Double Balanced Microphone Amplifier Notes (OM1556 from 1984)

Graeme John Cohen July 2008. Adelaide, Australia

Introduction:-

To be read in conjunction with ...

- AES Preprint 2106 "Double Balanced Microphone Amplifier" or
  Philips "Double Balanced Microphone Amplifier" (no document number) which contains all of the documentation and data as sent to the AES.

- Philips Note R01312 22 Oct 1985
  "Double Balanced Microphone Amplifier. Philips OM1556".

- Philips Data Sheet R01313 22 Oct 1985
  "Philips Data Sheet. Double Balanced Microphone Amplifier. OM1556".

Copies of the required documents are appended to this paper.

This preamplifier was developed over some years leading up to the first AES conference in Australia in 1984. Philips Microelectronics Australia has the original laboratory notes of some years previous to the AES conference paper.
This circuit was ultimately developed into the Philips OM1556 hybrid microphone amplifier in 1984.

The concept was not described as an invention and it was "new" in the overall description of being:

- Double balanced throughout. i.e. CMRR was carried through to the final output. Exceptional DC balance using cross couple dual matched multiple transistor arrays (not FETs).

- Adjustable current operation of the input transistors for optimum noise figure for different source impedances while maintaining tight DC balance.

- Very low value feedback resistors to the emitters of the input transistors so that the gain setting resistors are of extremely low value (approximately 1 ohm at 60dB of gain) to enhance the already low noise figure.

- The very good DC balance obtained over the operating input DC current range, due to the double balanced approach allows the use of full DC coupling throughout.
  No coupling capacitor is required in series with the gain setting resistor.

Notes:-

- The "Double Balanced" concept allows for exceptional common mode rejection for input signals right through to the output. This is enhanced by using a cross connected output stage to control any DC offset from the already balanced input stage. i.e. with both inputs tied together and driven from a low DC offset source the output DC offset is very good even at extreme gain settings. See figure 1.

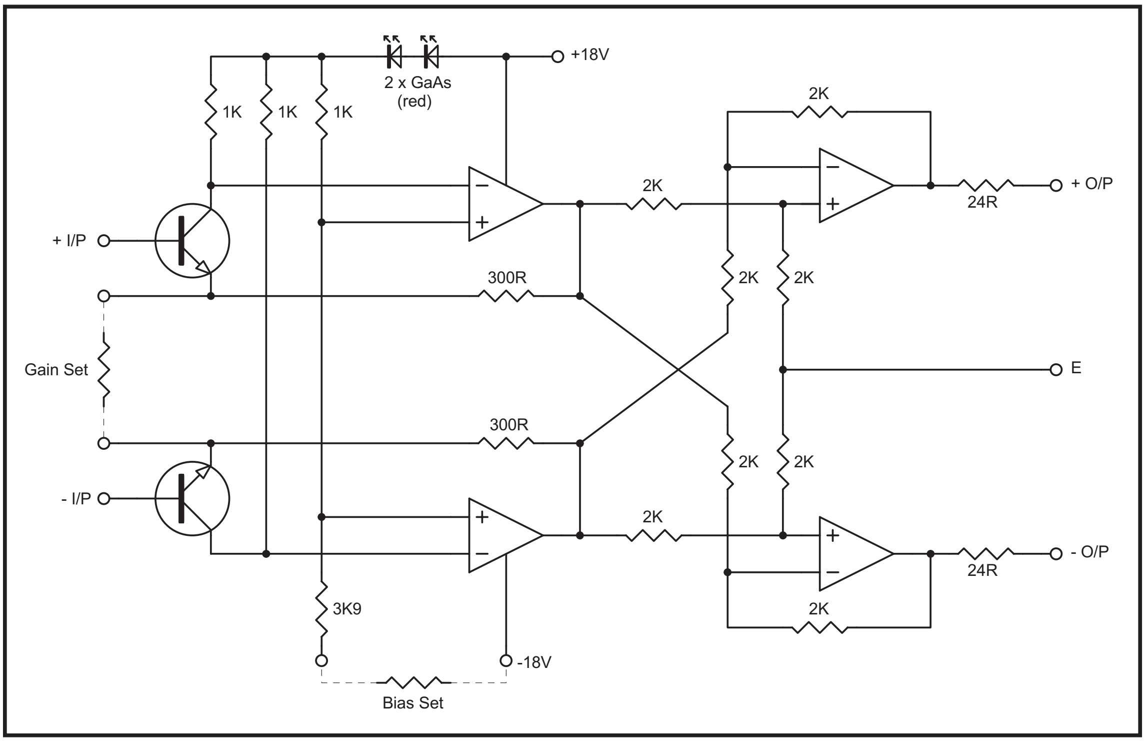

Figure 1.
Double Balanced Microphone Amplifier showing full DC push pull giving extra CMRR throughout. Both 300R resistors are matched. All 1K & 2K resistors are matched. Both 24 ohms are also matched for the following amp CMRR.

- The input transistors, two off LM194 (LM394) are multiple emitter transistors cross connected on a single crystal (chip). FETs do not have good gate to source DC match and do not have low enough noise figure at low input impedances. Two of the LM194 chips are used in a cross connected configuration to enhance the DC match and therefore the stability. See figure 2.

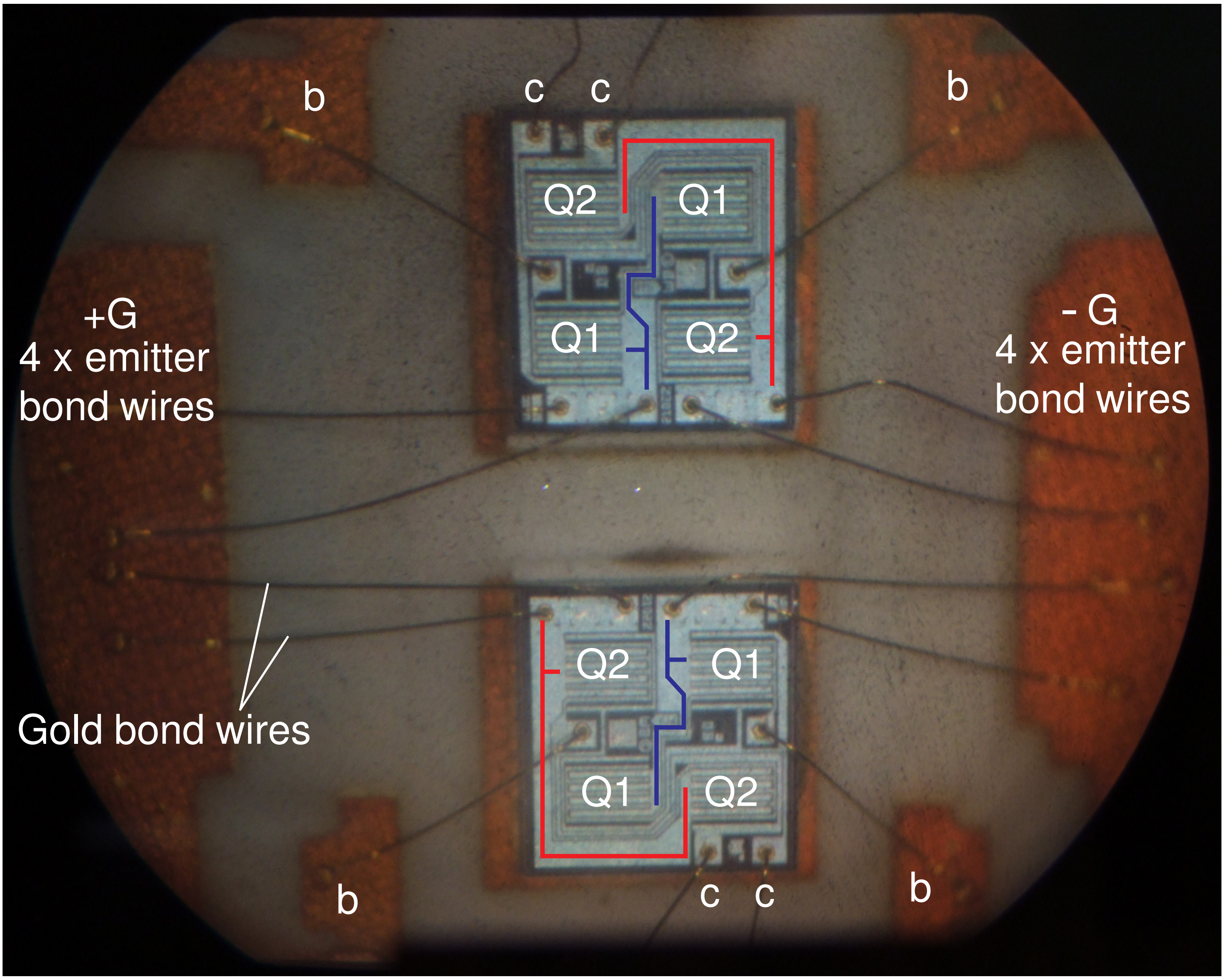

Fig 2.
2 x LM194 transistors on OM1556 hybrid.

The transistors are cross connected on each chip and each chip orientated to also be cross connected and in parallel. Q1 of the upper chip is in parallel with Q2 of the lower chip.
i.e. Double balanced also of chip for DC stability.
Notice that the emitter connections for Q1 & Q2 within each chip are not symmetrical. (red and blue traces).

For close matching, these two individual chips were hand selected adjacent pairs from the centre region of the chip wafer.

Notes (cont):-

- By optimising the adjustable current in the input transistors the optimum noise figure can be obtained. For very low input source resistance (<20 ohms) and therefore high input transistor current, a slight degradation of the excellent DC balance may occur.

- The use of very low feedback resistors to the input emitters (300 ohms each) allows for a very low value gain setting resistor between emitters.(300 ohms is seven times lower than is commonly used, > 2 kilohms). This low value enhances the already good noise figure. The gain setting resistor is in series with the rbb of the input transistors and is itself very low due to the multiple transistor arrays and two of these arrays also in parallel.

- Because of the inherent good DC balance obtained, the use of any coupling capacitors is eliminated. This very low noise amplifier can then be used down to DC with low offsets even at high gain settings. Also high output voltage swing is available due to the double balance of the offsets throughout.

- The first pair of Opamp outputs current drive the 300 ohm resistors. Therefore these output stages operate in class A.

I didn't know about Burdick of Benchmark Audio or the Harrison PC1041 or AD524. None of these are double balanced or have adjustable current for the input transistors.

- Burdick (Fig 3) is not DC coupled and has high value feedback resistors.

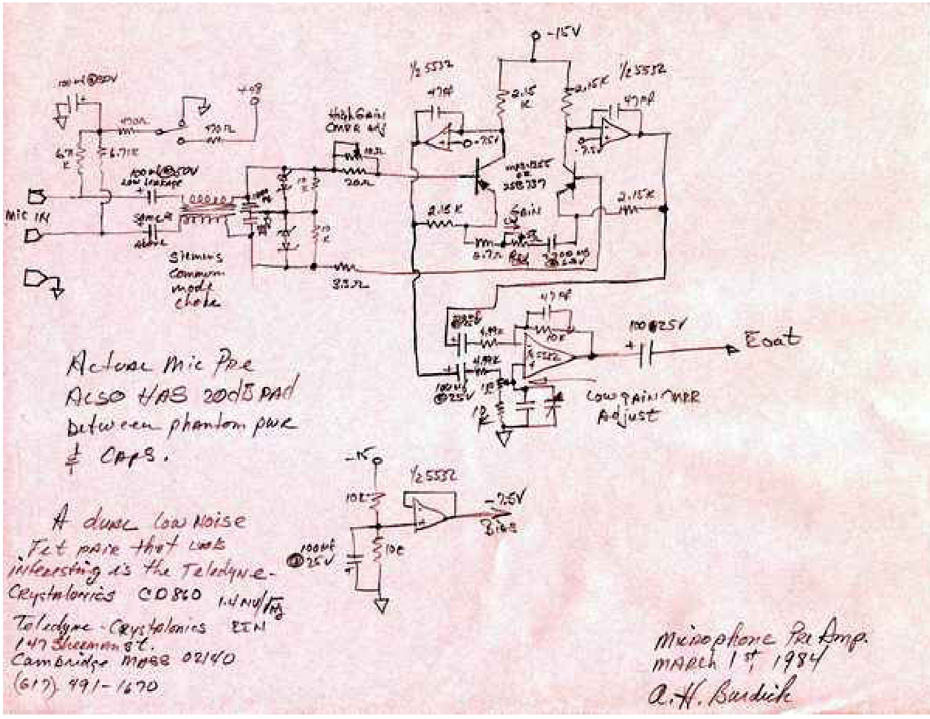

Figure 3.
Burdick of Benchmark Audio 1984

- Harrison (Fig 4) is not DC coupled and also has high value feedback resistors.
  It also uses current sources which should be avoided as these are another source of noise being injected into the emitters.

