from the second differential pair. As the inherent distortion of the amplifier is very low, only 45dB of negative feedback is used, this is fed from the output, back to the base of Tr5 via R46, R45, C31. The use of less feedback means that, at the overload point, the onset of distortion is less severe then would be the case with amplifiers using considerably more negative feedback. Diodes D4, D7 and Zeners D5, D6 form an overdrive protection circuit to prevent the gates of the m.o.s.f.e.t.s from receiving excessive drive voltages in the event of a fault condition.

Due to the excellent high frequency response of the amplifier only minimal feedback phase correction is required via C31, R45, and L1, R58, R59, C39. The amplifier is unconditionally stable.

As mentioned earlier, electronic decoupling has been included in each power amplifier to reduce the power

★ components

Resistors

5% 0·25W

100Ω	8	R27, 49, 50, 63, 64
150Ω	2	R44
220Ω	2	R47
330Ω	2	R52
560Ω	4	R55, 56
820Ω	2	R6
1kΩ	6	R2, 10, 20
2·2kΩ	4	R9, 40
2·7kΩ	6	R32, 42, 43
3·3kΩ	2	R33
4·7kΩ	8	R14, 15, 31, 54, 57
5·6kΩ	4	R4, 5
8·2kΩ	6	R28, 30, 35
10kΩ	2	R11
12kΩ	2	R46
15kΩ	2	R45
18kΩ	2	R48
22kΩ	2	R8
33kΩ	4	R22, 24
39kΩ	2	R41
47kΩ	10	R1, 3, 21, 29, 34
68kΩ	6	R12, 13, 23, 25
100kΩ	10	R17, 19, 26, 36, 39
120kΩ	4	R51, 53
150kΩ	2	R18
390kΩ	4	R7, 16

5% 0·5W

10Ω	2	R59
10kΩ	1	R62

5% 1W

10Ω	2	R58
4·7Ω	2	R61
1kΩ	2	R37, 38

7W wirewound

33Ω	2	R60

Potentiometers

100kΩ + 100kΩ lin.	2	VR1, 2
100kΩ + 100kΩ log	1	VR4
100kΩ lin.	1	VR3

Min. Preset horizontal mounting

1kΩ	4	VR5, 6

Switches

Min. toggle d.p.d.t.	2	S9, 10
Push button unit 8 keys	1	S1 to 8 (T & T Electronics)

Capacitors

Electrolytic

2·2µF 63V	10	C13, 14, 20, 25, 26
22µF 63V	1	C24
47µF 63V	10	C2, 3, 8, 10, 33, 34, 44, 45
100µF 16V	6	C4, 28, 29
220µF 16V	2	C30
4700µF 63V	2	C40, 41 (Note: 7A ripple rating)

Polystyrene

10pF	2	C31	
68pF	2	C19	
100pF	4	C1, 27	
320pF	4	C17, 18	
330pF	2	C6	2·5%
3·3nF	4	C5, 23	2·5%
10nF	2	C7	2·5%

Polyester

0·2µF	1	C42
0·1µF	12	C12, 15, 16, 32, 35, 36
47nF	7	C37, 38, 39, 43
47nF	4	C21, 22 (Note: matched 2·5%)
10nF	2	C9, 11

Semiconductors

Diodes

TIL209	1	D8
BZY88C15	6	D1, 2, 5, 6
1N4148	6	D3, 4, 7
KBL-02	1	D9–12

Transistors

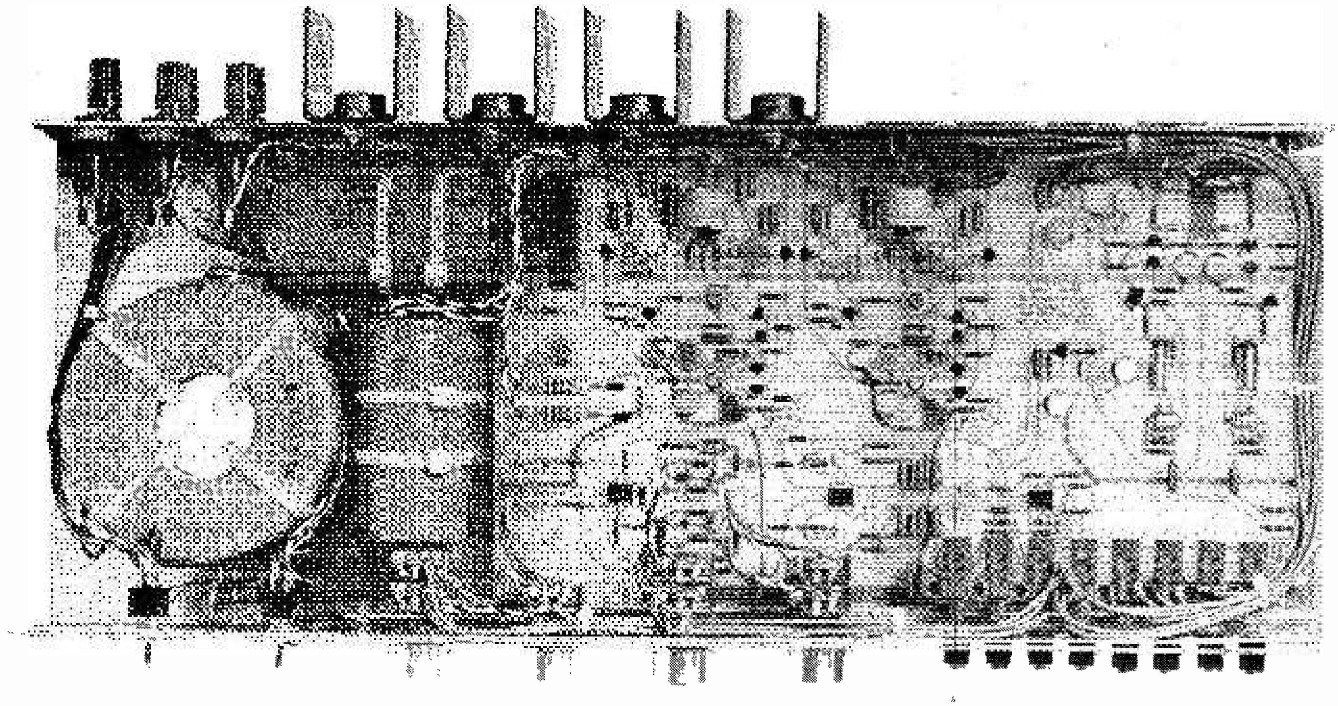
BC414	4	Tr1, 2
BC556B	11	Tr3, 4, 5, 8, 10, 14
BC546B	3	Tr9, 13
2SC1775E	4	Tr6, 7
2SK133	2	Tr11
2SJ48	2	Tr12

