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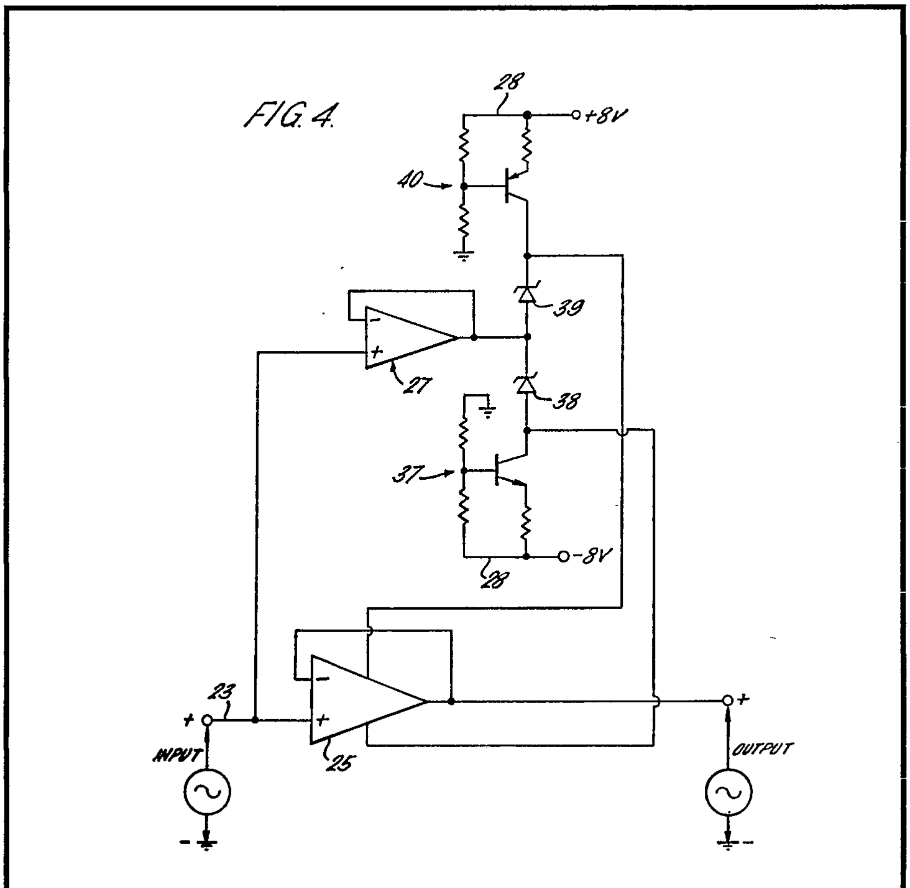
(54) **Interface circuits**

(57) An interface circuit comprises voltage followers 25, 27 having a common input 23, with voltage follower 27 having fixed power supply rails 28 and voltage follower 25 having swinging power supply rails the voltage levels of which are varied in accordance with the output signal of 27, and in phase with the input signal. It is shown mathematically in the Specification that the gain of 25 is then given by $(1-1/A_1A_2)$, where A_1, A_2 are the respective open loop gains of 25, 27, i.e. the gain is nearer unity than for 25 alone with fixed supply rails. In the circuit of Fig. 4 the PD between the swinging supply rails is maintained substantially constant by Zener diodes 38, 39 supplied by current sources 37, 40. When two interface circuits according to the invention are connected in the respective input circuits of a differential amplifier (15), Fig. 2 (not shown), its effective input impedance and common mode rejection are both increased.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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FIG. 1.

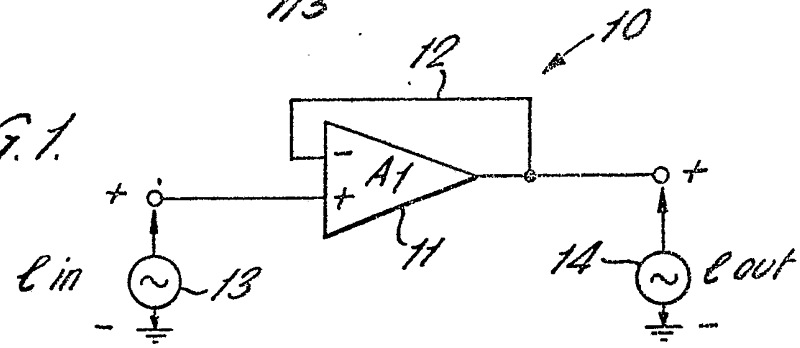


FIG. 3.