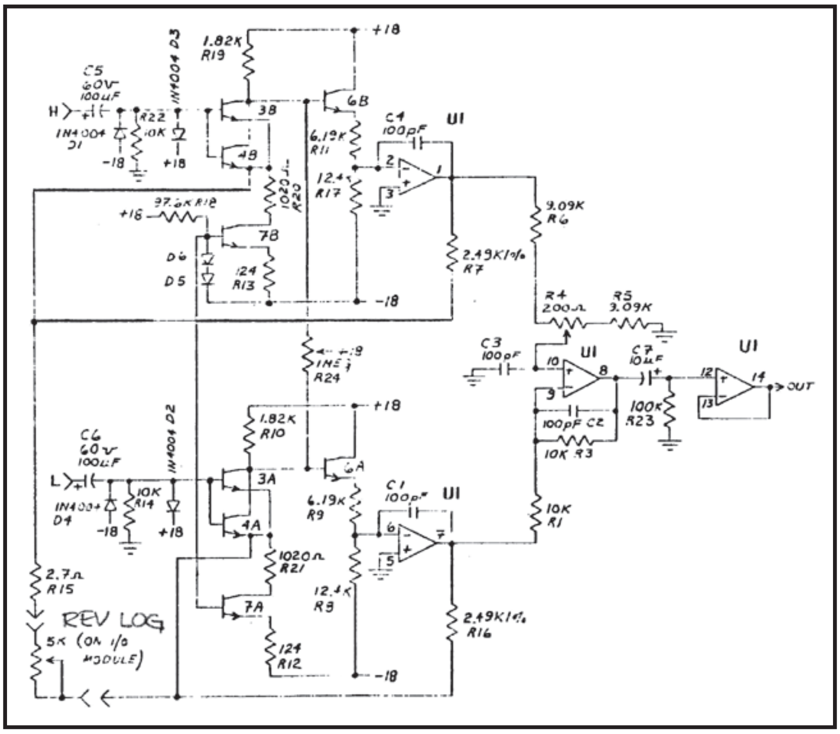

Figure 4. Harrison PC1041 in 1978.

- AD524. (Fig 5) Very high feedback resistors is not a low noise input.
  At 60dB gain, 40 ohms plus rbb and re of each device gives a high noise figure for 50 ohms or less source impedance. See figure 6

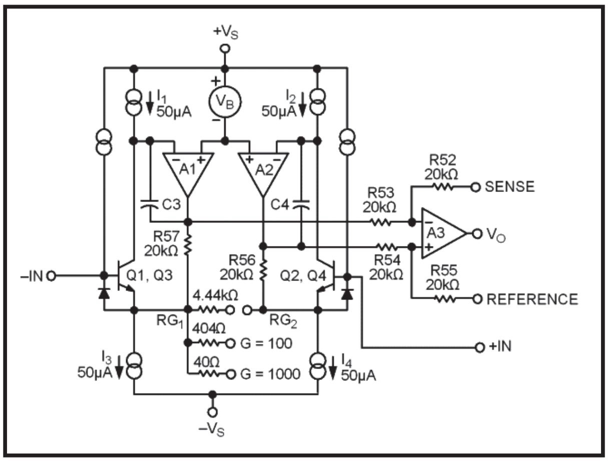

Figure 5.
AD524

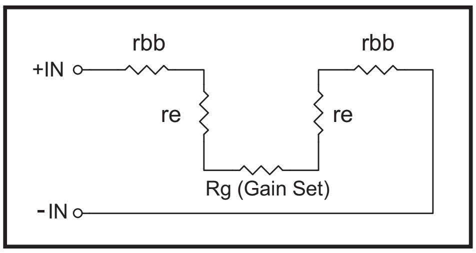

Figure 6.
Input noise sources.

Notes (cont):-

- The 300R resistors allow Rg to be about 1 ohm (at 60dB of gain)
  There is not much point making the 300R resistors lower and hence allow Rg to be even smaller, as rbb tends to swamp Rg.

- It can also be operated with uA bias currents giving input impedances of Megohms.

- See OM1556 “Typical connection” in R01313 for optional trim of CMRR and DC offsets for precision high gain DC applications such as strain gauges.

- The internal 100pF capacitors to ground on the middle 1K resistor (+ inputs of Opamps) matches the feedback 100pF capacitors to reduce transient overloads especially from power supply noise.

- The power supply pins are bypassed to common (usually the ground terminal) for HF bypassing.

Some of the test equipment now in use as well as wideband CRO;

<u>For IMD measurement & Plots:</u>
Anritsu Network/Spectrum Analyzer MS420B, 10Hz - 30MHz.
2 off Level Generator MG442A with separate combining/filter unit.

<u>For harmonic and noise figure measurements:</u>
Boonton Audio Analyzer 1120, 10Hz - 140KHz

<u>For DC and offset measurements:</u>
7 1/2 digit DVM

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July 2008
Australia.

OM1556 Hybrid Mic Amp.

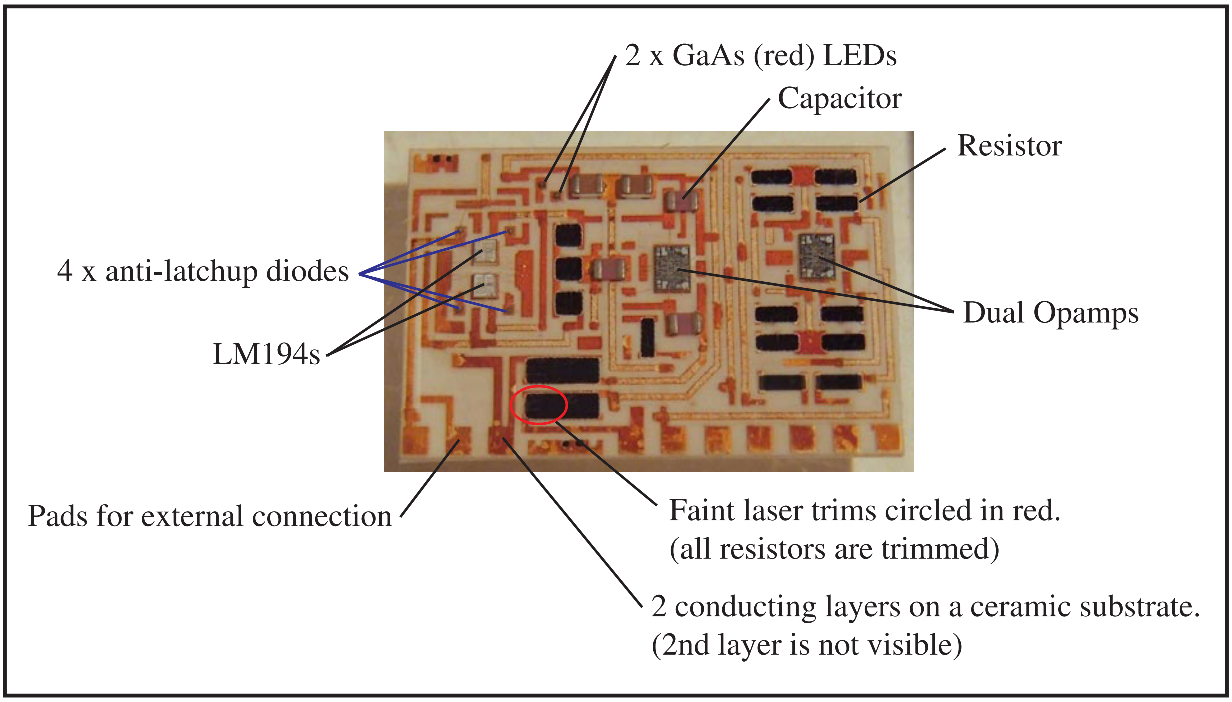


Figure 7.
OM1556 internals

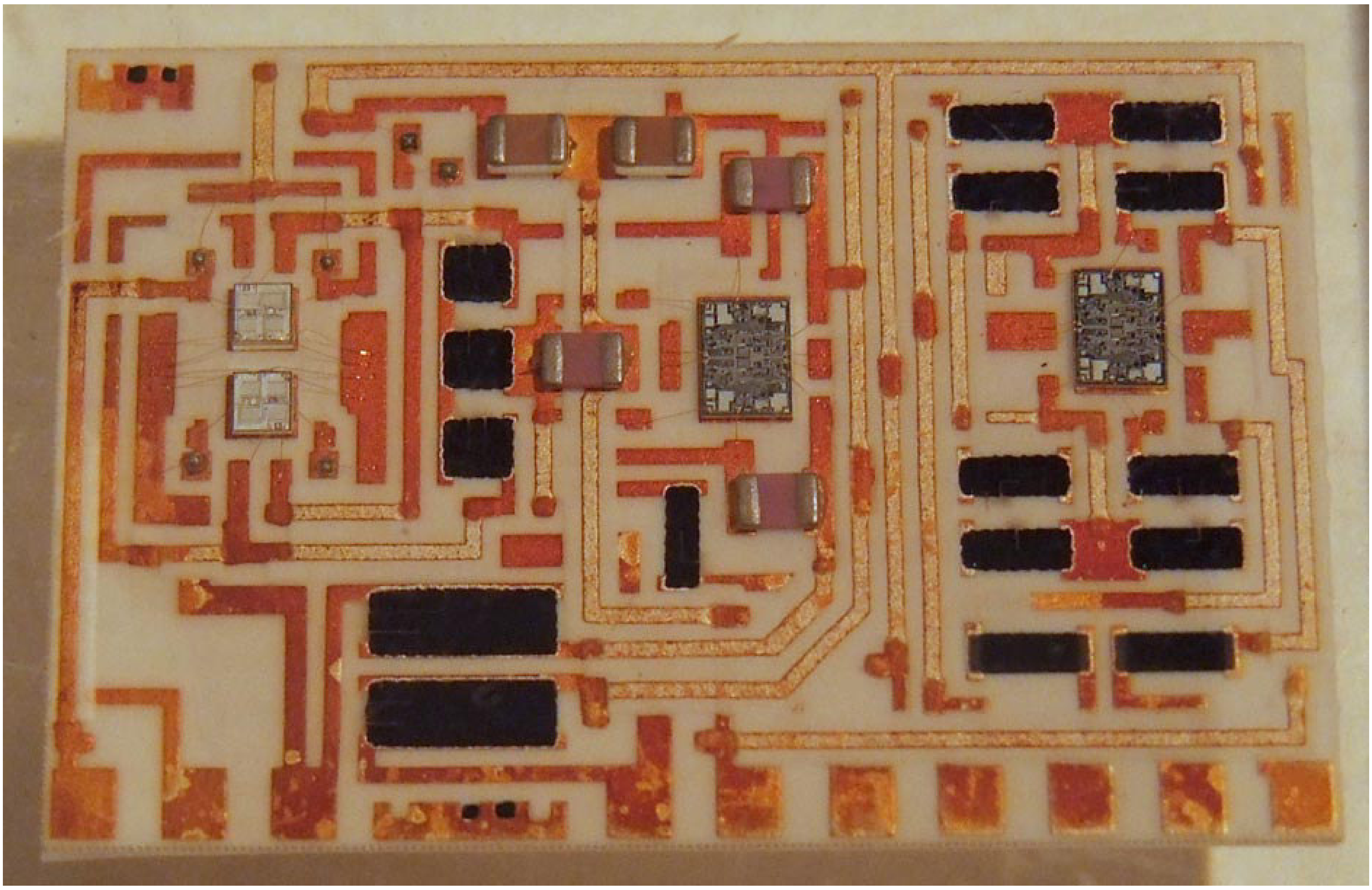


Figure 8.
The big picture.

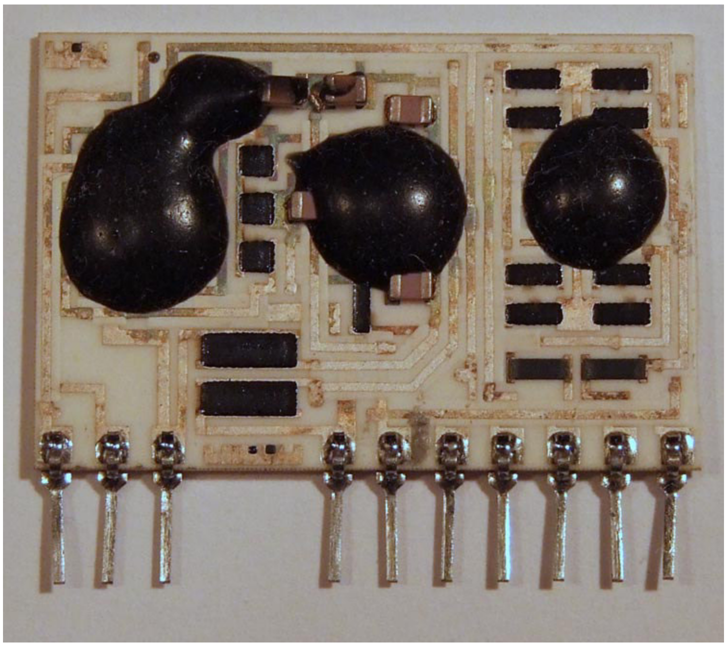


Figure 9.
All active parts have a rubberised coating to keep out light and to protect the bond wires & chips.

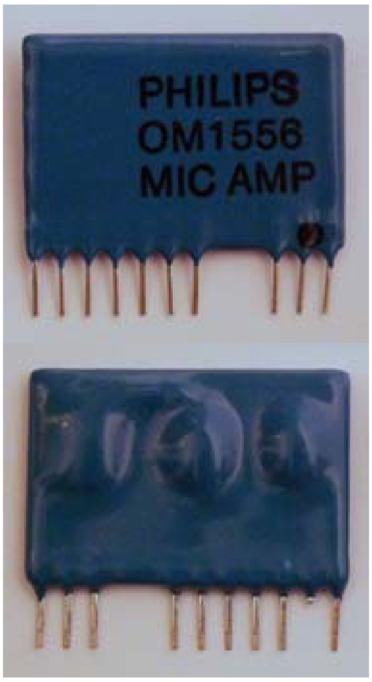


Figure 10.
Conformal coating.

Figure 11.
A serious Graeme Cohen in his lab.
July 2008

A few remaining hybrids were built up as general purpose preamps in June 2006

Figure 12
Dual preamp.

