

LOUDSPEAKER

This invention relates to loudspeakers and in particular to compound loudspeaker drive units in which separate diaphragms are provided for reproduction of the low and high audio frequencies.

In some known loudspeaker systems, separate loudspeaker drive units are provided for reproduction of bands of audio frequencies, for example a woofer unit for reproduction of sounds in a low frequency band and a tweeter unit for reproduction of sounds in a high frequency band. The voice coils of the loudspeaker drive units are connected to the output of a power amplifier, or other source, through a suitable cross-over filter network which ensures that only electrical signals representing sounds in the appropriate bands are applied to the individual loudspeaker voice coils. The characteristic of the cross-over filter is arranged so that in a mid frequency cross-over band intermediate the low and high frequency bands the outputs of the two loudspeaker drive units tail off; the output of the low frequency loudspeaker drive unit reduces with increase of frequency while the output of the high frequency loudspeaker drive unit reduces with decrease in frequency. At a so-called crossover frequency the low and high frequency loudspeaker drive units have outputs which are equal but reduced in comparison with their outputs within their respective frequency bands. The electrical energisations of the respective voice coils are adjusted so that the sound outputs of the loudspeaker drive units are relatively matched and together provide a substantially uniform output over the total frequency range of the combination of the two loudspeaker drive units. The sound radiated from each of the drive units may be said to emanate from the apparent sound source or acoustic centre of that unit; the position of the acoustic centre is a function of the design of the particular unit and may be determined by

acoustic measurement.

When separate loudspeaker drive units are provided, the apparent sound sources are physically offset from one another. The loudspeaker drive units are usually mounted on a common baffle such that they lie in a common plane and are offset in a vertical direction in the plane of the baffle. For a listener positioned approximately in line with the axes of the loudspeaker drive units and approximately equidistant from the acoustic centres of both drive units, a desired balance of output from the two drive units can be obtained. However if the position of the listener is moved from the equidistant position, the distances between the listener and the acoustic centres of the two loudspeaker drive units will be different and hence sounds in the mid frequency band produced by both loudspeakers will be received by the listener from the two drive units with a difference in time. This time difference between sounds received from the two drive units results in a change in phase relationship of the sounds received at the listening position from the two drive units. The sounds from the two drive units no longer add together as intended in the cross-over band. Consequently the resultant received sound levels will vary with frequency and the overall sound output of the loudspeaker combination will appear to the listener to be non-uniform. The resulting raggedness in sound output colours the sound and, with stereo sound systems, there is a loss of clarity in the apparent location of instruments in the sound stage. This is particularly apparent in respect of sound frequencies in the upper mid-range, for example in the region of 3kHz, at which the offset of the drive units relative to one another is comparable to the wavelength of the sound. At a frequency of 3kHz the wavelength is approximately 4 inches or 100 cm.

In an attempt to overcome the undesirable effects on

sounds received at positions which are not equidistant from the two loudspeaker drive units, it is known to combine the low and high frequency loudspeaker drive units in a single compound co-axial construction. The compound
5 co-axial loudspeaker drive unit consists of a generally conical low frequency diaphragm driven by a voice coil interacting with a magnetic structure having a central pole extending through the voice coil. A high frequency diaphragm is positioned to the rear of the structure and
10 sound output from this diaphragm is directed to the front of the loudspeaker drive unit by means of a horn structure extending co-axially through the centre pole of the magnetic structure which interacts with the low frequency diaphragm. Thus both the low frequency and high frequency
15 sounds are directed in a generally forward direction from the compound loudspeaker drive unit. In this co-axial form of loudspeaker construction there is no vertical or horizontal offset of the apparent sound sources for low and high frequencies. However the low frequency diaphragm
20 is positioned at the front of the loudspeaker unit whereas the high frequency diaphragm is positioned at the rear of the loudspeaker unit and this results in relative displacement of the apparent sound sources in the direction of the axis of the drive unit and an undesirable
25 time difference in the arrival, at the listener, of sounds from the high and low frequency diaphragms.