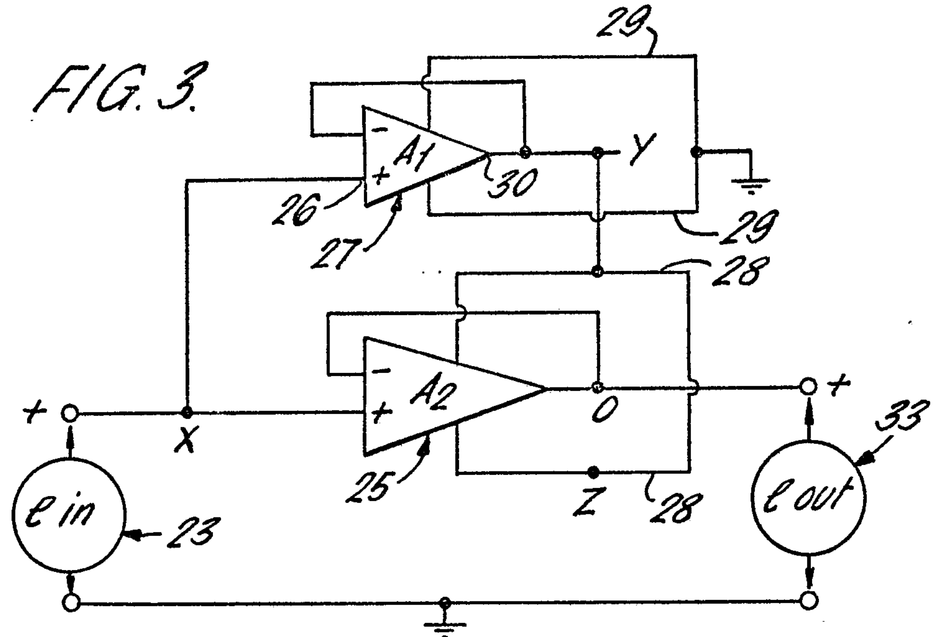
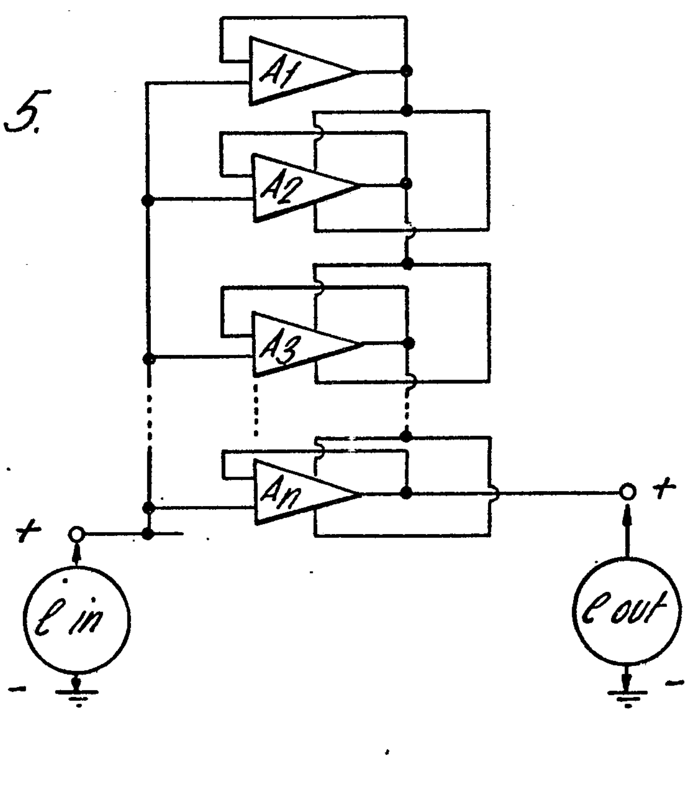


FIG. 5.