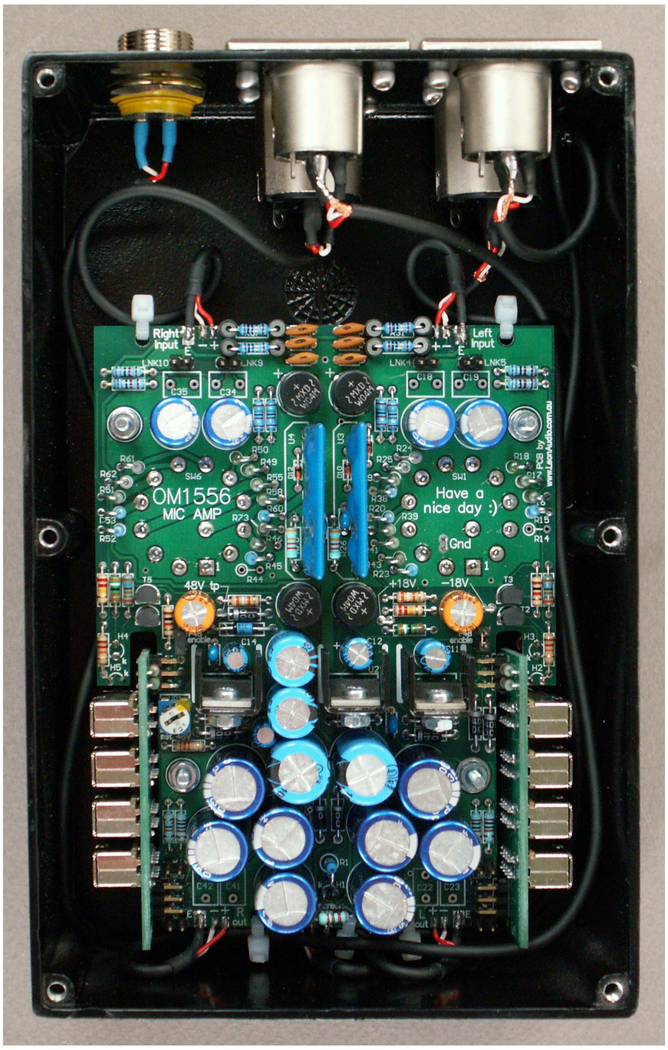


Figure 13
Inside the preamp.

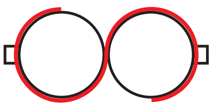
Many of the capacitors in the lower half of the photo are in the power supply which runs from an external 16V AC transformer. Plus and minus 18V rails are derived from voltage doublers and the 48V Phantom from a tripler.
Input and output coupling caps can be jumpered out for DC operation.
48V Phantom can also be disabled when input caps are not used such as when running from a ribbon microphone.

Frequently asked questions.

Any reason for balanced output only?
Use either output if AC coupled.
For best CMRR and/or DC offset use a 4 resistor diff amp on the balanced output which can then have their own trimpots.
A differential output is also useful for phase reversal.

Why was it made into a hybrid?
I was there and I could!
...and the staff selected matched chips etc.

If it were being made today, in the surface mount era, would it still be a hybrid?
Probably. But there would be different manufacturers of the chips etc.
Hybrid allows laser triming. See figure 7.
If SMD use phyisically largest parts for ease of matching on a bridge.
Thermal tracking of the LM194s needs to be taken into account.
One could clamp T05 types together with an ‘S’ shaped heatsink for through hole PCB.



Thermally coupled LM194s

Did Phillips sell many of the devices?
Don’t know.

Why not FETs on the front end?
Match of Vgs of depletion mode FETs is very poor, enhancement mode FETs are worse.
They also have too much noise for low impedance sources.
Need to use bipolar for low impedance work because of much better noise performance.
Vbe is very tightly matched in multiple emitter dual transistor chips.

What are the two LEDs for?
LEDs are used as a low noise fixed voltage source so that the input Opamps keep within their linear region because you can’t run their inputs closer than about 2 volts to rail.

DOUBLE BALANCED MICROPHONE AMPLIFIER

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The combination of a balanced microphone transformer and a low noise amplifier is normally used for studio microphones. A design is shown to replace the transformer and associated amplifier. This incorporates the balanced and floating virtues of a transformer without the signal loss introduced ahead of a low noise amplifier. Gain and input stage current is adjustable. High common mode rejection is achieved with a balanced output and a very good noise figure at all gain settings.

0. INTRODUCTION

The microphone amplifier presented has been designed to meet the criteria of a microphone transformer and includes power gain which normally follows the transformer. Some of the important microphone characteristics are :-

1) Good differential balance with common mode rejection of input signals.

2) Impedance match with low loss.

3) Wide signal bandwidth.

4) Isolation of output from input.

5) Large signal handling without distortion.

The isolation of output from input and good common mode rejection are the obvious difficulties in substituting a transformer. A good transformer has a very good voltage isolation and can also have a floating input and/or output. It can also have a floating differential input and output, that is double balanced.

An attempt has been made to duplicate the above performance. The obvious limitation is the very large common mode signal the transformer can handle. The design presented can handle volts of common mode signal, has an exceptionally good noise figure and a wide dynamic range. A transformer can limit the dynamic range of an amplifier.

1. GENERAL DESCRIPTION

Two noise optimised single ended input stages are used, each using power driven feedback with a single gain setting resistor between them. A single resistor is used to optimise the current for the input stage to suit the source impedance which may vary from tens of ohms to several thousand ohms. The differential gain of the input stage can be varied from unity to more than five hundred whilst preserving dynamic range, common mode rejection and noise figure. The input stage uses two very low noise and well matched LM194 dual transistors in parallel. The design has provision for optimising and matching the input stage operating current.

The signal from each input transistor is amplified in the very low noise operational amplifier NE5532. One amplifier section being used for each input transistor. The good noise figure and balance is maintained along with a power capability for driving the feedback network.

From the two input stages the signal is combined in the classic differential to single ended amplifier configuration. This stage is duplicated with mirror like connections and uses another NE5532 dual amplifier. Power feedback is also used in this stage to preserve the low noise figure at low gain settings. The differential gain of this stage is two with a balanced output, and is capable of driving a balanced load of less than two thousand ohms at full output swing. Good common mode rejection is achieved on both outputs.

2. TYPICAL INPUT STAGES

Two conventional balanced input stages are shown in Figure 1 and Figure 2. The first design has emitter degeneration to define the gain. It has been shown elsewhere, Ref. 1, that collector-base modulation (early-effect) can cause considerable distortion. In Figure 1 it can be seen that the second transistor has a voltage gain. Due to the summing nature of the operational amplifier, the first transistor also has a voltage gain on its collector and hence collector voltage swing. This can cause early-effect distortion in both transistors, particularly with inductive sources. The gain is not well defined and can vary with frequency due to the source impedance particularly at higher gain settings. These gain variations can be small, but may not be tolerated. This microphone-amplifier interaction may be one of the reasons microphone amplifiers sound different or coloured.

A feedback stabilised input stage is shown in Figure 2. This design uses overall series feedback to each input transistor. The voltage swing on the collectors is now very small, either due to the large gain of the operational amplifier or the effect of shunt feedback to the collectors as shown. The gain is now well defined and the circuit is less dependant on source impedance effects.

In Figure 3 a typical instrumentation amplifier configuration is shown. This type of amplifier usually has a limited bandwidth as it is designed for high D.C. gain with low D.C. offset and drift. It can be seen that no coupling capacitors are needed as in the other two circuits. A good recovery from an input overload is thus obtained. The noise figure however, is not usually very good, having low operating currents and high impedances particularly in the feedback network. Also there are four base-emitter junctions in series between the inputs.

3. NEW INPUT STAGE

A new configuration has been developed to overcome many of the shortcomings used in previous designs. A balanced input requires a minimum of two transistors, one for each input. The problem is to have direct coupling of signal and feedback without the use of coupling capacitors and without having two more transistors, to make long-tailed pairs, on each input.

By using the well matched, for offset voltage (Vos = 25µV), pair of transistors LM194 and a dual operational amplifier a circuit has been developed as described below, and with reference to Figure 4.

The current through Q1 is adjusted by "sinking" its emitter current into the output of I.C.1. The collector current of Q1 sets up a voltage across R1 which is compared to a voltage across R2 which has been preset by R4. The two voltages on the inputs of I.C.1 are compared and the output voltage of I.C.1 sets a current through R5 so that the two input voltages of I.C.1 are equal.

The loop has negative feedback. The same conditions apply to Q2 and I.C.2 using R2, R3 and R7.

The important points to note are :-

1. *Resistor R4 sets both Q1 and Q2 current.*

2. *Resistors R1 and R3 are equal as are Resistors R5 and R7. Also I.C.1 and I.C.2 are a dual operational amplifier having low input offset voltage and tends to be equal being a dual amplifier.*

3. *Transistors Q1 and Q2 are a very well matched low noise pair of transistors having an extremely low offset.*

4. *The offset voltage on the output of I.C.1 and I.C.2 is similar and can be cancelled in a differential to single ended amplifier having good common mode rejection.*

5. *Resistor R6 sets the differential gain and is direct coupled due to the excellent balance in the amplifier.*

6. *Transistors Q1 and Q2 currents flow down the feedback resistors R5 and R7 and therefore there is no extra noise generators due to resistors or current sources.*

7. *Resistors R5 and R7 are a low a value as possible that the operational amplifier can drive and therefore R6 is very low. This ensures a very low noise figure.*

The virtues of this design is the excellent balance achieved both D.C. and A.C. The collector currents of Q1 and Q2 are made equal, due to both operational amplifiers acting as voltage comparators across R1 and R3 as to R2. Signal power is applied to the feedback network R5, R6 and R7 thus assuring a very good noise figure. Resistor R6 can become very low, depending on gain, and can be in the order of an ohm. The circuit, however, maintains D.C. stability due to the method of comparing collector currents.

The circuit has a response to D.C. with excellent stability even though low value resistors are used, thus minimising noise figure.

The input transistors are biased to a common voltage with equal resistors.

The outputs can be connected to a differential to single ended amplifier to cancel any offset voltage present and to give common mode rejection of input signals.

The gain is equal to R5 + R6 + R7 divided by R6.

4. NOISE COMPONENTS

The input transistors used have a base spreading resistance rb of approximately 10 ohms, Ref. 2. For a short circuit input the intrinsic emitter resistance is :-

$$r_e \text{ opt} = \frac{Rs + R6 + Rb}{hfe^{\frac{1}{2}}}$$

With R6, gain setting resistor, set at 4 ohms to give 50dB overall gain, then r_e opt is approximately one ohm for each transistor. As the maximum current for the LM194 is 10 milliamps a reasonable current would be 4 milliamps giving r_e of approximately 6 ohms. It was decided two LM194 dual transistors connected in parallel would allow r_e to approach the optimum value for very low source resistances and effectively halving of rb. Several pairs were tried and all gave a 2dB improvement in noise. A total of 8 milliamps can be used for each input side while still allowing low currents to be set for high input source impedances. The noise performance of the LM194 (LM394) has been well documented in Ref. 3.

It has been shown in Ref. 4 and Ref. 5 that a transistor connected in common emitter or common base configuration has very nearly equal input noise components. The feedback network also produces a similar amount of noise when connected to either the base or emitter of a transistor. When connected to the emitter it reduces the stage gain by virtue of emitter degeneration. The feedback network therefore needs to be of low value and in this case is less than 4 ohms for 50dB gain.

Two BFW16A transistors were substituted for the two LM194 dual transistors. A large blocking capacitor was connected in series with the common feedback resistor R6 for the following noise test.

Figure 11 shows the noise performance for two BFW16A and for two parallel connected LM194 transistors. The BFW16A transistors give a 1.5dB improvement and not 2.5dB as shown, for higher frequencies, due to a lower overall gain obtained at this gain setting.

Figure 10 shows the excess flicker noise (1/f) of the high frequency specified BFW16A device. This transistor has a rb of 4 ohms and was included to show how close to the theoretical ideal the design has approached for source resistances of tens of ohms, see Ref. 4.

The following amplifiers, the NE5532 operational amplifier, contribute little to the overall noise for gains of 20dB or more. At unity gain the input transistors have a 10dB gain, compared to the NE5532, set by the feedback resistors as to the collector load resistors. The NE5532 amplifiers have been compensated with feedback capacitors, for the 10dB increase in loop gain at a unity gain setting for the stage. A capacitor of equal value has been added from the other input of the NE5532 to ground to give the same time constant on both inputs. The NE5532 is the dual of the NE5534 and is compensated for unity gain.

It can be seen that no current sources are used that can act as noise generators and that the operational amplifiers act as comparators for setting the collector current of the input transistors. The stage is unconditionally stable with a good phase margin. The square wave response shown in Figure 9, of the output signal shows little overshoot into a capacitive load and has no sign of slew induced distortion during rise and fall times.

The input transistors are cross connected in parallel, section A in parallel with section B of the other, to balance any second order effects of the dual transistors. It can be seen the remainder of the circuit is also balanced.

5. OUTPUT STAGE

The requirement of the output stage is to combine the differential signal, and not common mode signals, and to supply sufficient output capability for driving balanced lines. Also a differential output is useful for phase reversing of the signal.

Each amplifier is connected in the standard differential to single ended configuration with the second amplifier having the opposite phase output. The four resistors associated with each amplifier are equal and of low value for best noise performance at low gain settings. The resistors going to each non-inverting input have small value capacitors across them to compensate for phase shift in the amplifiers. The internal phase shift effectively reduces negative feedback to the inverting input at high frequencies. The overall common mode balance is maintained to 100KHz.