Integrated Circuits

TL072CP	1	IC1
TL082CP	2	IC2, 3

Miscellaneous

PCB Winton (T & T Electronics). Mains Transformer, Belclere 6854/3 (T & T Electronics). Chassis and front panel, Winton (T & T Electronics). Case Winton (T & T Electronics) Pins, RS 433-630 (47); Fuse holder, RS 412-879 (3); Fuse 2·5A Quick Blow (2); Fuse, 1A Slow-Blow (1); Pillars, RS 543-737 (5); Cable Ties, RS 543-349 (8); Cable Ties, RS 543-428 (6); 4mm Terminals, Black (1), Blue (2), Red (2); DIN Socket 5-way 180° (5); Jack Socket, RS 478-015 (1).



Internal view of the *PW* "Winton" amplifier. Here, we show the final version using a printed circuit board. The model illustrated on our front cover is the prototype, which was constructed on perforated board with hard wiring

supply noise and ripple voltage, as well as improving the cross-talk (Fig. 5) between channels. Transistors Tr9, BC546 and Tr10, BC556 are used for the decoupling circuit.

Provision is made to adjust the d.c. offset at the output to zero. By adjusting VR5, the current through the differential input stage can be adjusted to compensate for the slight gain variation in each half of the differential pairs. It is very important that the output from the amplifier does not contain any d.c. voltage, as this would cause the loudspeaker cone to take up a position away from its centre which in turn would cause distortion because of the resulting non-linear cone movement.

Power Supply

By no means least important, the power supply of the Winton has been subjected to the same standard of design as the rest of the circuits, although on the surface it may look simple.

In a high fidelity amplifier the power supply can either turn a good amplifier into a top quality model or into a not so good one. There are two main reasons for this:

1) The regulation of the supply volts must enable the amplifier to reach its full power potential under the worst possible signal conditions. At the same time, it must not let the voltage rise to dangerous levels under quiescent conditions.
2) The external magnetic field from the transformer must not inject any hum into the amplifier circuits, particularly the disc amplifier.

To enable the full performance that the Winton is capable of to be achieved, it was decided to use a toroidal type of transformer. The design and development of this special low-field transformer was carried out by Belclere Ltd., and this transformer is now available from T & T Electronics.

The output from the transformer goes to a bridge rectifier and then to the two 4700µF capacitors C40, C41. These, and the electronic decoupling circuits used in the power amplifiers, coupled with the Zener stabilised supply to the control unit and further electronic decoupling to the disc pre-amplifier, ensure that only about 0·001% of the total output from the Winton is noise from the power supply. Even on the disc input the total noise in the output from all sources combined is only about 0·04%.

Heat Sink Ratings

When designing an amplifier for domestic use, the design is almost always a compromise between all the various requirements. In the case of the Winton amplifier this applies to the size of the heat sink and mains transformer.

It is possible to make both of these components in such a way that the amplifier could deliver 50 + 50W continuous power for hours on end without much temperature rise. The cost of doing this would be so high as to put the amplifier out of reach of most peoples' budget. On the other hand these components could be made down to a low price and the amplifier allowed to run very hot, which would lower the reliability.

In the design of the Winton the author has arranged that these two components will allow the power f.e.t.s and the transformer to run well inside their respective maximum rating under continuous drive conditions, although under these conditions both the heat sink and transformer will reach quite high temperatures and certainly be too hot to touch.

When used for its normal purpose, i.e., reproducing music, the temperature rise is very much less and after some hours of loud music will still be only moderately "Hot". The actual heat sink may reach 60°C under these conditions.

This compromise doesn't reduce the quality of the reproduced sound in any way, but it does avoid a severe pain in the wallet.

NEXT MONTH
Constructional details