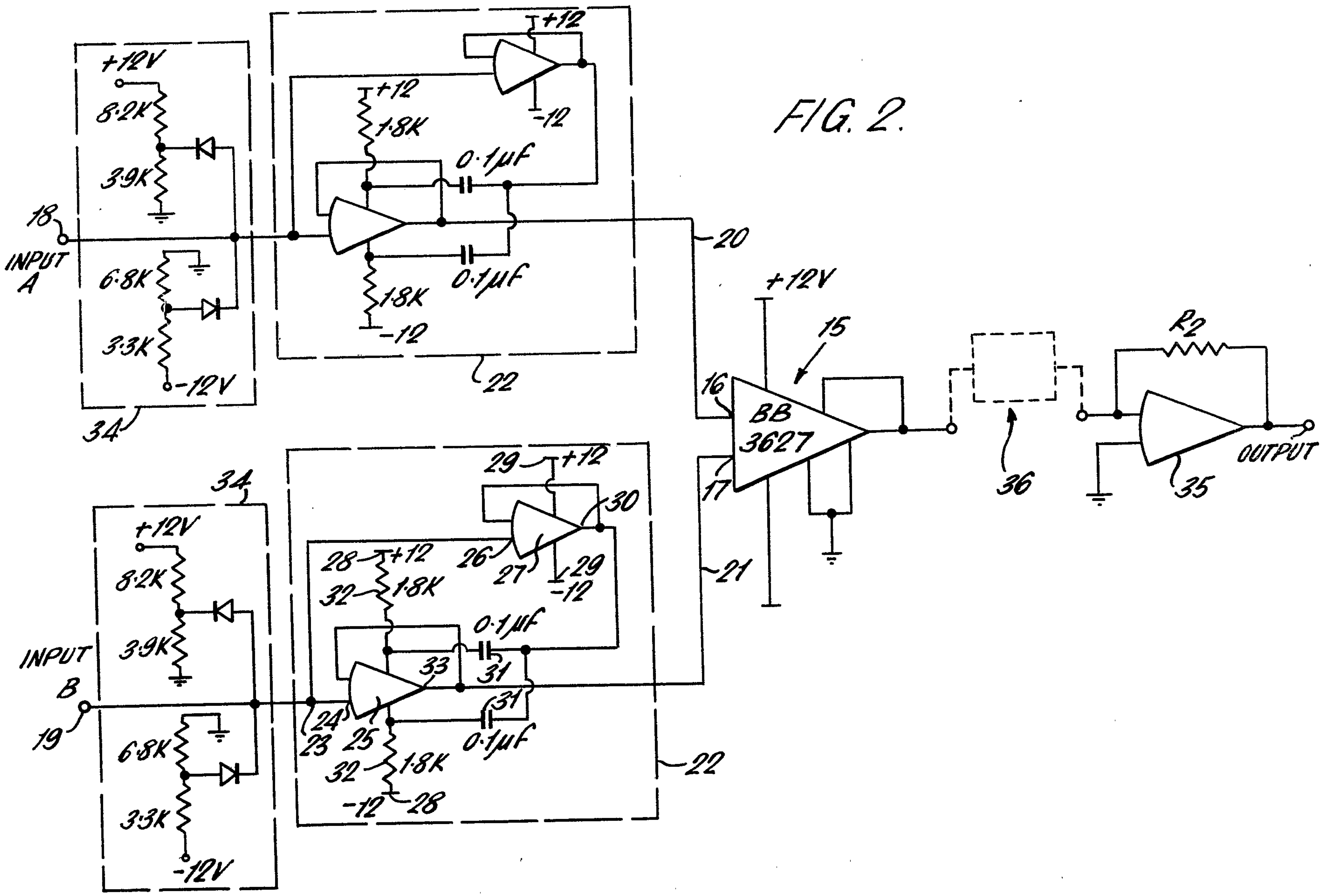
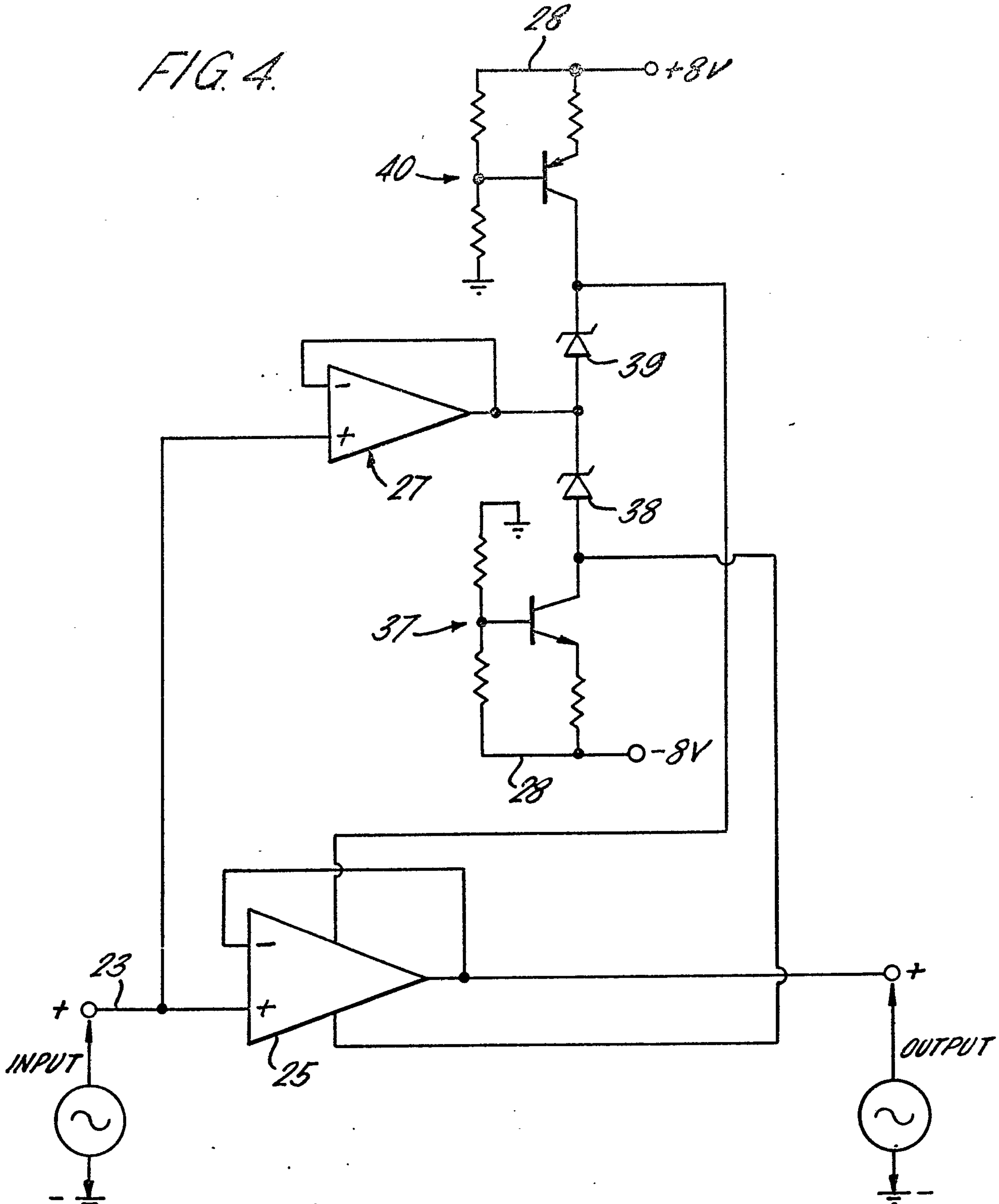