Output resistors of a low value are used to isolate capacitive loads from the feedback network and to present a 50 ohm resistive output impedance to terminate balanced output lines. The output drive capability is 20 volts RMS into 1K5 ohms at 100KHz.

The output at 20 volts peak to peak of 100KHz square wave is shown in figure 8 and of adding a capacitance of 3n3 is shown in Figure 9.

The output stages in the NE5532 operational amplifier are biased in class AB mode and no sign of crossover distortion is evident. The residual distortion of 100KHz sine wave is shown in the centre of Figure 7.

Measurement of the intermodulation distortion is shown in Figure 12. The output from a HP8903A Audio Analyser, used to reject the 60Hz and 750Hz signals, was observed on a HP3582A Spectrum analyser. Top of the screen is 60dB below the original 750Hz signal. The 60Hz signal is not fully rejected and accounts for half the 0.006% meter reading. Intermodulation products appear around the second and third harmonies of the 750Hz fundamental signal. Second harmonic distortion is >100dB below fundamental, <0.002%, and shows the overall balance of the amplifier.

Transient Intermodulation Distortion (TIM) cannot be detected and in view of the slew rate of 18V/µS, as measured, this is understandable, see Ref. 6.

6. CONCLUSION

The design of a balanced input and balanced output low noise microphone amplifier has been described and is a serious attempt to replace the microphone transformer.

Field tests in various studios have shown good results, with no apparent problems normally associated with transformerless input stages. When compared to some of the top recording desks the only obvious difference is the low noise figure of the amplifier. If used with phantom power of greater than eight volts then blocking capacitors need to be used. These should be large, and matched, to preserve the noise figure and common mode rejection.

An alternative output stage is suggested as an area for further development, Figure 6. This addition generates an output centre tap and allows either output terminal to be grounded giving a true floating, balanced output. This version has been tried and needs some high frequency phase correction. A dual operational amplifier version, with separate feedback paths, is being investigated to provide a more attractive alternative. This approach will give a centre tap output instead of only floating the outputs. Reference 10 has details of floating outputs.

A microcircuit hybrid of the amplifier is being developed as an alternative to the microphone transformer. A phase two microcircuit is being studied to give a true floating output with a centre tap.

APPENDIX 1 PERFORMANCE OF AMPLIFIER

Noise Voltage Spectral Density	$0.7nV/\sqrt{Hz}$
Noise Current Spectral Density	$1PA/\sqrt{Hz}$
Equivalent Input Noise in a 20KHz Bandwidth with Shorted Input	100nV
Corresponding Voltage Level	-140dBV
Total Harmonic Distortion at 20V RMS into 1K5 Balanced Load and 60dB Gain	
i) 20 KHz	0.03%
ii) 100 KHz	0.2 %
Large Signal Bandwidth	140 KHz
Slew Rate	18V/µS
Overshoot into Capacitive Load	10%
Maximum Output into 1K5 Balanced Load at 100KHz	20V RMS
Corresponding Voltage Level	+26 dBV
Maximum Output into 600 Ohms Balanced Load at 100KHz	14V RMS
Common Mode Input Range	+8V -10V
Supply Voltage	± 18V
Supply Current with no Input	30mA
Gain Range Single Output	0dB to 60dB
Gain Range Balanced Output	6dB to 66dB

$$Gain = \frac{600}{RG} + 1 \quad \text{for a Single Output}$$

$$Gain = 2\left(\frac{600}{RG} + 1\right) \quad \text{for a Balanced Output}$$

Note, RG Minimum is 0.6 Ohm

$$\text{Input Stage Collector Current} = \frac{Vs\ Total - 3.4V}{4K9 + RI}$$

RI = 1K5 (5mA) Used for all Measurements.

APPENDIX 2 *TYPICAL APPLICATIONS*

	MICROPHONE/TAPE HEAD PREAMPLIFIER	*MICROPHONE/MOVING COIL CARTRIDGE PREAMPLIFIER*
Gain Required for Balanced Output	*20 dB*	*40 dB*
Output Stage Gain	*6 dB*	*6 dB*
Input Stage Gain	*14 dB*	*34 dB*
Feedback Resistor, RG	*150 Ω*	*12 Ω*
Feedback Noise Resistance	*120 Ω*	*11.5 Ω*
Allowing r_e of 10 and rb of 10 , then Feedback + r_e + rb	*140 Ω*	*31.5 Ω*
Equivalent Noise Voltage for 3dB Noise Figure in 20KHz Bandwidth and Allowing for Output Stage	*200 nV*	*140 nV*
Referred to Output	*2 μV*	*14 μV*
Maximum Output Level	*20 V*	*20 V*
Input Overload	*2 V*	*200 mV*
Dynamic Range	*140 dB*	*123 dB*
Source Resistance	*140 Ω*	*31.5 Ω*

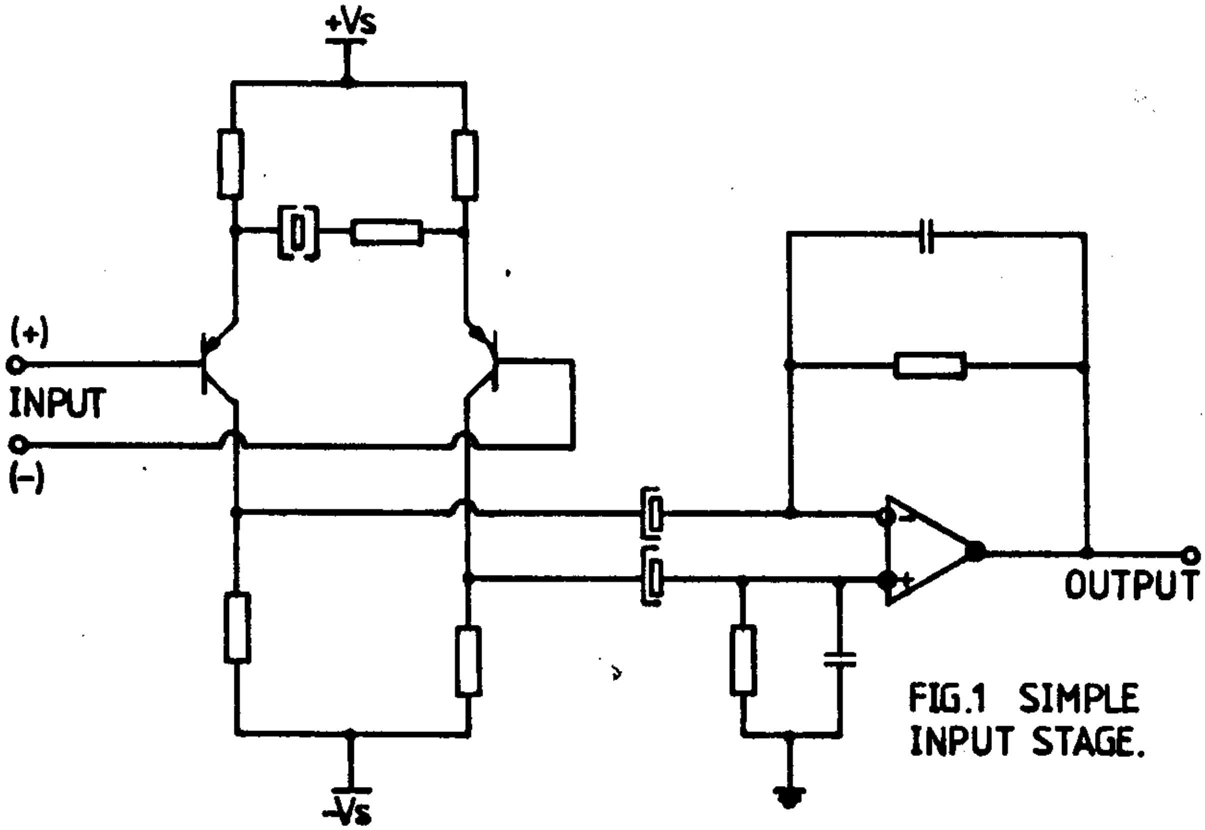

FIG.1 SIMPLE INPUT STAGE.

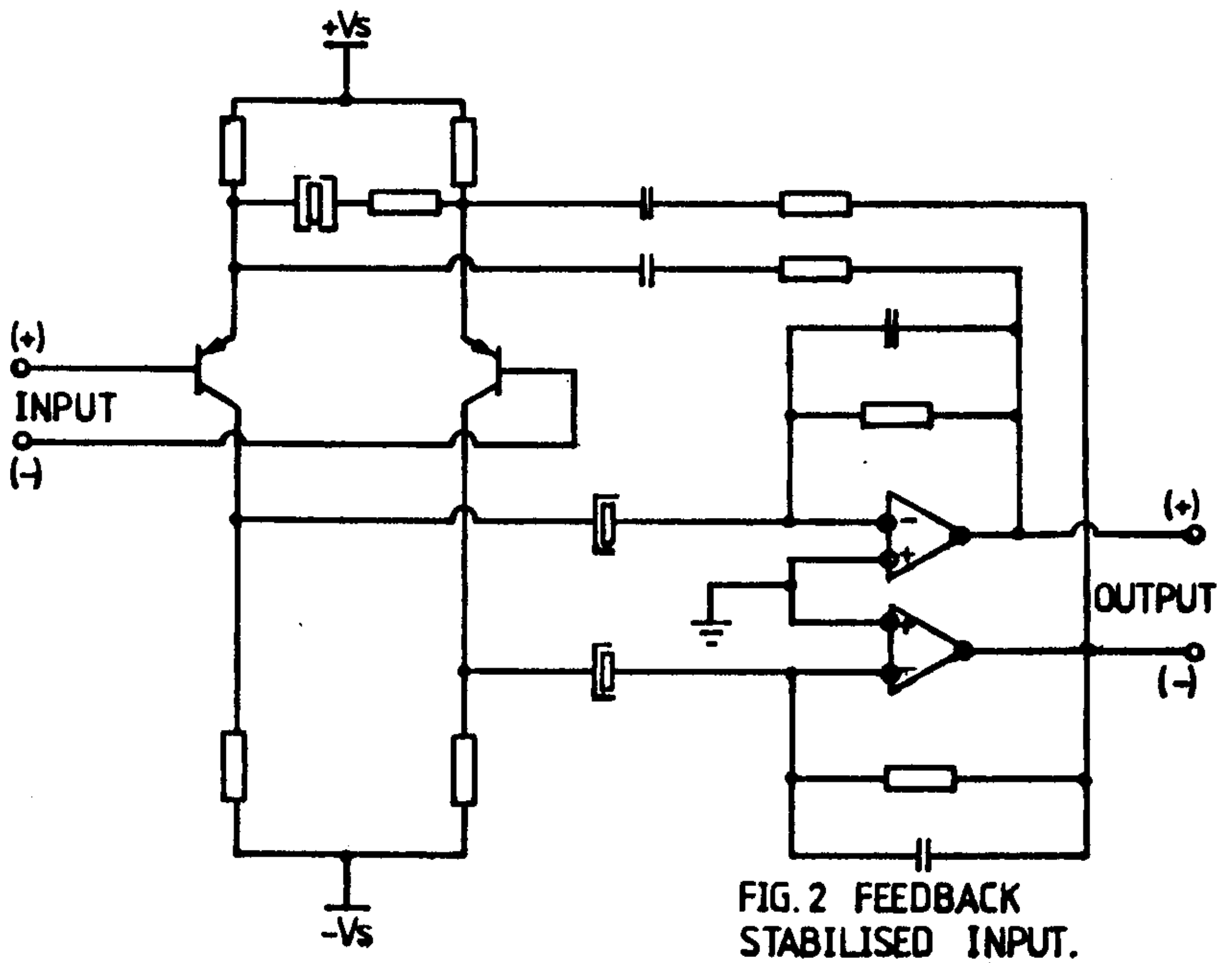

FIG. 2 FEEDBACK STABILISED INPUT.

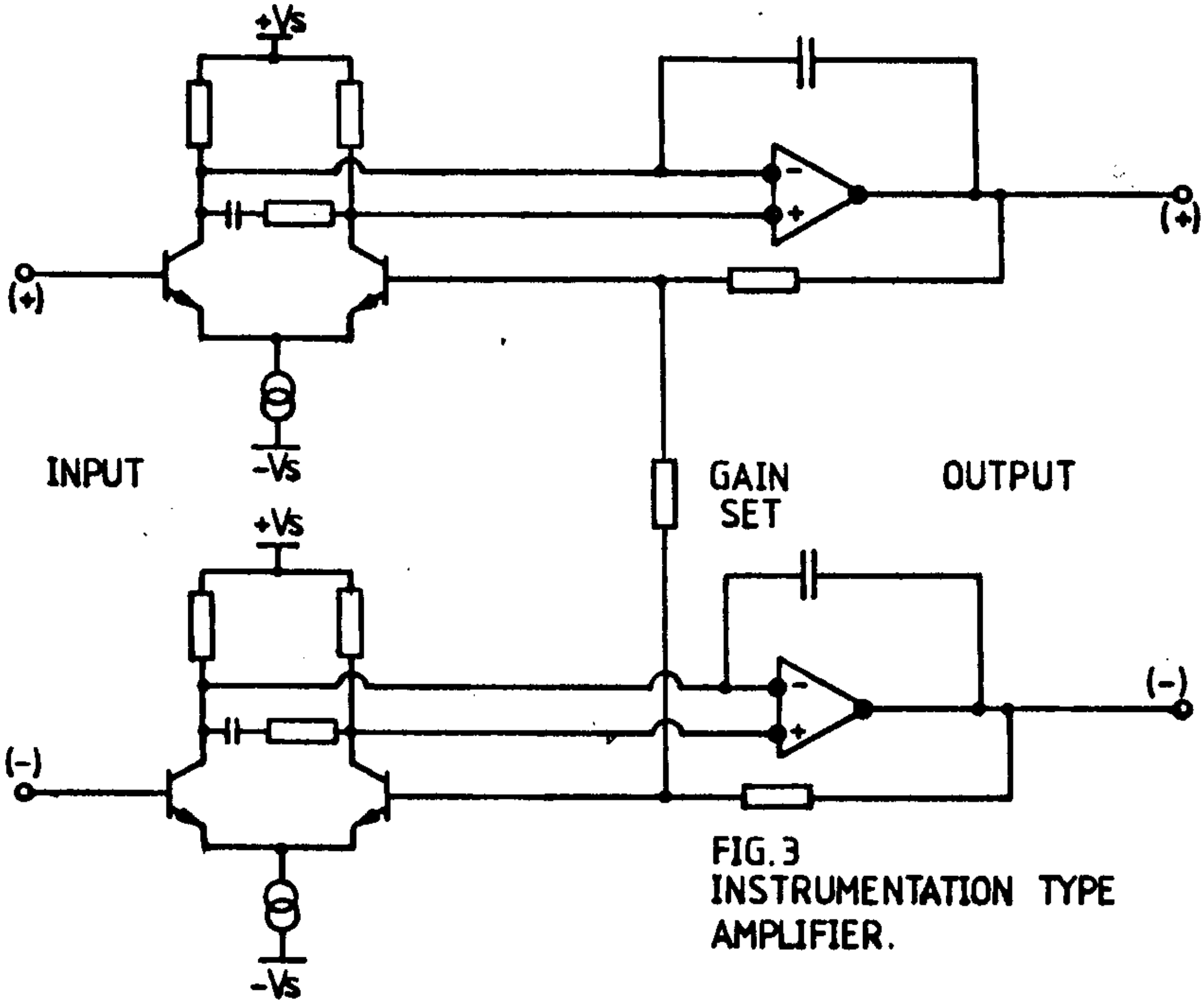

FIG. 3
INSTRUMENTATION TYPE
AMPLIFIER.

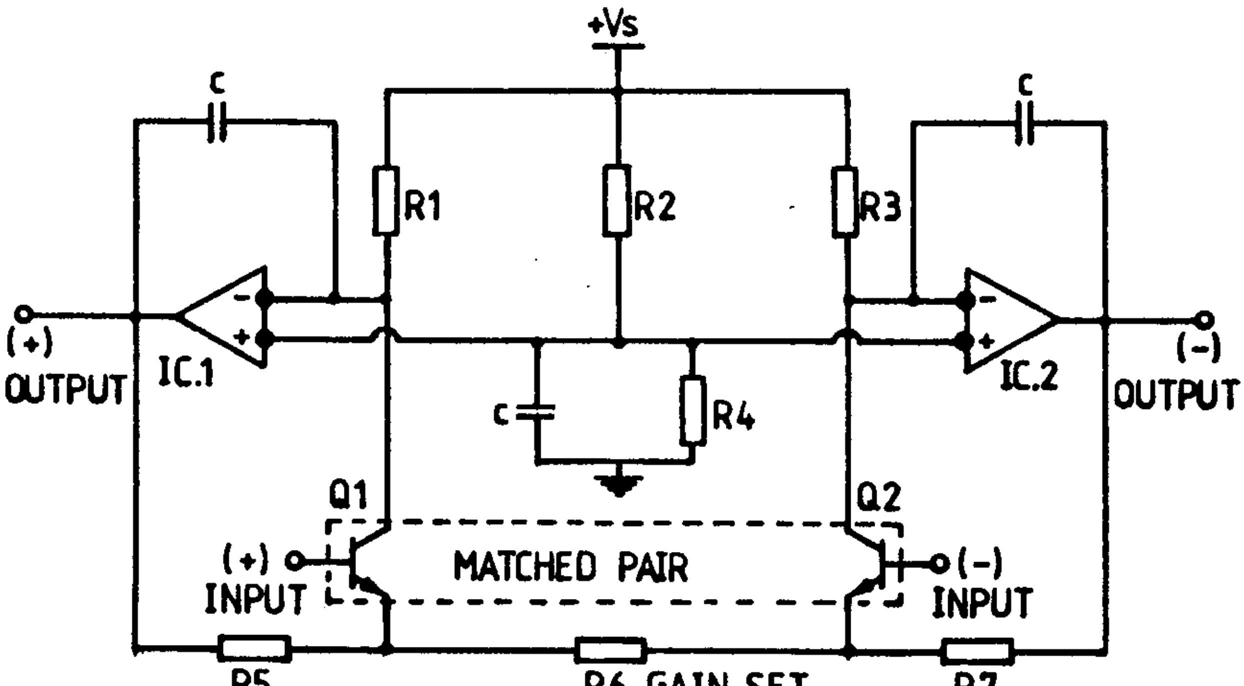

FIG. 4 NEW INPUT STAGE.

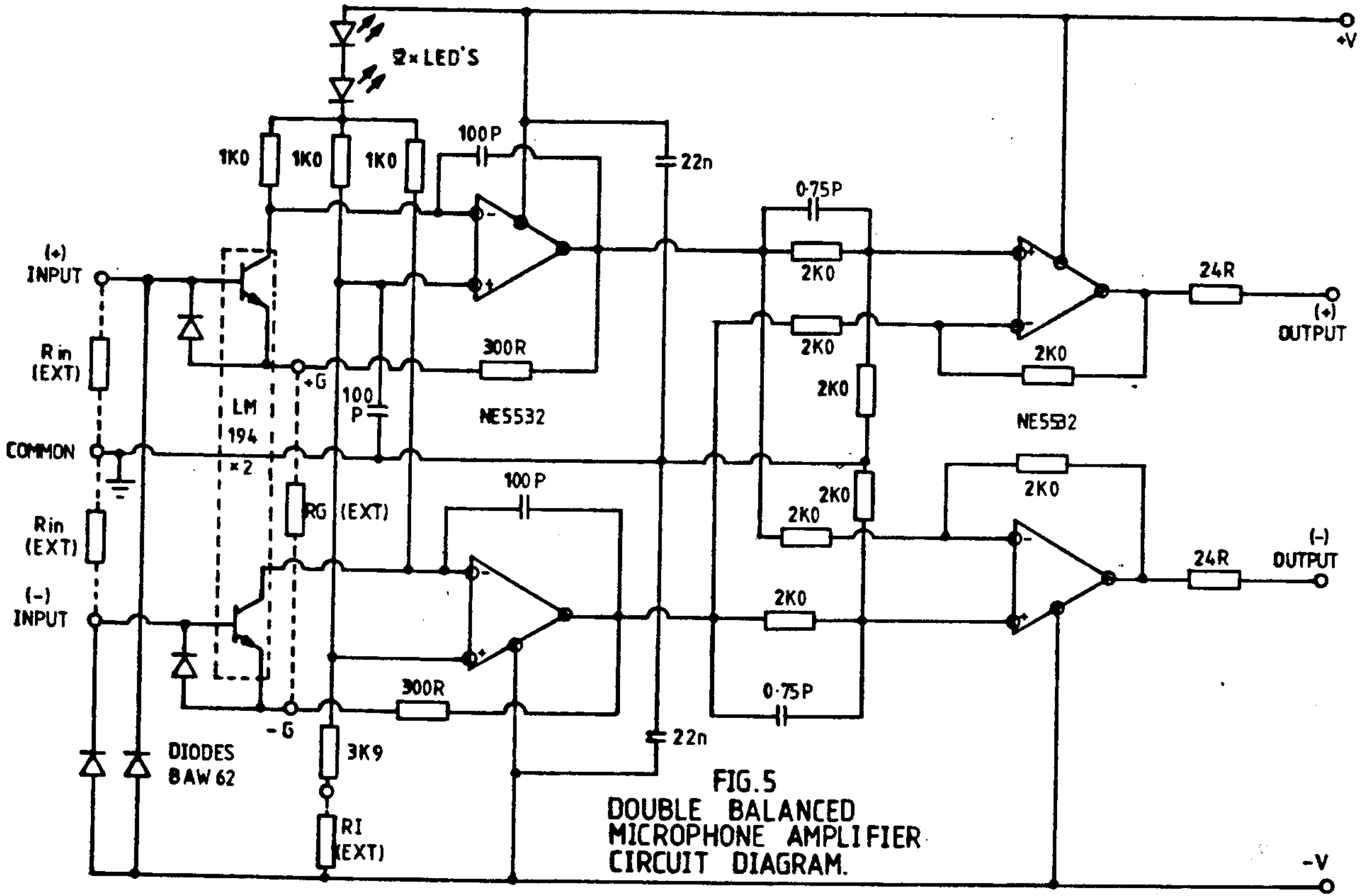

FIG. 5
DOUBLE BALANCED
MICROPHONE AMPLIFIER
CIRCUIT DIAGRAM.

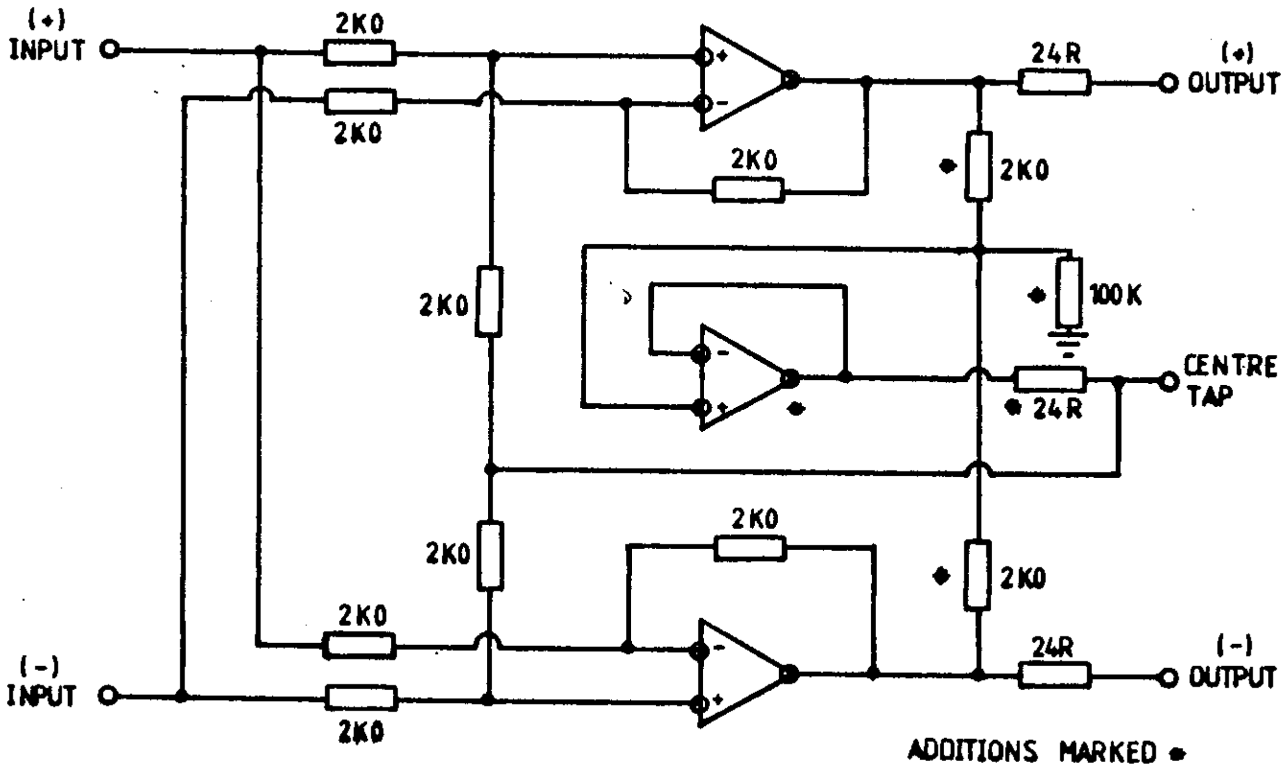

FIG. 6
PROPOSED OUTPUT STAGE
WITH CENTRE TAP.

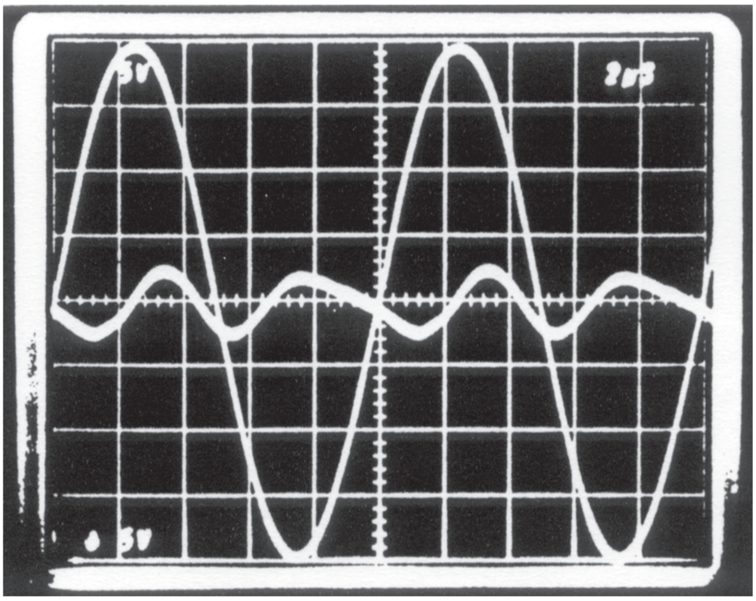

FIGURE 7

100 KHz Sine Wave
60 dB Gain
1K5 Balanced Load
40V P.P. Output
0.15% T.H.D.

Only Low Order
Distortion Visible.