INPUT A
18
+12V
8·2K
3·9K
6·8K
3·3K
-12V
34
+12
-12
1·8K
0·1μF
22
20
INPUT B
19
23
24
25
26
27
28
29
30
31
32
33
21
+12V
15
16
17
BB 3627
36
R2
35
OUTPUT

FIG. 2.

FIG. 4.



SPECIFICATION

Improvements in or relating to interface circuits

This invention relates to interface circuits, for example buffer circuits, and particular, but not exclusively, to voltage follower circuits.

According to the present invention there is provided a circuit comprising an input, an output, a first voltage follower connected between the input and the output a pair of swinging supply rails for feeding power to said voltage follower, a second voltage follower, and a pair of fixed power supply rails for feeding power to said second voltage follower, the input of the second voltage follower being connected to the circuit input and the output of the second voltage follower being connected to the swinging power supply rails via d.c. decoupling means whereby, in use, the voltage levels of the swinging power supply rails are varied in accordance with an input signal on the circuit input whilst the voltage drop between the swinging supply rails is maintained substantially constant.

For the purposes of this specification the term "d.c. decoupling means" includes active means which maintain the d.c. levels in he circuit substantially constant.

The d.c. decoupling means may comprise at least one capacitor.

Alternatively the d.c. decoupling means may comprise a series circuit of a constant current source, zenner diode, a znner diode and a constant current source, the series circuit being connected between the swinging power supply rails, the output of the second voltage follower being connected between the zenner diodes and the first voltage follower being connected to the series circuit between the respective pairs of zenner diodes and constant current sources.

According to a further aspect of the invention there may be provided a circuit assembly comprising at least two circuits claimed in any one of Claims 2 to 3, the circuits being connected such that, in use, the input signals is fed to each circuit and such that the output of each but the last of said circuit controls the voltage levels of the swinging power supply rails of the succeeding circuit.