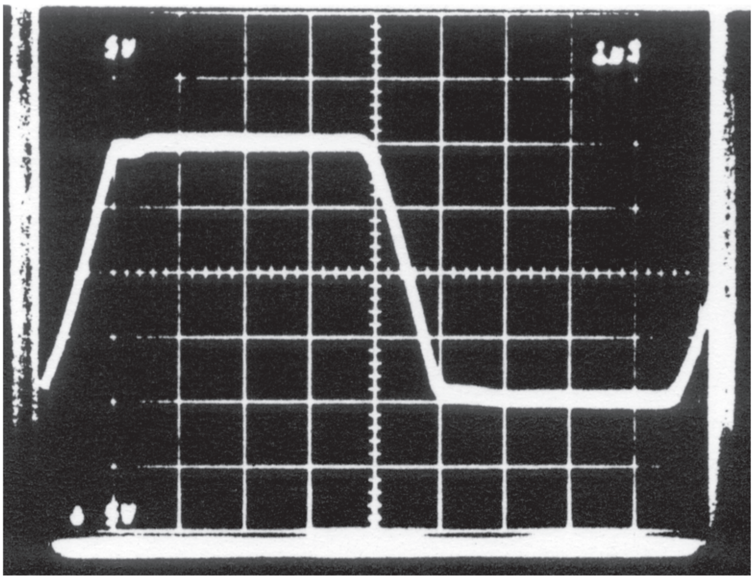

FIGURE 8

100 KHz Square Wave
60 dB Gain
1K5 Balanced Load
< 1µS Rise Time

No Slew Induced
Distortion Visible.

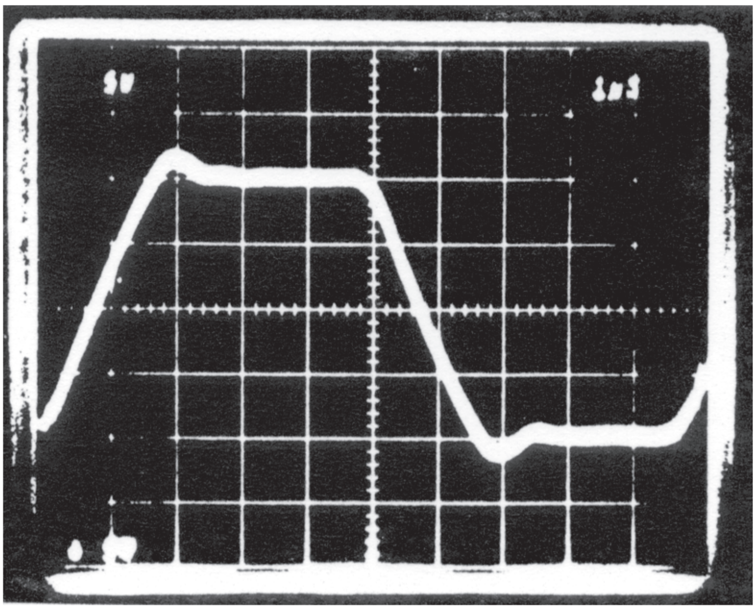

FIGURE 9

100 KHz Square Wave
60 dB Gain
1K5 and 3n3 Balanced Load
< 1.5µS Rise Time
< 10% Overshoot

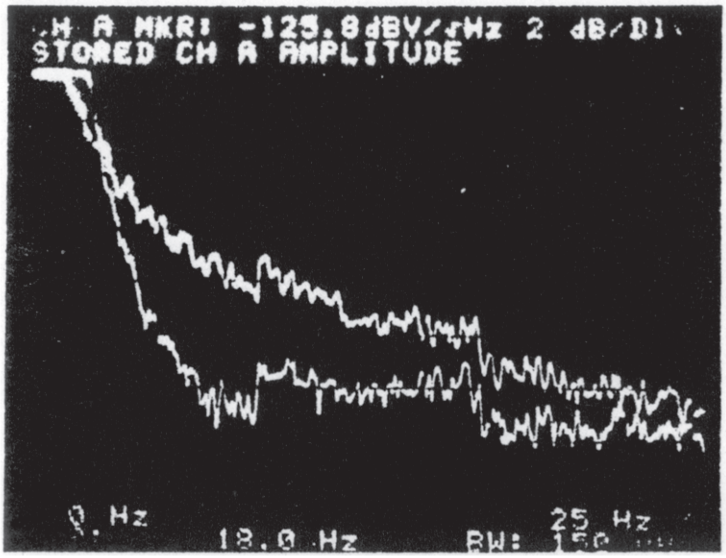

FIGURE 10

DC to 25 Hz Noise

54 dB Gain

Top Trace

2 x BFW16A add +1.5 dB for Lower Gain Devices

Bottom Trace

2 x LM194

4mA Collector Current
Input Short Circuit

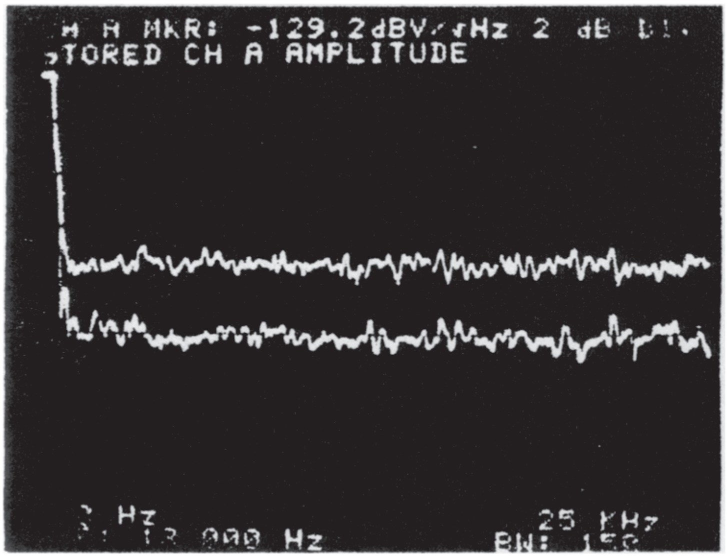

FIGURE 11

DC to 25 KHz Noise

54 dB Gain

Top Trace

2 x LM194

Bottom Trace

2 x BFW16A add +1.5 dB for Lower Gain Devices

4mA Collector Current
Input Short Circuit.

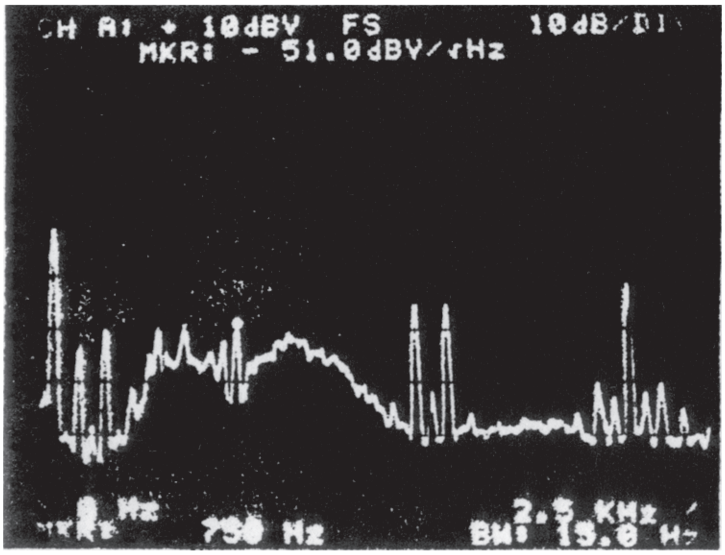

FIGURE 12

Intermodulation Distortion

60 Hz and 750 Hz

1:4 Amplitude

20 Volt Peak to Peak

1K5 Balanced Load

54 dB Gain

0.006% Total

Residual Components

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DOUBLE BALANCED MICROPHONE AMPLIFIER

PHILIPS OM1556

The combination of a balanced microphone transformer and a low noise amplifier is normally used for studio microphones. A hybrid microcircuit has been developed to replace the transformer and the associated amplifier. This incorporates the balanced and floating virtues of a transformer, without the signal loss introduced ahead of a low noise amplifier. The gain and input stage current is adjustable. High common mode rejection is achieved with a good noise figure at all gain settings. The output is available as a single ended or balanced output and is capable of driving 600 ohm lines.

Transformers are commonly used on microphone pre-amplifier inputs for several reasons : Isolation, "Phantom" powering of the microphone, obtaining good common mode rejection of unwanted signals, and impedance step up to obtain a good noise performance.

Some disadvantages are frequency response limitations, size and cost requirement for magnetic shielding, and loss of dynamic range due to voltage step up. Transformers can exhibit relatively high distortion particularly at low frequencies.

The hybrid, OM1556, microphone amplifier replaces the transformer for most applications. Being direct coupled on its input the large and matched input coupling capacitors required for transformerless designs are not required.

The input stage has several unique features. Two LM194 super matched dual transistors are physically cross connected in parallel. Each transistor is connected in a feedback loop with half a NE5532 operational amplifier. The emitter current of each trasistor goes into the output of each operational amplifier.

The transistor current is set by a bridge connection on the inputs of the operational amplifiers. The 300 ohm feedback resistors give the highest dynamic range, that is, maximum output level consistent with the best noise figure. The external gain setting resistor can have a low value particularly at high gain settings, where it can be less than one ohm. This enhances the excellent noise performance of the input transistors.

Each output stage is connected in the classic four equal resistor instrumentation amplifier connection. The output stages sum the output from both input stages. A gain of two is therefore obtained between the two outputs of the out- put stage.

.../2

The output impedance of each output is 25 ohms and this terminates long lines when the hybrid is used for this purpose.

The input stage transistor collectors have very little signal at any gain setting or level. This results in virtually no collector modulation of the transistor base region (Early Effect), that is common in many input stage designs. The miller input capacitance variation is also reduced. Both these effects, if present, can have an effect on the signal source particularly if it is inductive, and could degrade the quality of the input signal.

Field tests in various studios have shown good results with no apparent problem that can be present with transformerless input stages. When substituted in some of the better quality mixing consoles the only obvious difference being the better noise figure of the hybrid. The input stage can have up to twelve volts applied as "Phantom Powering" for condenser or electret type microphone polarisation.

A technical paper on the design and development of the hybrid was presented at the first Australian Regional Convention of the Audio Engineering Society in Melbourne on 26th September, 1984.

GRAEME J. COHEN

PHILIPS DATA SHEET OCTOBER, 1986

DOUBLE BALANCED MICROPHONE AMPLIFIER OM1556

General Description

The OM1556 is a very low noise balanced input and balanced output audio preamplifier hybrid. It can be used to replace the balanced microphone transformer and associated amplifier in high grade audio equipment such as studio consoles.

It is direct coupled to eliminate the normal large input coupling capacitors. The input stage has a good common mode voltage swing to accommodate phantom powering.

The common mode rejection can be trimmed to give excellent performance up to 100KHz.

Being double balanced the hybrid module has four basic circuit configuration for maximum flexibility.

1. Balanced input to Balanced output
2. Balanced input to Single ended output
3. Single ended input to Balanced output
4. Single ended input to Single ended output

Features

. Fully Balanced input and output

. Very low noise < $1nV/\sqrt{Hz}$

. D.C. coupled

. Large small signal bandwidth

. Power bandwidth to 140KHz

. Output drive capability of 600 ohms

. Common mode input range > +/- 6V to +/- 12V

. Input stage current optimisation for input impedance

.../2

Hybrid Circuit Description

The input stage uses two super matched dual transistors physically cross connected in parallel. Each transistor is connected in a feedback loop with half a operational amplifier. The emitter current of each transistor goes into the output of each operational amplifier.

The transistor current is set by a bridge connection on the inputs of the operational amplifiers. The 300 ohm feedback resistors give the highest dynamic range i.e. maximum output swing consistent with the best noise figure. The external gain setting resistor can have a low value particularly at high gain settings where it can be less than one ohm. This enhances the excellent noise performance of the input transistors.

Each output stage is connected in the classic four equal resistor instrumentation amplifier connection. Each stage sums the output from both input stages. A gain of two is therefore available between the two outputs of the output stage.

The output impedance of each output is 25 ohms and this terminates long lines when the hybrid is used for this purpose.

A more detailed analysis of the advantages and circuit description is available.

Reference Data	Typical
Maximum Supply Voltage	+/- 18V
Supply Current	18mA to 32mA
Noise Voltage Spectral Density	0.7nV/ Hz
Noise Current Spectral Density	1pA/ Hz
Equivalent Input Noise in 20KHz Bandwidth	100nV
Large Signal Bandwidth	140KHz
Slew Rate	18V/µS
Output into 600 Ohms at 100KHz	16V RMS
Corresponding Voltage Level	24 dBV
Output into 1200 Ohms at 100KHz	20V RMS
Corresponding Voltage Level	26 dBV
Gain Range Single Ended Output	0 to 60dB
Gain Range Balanced Output	6 to 66dB
Total Harmonic Distortion at Maximum Loaded Output with 30dB Gain at 20KHz	.003%
Common Mode Input Range	+/- 6V to +/- 12V

$$\text{Gain} = \frac{600}{RG} + 1 \quad \text{for Single Output}$$

$$\text{Gain} = 2\left(\frac{600}{RG} + 1\right) \quad \text{for Balanced Output}$$

$$\text{Input Stage Collector Current} = \frac{\text{Vs total} -3.4V}{4K9 + RI}$$

RI = 1K5 (5mA) Used for Measurements

Balanced Microphone Preamplifier - Line Driver

Application Notes

The two inputs, pin 1 and pin 2, require bias resistors to a common point within 12 volts of the earth or common pin, Pin 7. The maximum input offset voltage, if used, depends on input stage current set, and the maximum output required.