According to a still further aspect in the invention there is provided signal amplifying apparatus comprising a differential amplifier, an input for each of the differential amplifier input and a voltage follower connected between each input and its respective differential amplifier input.

The voltage followers circuits in the above signal amplifying apparatus may be constituted by any one of the circuits set out above or by the circuit assembly as set out above.

Specific embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a circuit diagram of a known voltage follower;

Figure 2 is a circuit diagram of a signal amplifying apparatus including a circuit according to the invention;

Figure 3 is an a.c. equivalent circuit of the circuit according to the invention shown in Fig. 2;

Figure 4 is an a.c. equivalent circuit of an alternative embodiment of the circuit according to the invention shown in Fig. 2; and

Figure 5 is a schematic circuit of a further embodiment of the circuit according to the invention shown in Fig. 2.

Fig. 1 shows a conventional voltage follower circuit, generally indicated at 10, comprising a operational amplifier 11, having a feed back loop 12 a signal input 13 and a signal output 14.

The ratio of the input voltage, e_{in}, and the output voltage, e_{out}, is known as the close loop gain, G_1. It is well established for a voltage follower of this type that

$$G_1 = \frac{A_1}{1 + A_1},$$

where A_1 is the open loop gain.

By applying the binomial approximation this equation becomes

$$G_1 = 1 - \frac{1}{A_1}.$$

It will thus be appreciated that whilst the voltage follower should have a gain of unity, in practice with this conventional circuit the gain is less than this by a factor of

$$\frac{1}{A_1}.$$

This factor can be reduced by increasing A_1 but if it is increased too much the circuit becomes unstable and also heavy frequency compensation must be applied.

This means that not only do conventional voltage followers not operate very satisfactorily but also where it is important that pairs of such circuits operate substantially identically considerable trouble has to be taken to test circuits to find matched pairs, because in manufacture variations occur in the open loop gain of the amplifiers of such circuits.

Fig. 2 shows a single amplifying apparatus, which is particularly designed for use as a bio-instrumentation amplifier. Because the signal to noise ratio of bio-instrumentation signals it is often low, it is desirable for such amplifiers to have both a high CMRR and a high input impedance. Conventionally differential amplifiers are used, and although many such amplifiers are available with a high theoretical CMRR, in practice there CMRR is often severely deteriorated by imbalance in the input leads to the inputs of the differential amplifiers. Further frequently the input impedance of such device is lower than is desirable for bio-instrumentation.

The amplifying apparatus shown in Fig. 2 comprises a unity gain differential amplifier generally indicated at 15, having inputs 16 and 17, which are connected to respective inputs 18 and 19 by means of leads 20 and 21 voltage follower circuits 22.

The provision of voltage followers circuits in the input leads to the differential amplifier, if they are properly matched, will provide the differential amplifier 15, with matched input and thus help to maintain a high CMRR for the differential amplifier. Also the high input impedance of the voltage followers will provide the amplifier as a whole with the desired high input impedance.

Referring to one of the circuits 22 it comprises an input 23, which is connected to the positive input 24 of a first voltage follower 25. The input 23 is also connected to the positive input 26 of a second voltage follower 27. The first voltage follower 25 is provided with swinging power supply rails 28, whilst the second voltage follower is provided with fixed power supply rails 29. The output 30 of the second voltage follower 27 is connected to each of the swinging power supply rails 28 via decoupling capacitors 31 and resistors 32. The output 33 is connected to the input 17 of the differential amplifier.

The operation of circuit 22 will now be described with reference Fig. 3, which shows a schematic a.c. equivalent circuit of the circuit 22.

The output voltage Vy of the second voltage follower 27 is equal to

$$e_{in}\left(1-\frac{1}{A_1}\right)$$

and it will be seen that with respect to ground this is also the value of the voltage at Z, V_z. Thus the voltage drop VxZ between points X and Z, i.e. the input of voltage follower 25, equals

$$e_{in}-V_y = e_{in} - e_{in}\left(1-\frac{1}{A_1}\right) = \frac{e_{in}}{A_1}.$$

The output voltage of voltage follower 25 with respect to power rail 28,

$$V_{oz}, \text{ equals } V_{xz}G_2 = V_{xz}\left(1-\frac{1}{A_2}\right) = \frac{e_{in}}{A_1}\left(1-\frac{1}{A_2}\right)$$

where G_2 is the close loop gain of the first voltage follower 25 and A_2 is the open loop gain of voltage follower 25. It will be appreciated that

$$e_{out} = V_{oz} + V_z = e_{in}\,(1 - \frac{1}{A_1A_2})\,.$$

$$\text{If } A_1 \widehat{=} A_2 \widehat{=} A, \text{ then } e_{out} = e_{in}(1 - \frac{1}{A^2})\,.$$

It will thus be seen that using circuit 22 e_{out} is much closer to e_{in} then using the conventional circuit and therefore the manufacturing differences in the open loop gain are considerably less relevant and hence the need to test circuits to find matched pairs is removed.