For best D.C. stability these resistors should be of a low value without loading the source resistance.

Pin 8, the input stage current setting pin, requires a resistor to Pin 10, the negative power supply pin. This current can be determined using the "Optimum input stage current graph" and depends on total source resistance. The current should be measured directly in series with RI, as it will vary with the supply voltages. Alternatively a current source may be substituted for RI to give ultimate power supply rejection.

A final resistor, RG, is required to set the gain. The gain is calculated as shown in the reference data. For example a 1.2 ohm resistor gives a gain to one output terminal of 54dB. A gain of 60dB is then obtained between the output terminals.

A 1K ohm antilog potentiometer in series with a 1 Ohm resistor will give a gradual 50dB of gain control.

For typical low impedance microphones the input resistors could be 300 ohm each, and the input stage current setting resistor RI could be 1K5.

The output pins have an output impedance of approximately 25 ohm which terminates long cables. The outputs are current limited and are capable of driving a balanced 600 Ohm load.

The common mode rejection and D.C. balance can be externally trimmed for ultimate performance in critical applications.

The +Vcc and -Vcc pins should not exceed 18 volts each.

Diodes should be fitted across the input transistor base emitter junctions as shown. Either power diodes or schottky diodes should be used as either has a low turn on voltage.

The two input bias resistors should be compatible with the input stage bias current; that is a low value used with high input stage current.

For most applications phantom powering directly onto the input terminals of six volts will not inhibit the output level from the hybrid. Also up to twelve volts can be applied with some reduction of the output level. No blocking capacitors are required and only matching of the input resistors is needed to ensure good common mode rejection.

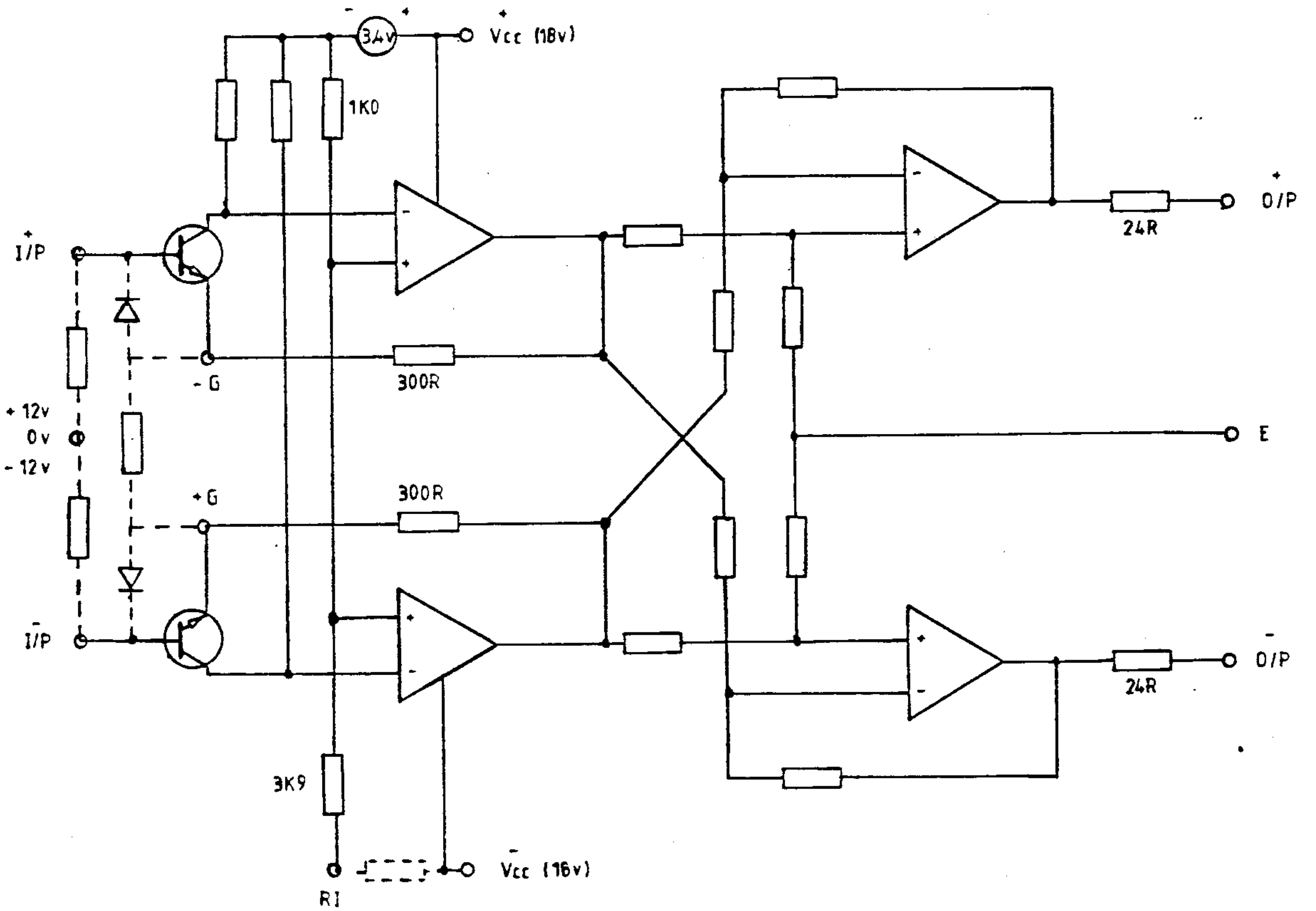
.../5

TYPICAL APPLICATIONS

	Microphone/Tape Head Preamplifier	Microphone/Moving Coil Cartridge Preamplifier
Gain required for Balanced Output	20 dB	40 dB
Output Stage Gain	6 dB	6 dB
Input Stage Gain	14 dB	34 dB
Feedback Resistor, RG	150 Ω	12 Ω
Feedback Noise Resistance	120 Ω	11.5 Ω
Allowing re of 10Ω and rb of 10Ω then Feedback plus re + rb	140 Ω	31.5 Ω
Equivalent Noise Voltage for 3dB Noise Figure in 20KHz Bandwidth and allowing for Output Stage	200 nV	140 nV
Referred to Output	2 μV	14 μV
Maximum Output Level	20 V	20 V
Input Overload	2 V	200 mV
Dynamic Range	140 dB	123 dB
Source Resistance	140 Ω	31.5 Ω

JM 1556

BLOCK DIAGRAM



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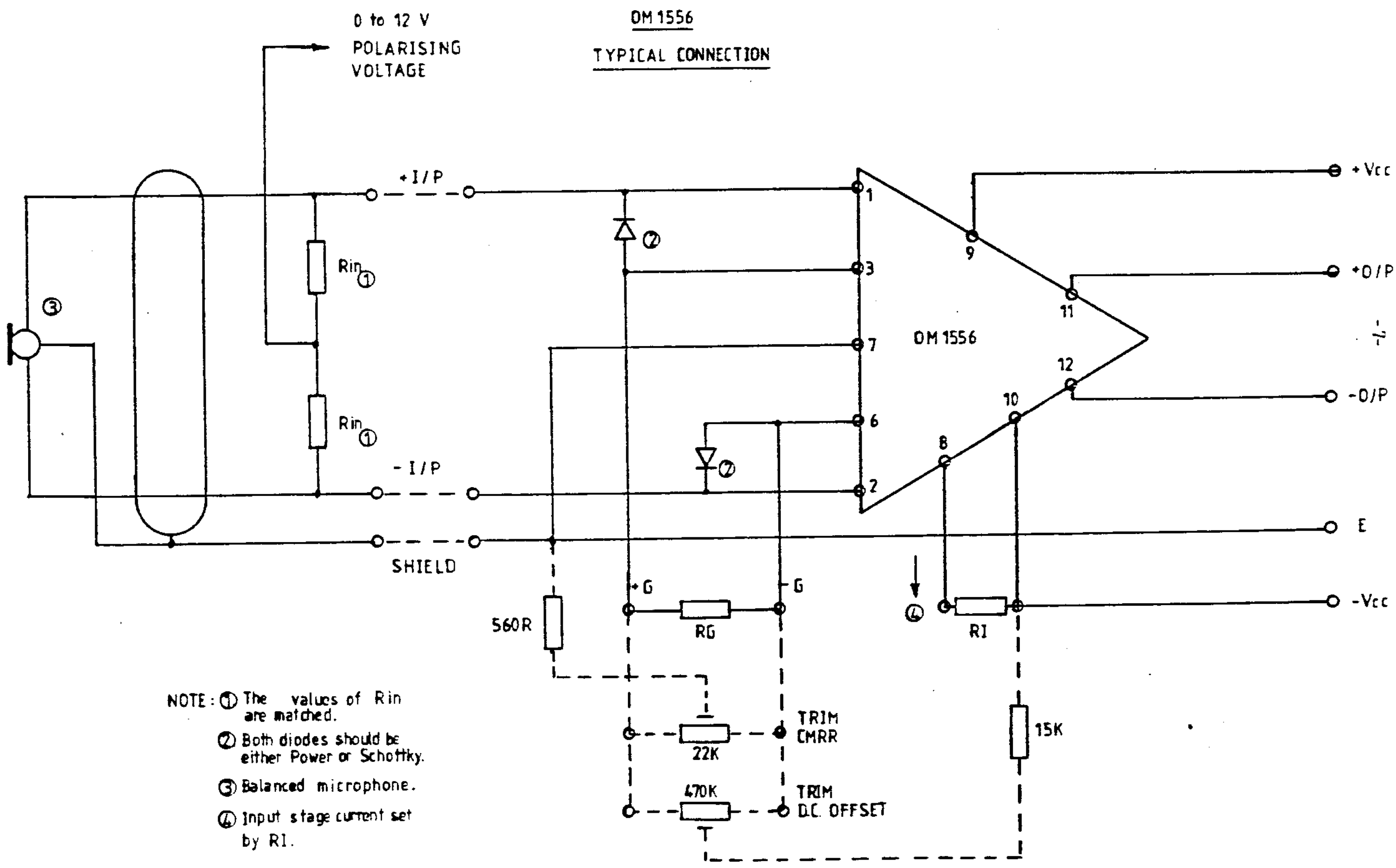
TYPICAL CONNECTION



NOTE: ① The values of Rin are matched.

② Both diodes should be either Power or Schottky.

③ Balanced microphone.

④ Input stage current set by RI.

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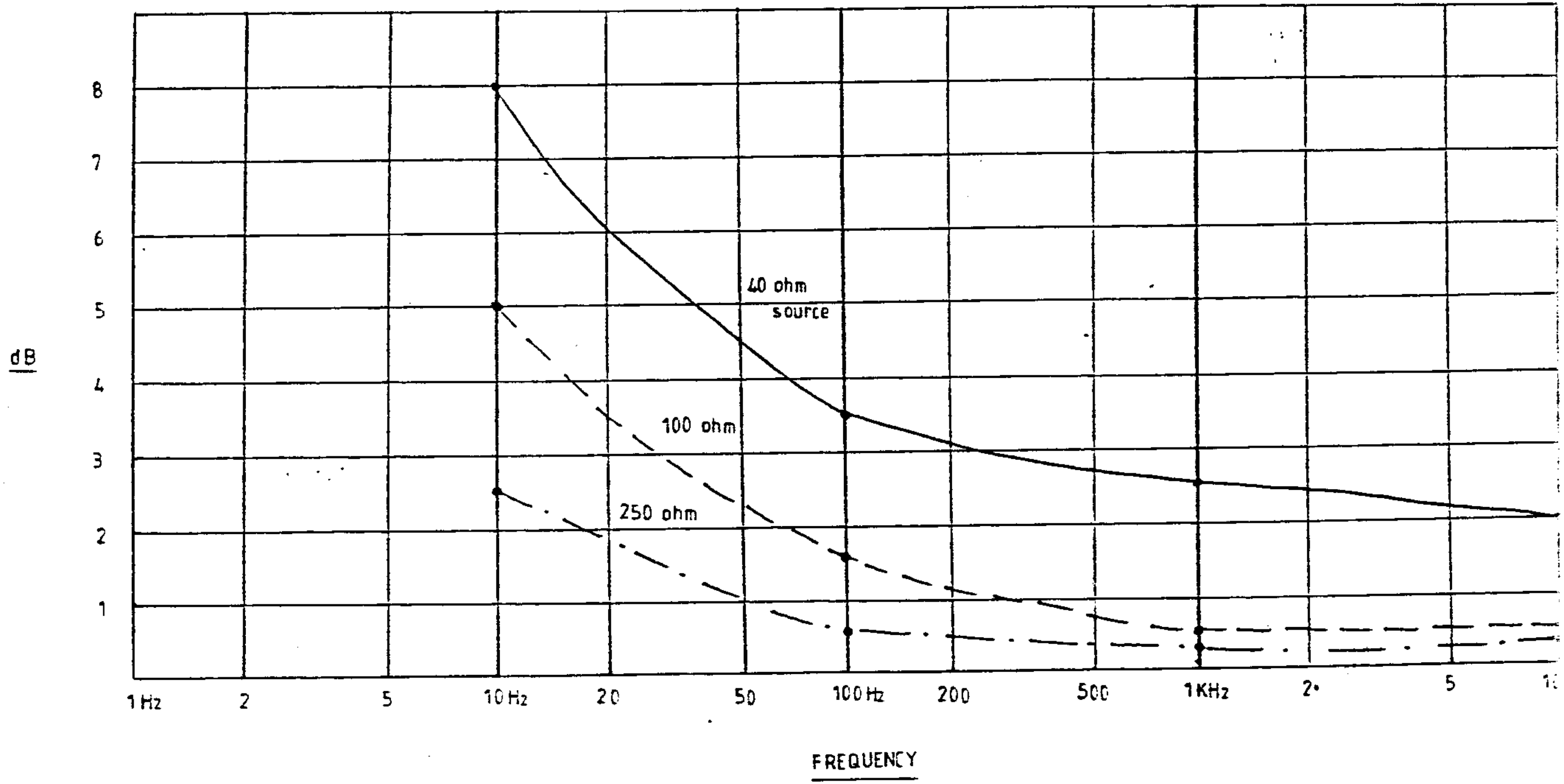
TYPICAL NOISE FIGURE FOR
4mA INPUT STAGE CURRENT



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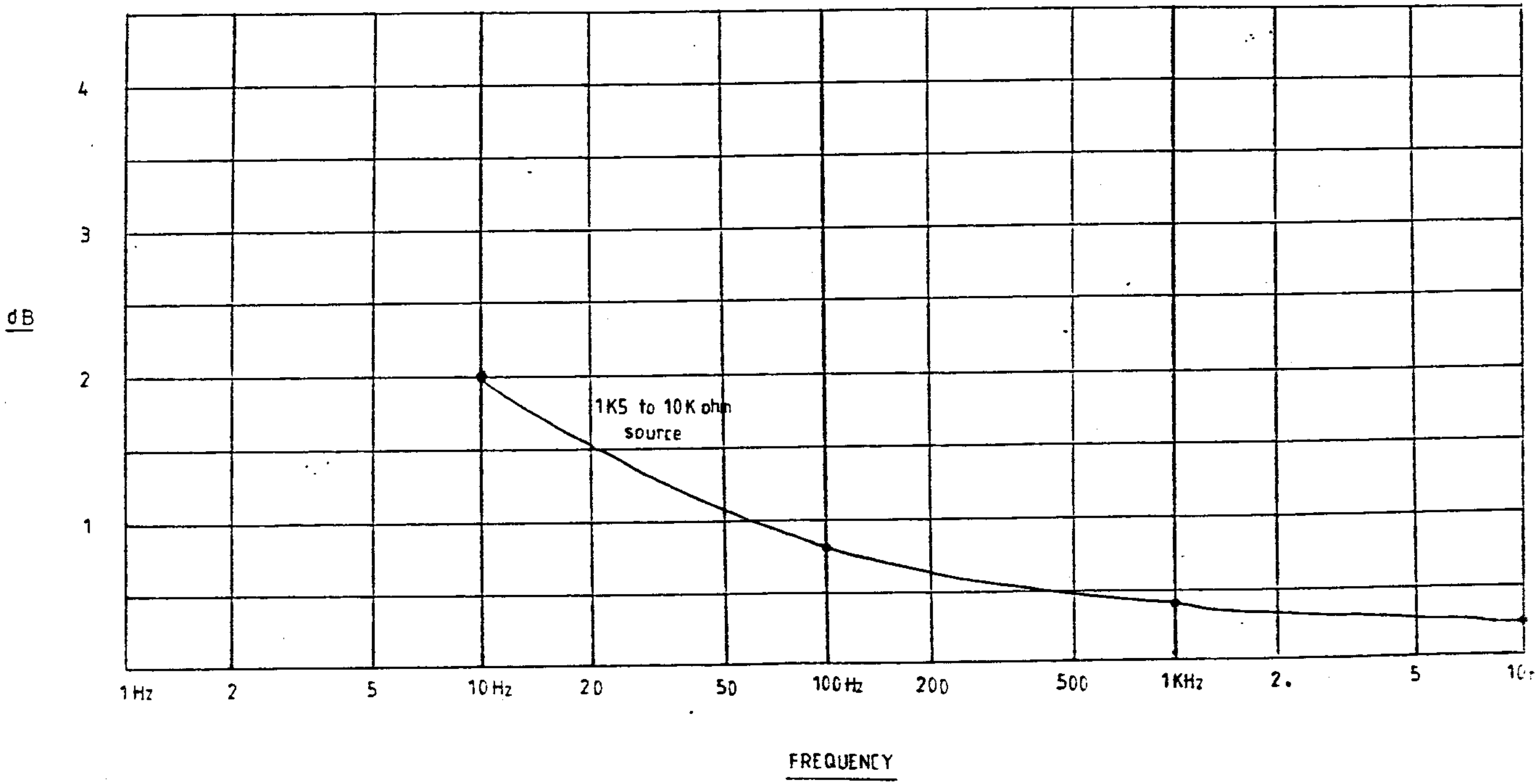
TYPICAL NOISE FIGURE FOR
500μA INPUT STAGE CURRENT



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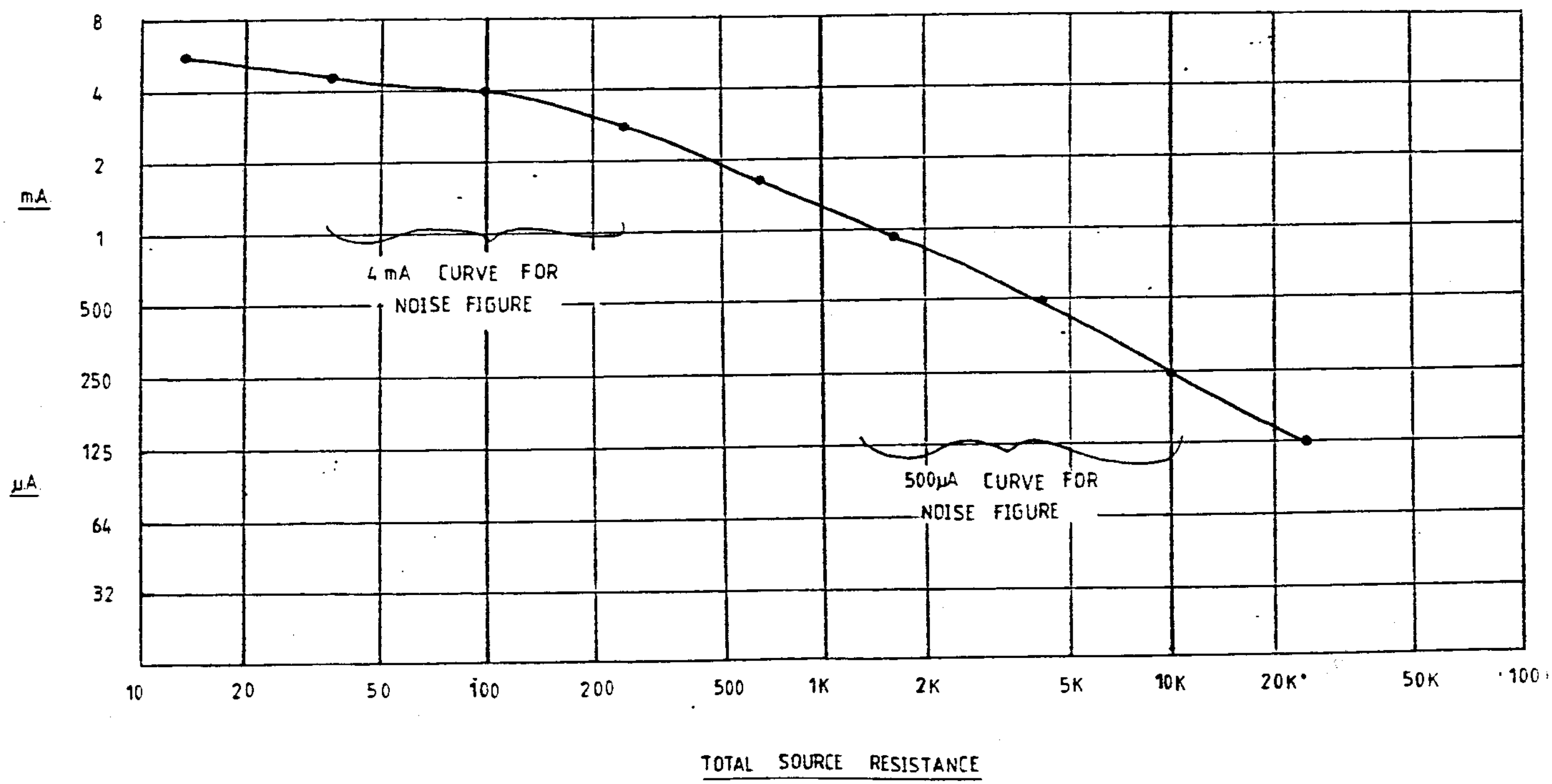
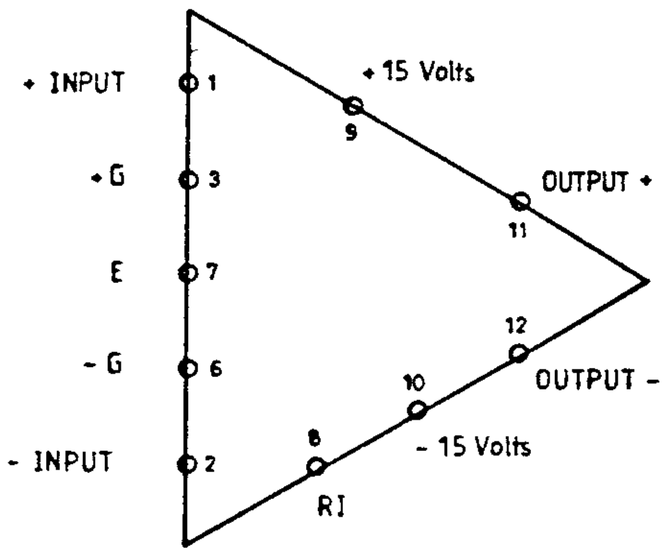
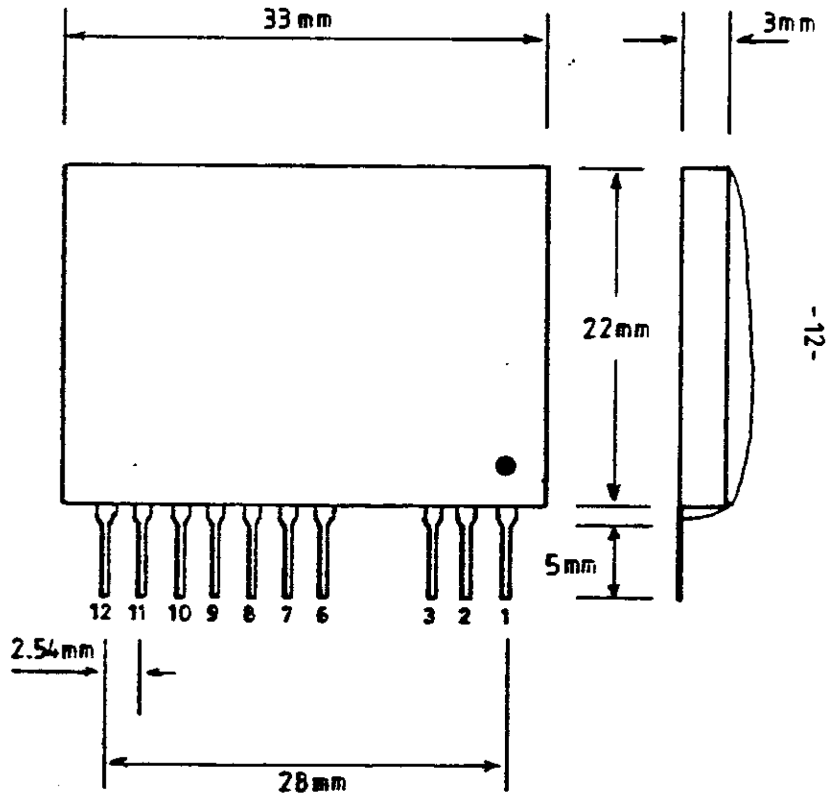
OPTIMUM INPUT STAGE CURRENT



DOUBLE BALANCED MICROPHONE AMPLIFIER

DM 1556





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$49 + s/t

11/87

7th November, 1985

THICK FILM HYBRID

DOUBLE BALANCED MICROPHONE AMPLIFIER

TYPE OM1556

PRICE

1 - 10 PCS	$29.00
11 - 50 PCS	$27.00
51 - 100 PCS	$25.00

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▷ *Precision RF Channel Development for High Performance HF Systems*
Presented at the Fifth International Conference of Radio Receivers, York University, UK, 1994
(co-author: Winkler, C.)

▷ *Linear Wideband Receiver System*
Presented at the Sixth International Conference of Radio Receivers, Bath University, UK, 1995

Technical Papers (Audio)

▷ *Double Balanced Microphone Amplifier*
Presented at the 1984 Australian Regional Convention of the Audio Engineering Socity (AES), Melbourne, Australia. Preprint 2106.

▷ *A Music Amplifier - A New Approach*
Presented at the 1988 2nd Australian Regional Convention of the AES, Melbourne, Australia. Preprint 2677.

▷ *A Pulse Test Method for Amplifiers*
Presented at the 1991 3rd Australian Regional Convention of the AES, Melbourne, Australia. Preprint 3087.

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▷ *Transmission Line Audio Transformers*
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▷ *Dual Single Ended Amplifier*
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This concept is patented.

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