It will be seen from the mathematics that as e_{in} rises the swinging power supply rails 28 are raised in accordance with e_{in}, by virtue of the output signal of voltage follower 27. This not only has the effect of reducing the error in unity gain, as explained above, but also reduces the level of the input signal e_{in} as seen by voltage follower 25. This means that the voltage follower 25 operates within a small dynamic range and hence introduces less distortion.

Returning to Fig. 2 it will now be seen that the combination of circuits 22 and differential amplifier 15 provide an amplifier with a high input impedance and high CMRR.

Protection diode circuits 34 are provided between the amplifier inputs 18 and 19 and their respective circuits 22.

As differential amplifier 15 is a unity gain amplifier, a high gain amplifier 35 is provided to amplify the output of differential amplifier 15 which may be previously filtered at 36.

Fig. 4 shows an preferred circuit to the arrangement shown in Fig. 3. In this embodiment the decoupling capacitors 31 are replaced by an active series circuit connected between rails 28, the circuit comprising a constant current source 37, a zenner diode 38, further zenner diode 39 and a further constant current source 40.

The output of voltage follower 27 is connected between the zenner diode 38 and 39 whilst the voltage follower 25 is connected to the series circuits between the pairs of zenner diodes and constant current sources. It will be seen that the series circuits serve to maintain constant d.c. levels in the circuit connecting voltage follower 25 to voltage follower 27. Thus the voltage follower 25 is only sensitive to a.c. variations in the output of voltage follower 27. It will be appreciated that the series circuit therefore fulfils the same function as the decoupling capacitors 31, but it has the advantage that it can be constructed with the voltage followers in a single chip.

Fig. 5 shows how a series of voltage followers can be connected essentially in the manner hereinbefore described. It will be seen that the close loop gain

$$G = (1 - \frac{1}{A^n})$$

where n is the number of amplifiers and hence the error in the unity gain of the circuit can be significantly reduced by increasing the number of voltage followers.

It will be appreciated that the high input impedance and low gain error of the circuit 22 and its variations described above make it particularly useful as a buffer circuit or interface circuit.

CLAIMS

1. A circuit comprising an input, an output a first voltage follower connected between the input and the output, a pair of swinging supply rails for feeding power to said first voltage follower, a second voltage follower, and a pair of fixed supply rails for feeding power to said second voltage follower, the input of the second voltage follower being connected to the circuit input and the output of the second voltage follower being connected to the swinging power supply rails via d.c. decoupling means whereby, in use, the voltage levels of the swinging power supply are varied in accordance with an input signal on the circuit input whilst the voltage drop between the swinging power supply rails is maintained substantially constant.

2. A circuit as claimed in Claim 1 wherein the d.c. decoupling means comprises at least one capacitor.

3. The circuit as claimed in Claim 1 where in the d.c. decoupling means comprises a series circuit of a constant current supply, zenner diode, zenner diode and a constant current supply, the series circuit being connected between the swinging power supply rails, the output of the second voltage follower being connected between the zenner diodes and the first voltage

follower being connected to the series circuit between the respective pairs of zenner diodes and constant current supplies.

4. A circuit assembly comprising at least two circuits as claimed in any one of Claims 2 to 3 the circuits being connected such that, in use, the input signal is fed to each circuit and such that the output of each but the last said circuit controls the voltage levels of the swinging power supply rails of the succeeding circuit.

5. Signal amplifying apparatus comprising a differential amplifier, having an input for each of the differential amplifier inputs and a voltage follower connected between each input and its respective amplifier input.

6. Signal amplifying apparatus as claimed in Claim 5 wherein the voltage followers circuits are constituted by circuits as claimed in any one of Claims 1 to 3 or the circuit assembly as claimed in Claim 4.

7. A voltage follower circuit as hereinbefore described with reference to Figs. 2 and 3 or modified as by Fig. 4 or Fig. 5.

8. Signal amplifying apparatus substantially as hereinbefore described with reference to and as illustrated in Fig. 2 or Fig. 2 as modified by Fig. 4 or Fig. 5.

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