According to one aspect of the invention a compound loudspeaker drive unit comprising a first transducer
30 operable to generate sounds in a relatively low frequency range and a second transducer operable to generate sounds in a relatively high frequency range, said relatively low and relatively high frequency ranges overlapping in a cross-over region; said first transducer having a conical
35 diaphragm flaring outwardly and forwardly from a neck is characterised in that said second transducer is located in or adjacent to the neck of the conical diaphragm of the

first transducer in such a position that effective acoustic centres of the first and second transducers are coincident and that in said cross-over region the flaring of the conical diaphragm imposes a directivity upon the radiation of sound from the second transducer whereby the directivities of the first and second transducers are matched over frequencies in the cross-over region where both transducers make significant contributions to the sound output of the drive unit and in that the second transducer has a magnetic structure including a permanent magnet formed of a neodymium iron boron compound.

According to a second aspect of the invention a compound loudspeaker drive unit comprising a first transducer operable to generate sounds in a relatively low frequency range and a second transducer operable to generate sounds in a relatively high frequency range, said relatively low and relatively high frequency ranges overlapping in a cross-over region; said first transducer having a conical diaphragm flaring outwardly and forwardly from a neck is characterised in that said second transducer is located in or adjacent to the neck of the conical diaphragm of the first transducer in such a position that effective acoustic centres of the first and second transducers are coincident and that in the cross-over region the flaring of the conical diaphragm imposes a directivity upon the radiation of sound from the second transducer whereby the directivities of the first and second transducers are matched over frequencies in the cross-over region where both transducers make significant contributions to the sound output of the drive unit and in that the second transducer has a magnetic structure including a permanent magnet producing a magnetic flux in an air gap, the permanent magnet being formed of a material having magnetic properties similar or superior to those of a neodymium iron boron compound.

According to a third aspect of the invention a compound loudspeaker drive unit comprising a low frequency moving coil drive unit for generating sound in a relatively low frequency range and a high frequency moving coil drive unit for generating sound in a relatively high frequency range; said high frequency drive unit including magnetic means interacting with a high frequency voice coil thereof is characterised in that the magnetic means includes a permanent magnet formed of a neodymium iron boron compound.

According to fourth aspect of the invention a compound loudspeaker drive unit comprising a low frequency moving coil drive unit for generating sound in a relatively low frequency range and a high frequency moving coil drive unit for generating sound in a relatively high frequency range; said high frequency drive unit including magnetic means interacting with a high frequency voice coil thereof is characterised in that the magnetic means includes a permanent magnet producing a magnetic flux in an air gap, the permanent magnet being formed of a material having magnetic properties similar or superior to those of a neodymium iron boron compound.

According to a fifth aspect of the invention a compound loudspeaker drive unit comprising a first transducer operable to generate sounds in a low frequency range and a second transducer operable to generate sounds in a high frequency range, said low and high frequency ranges overlapping in a cross-over region; said first transducer having a conical diaphragm flaring outwardly and forwardly from a neck is characterised in that said second transducer is located in or adjacent to the neck of the conical diaphragm of the first transducer in such a position that effective acoustic centres of the first and second transducers are coincident and that in the cross-over region the flaring of the conical diaphragm imposes a

directivity upon the radiation of sound from the second transducer whereby the directivities of the first and second transducers are matched over frequencies in the cross-over region where both transducers make significant contributions to the sound output of the drive unit; in that the second transducer comprises a magnet structure consisting of a first element mounted on a central pole piece of the first transducer and having a cylindrical outer wall dimensioned to be located with a clearance within means mounting a low frequency voice coil to the neck of the low frequency diaphragm; in that a disc shaped permanent magnet member formed of a neodymium iron boron compound is located in a cylindrical recess in said first element; in that a disc shaped pole piece is mounted on a face of the permanent magnet member and an annular pole piece is mounted on the first element to define, with the disc shaped pole piece, an air gap; and in that a high frequency voice coil of the second transducer interacts with magnetic flux produced in the air gap by said disc shaped permanent magnet member.

An embodiment of the invention will now be described by way of example with reference to the drawing which shows a cross section through the axis of a moving coil compound loudspeaker drive unit.

Referring to the drawing, a compound loudspeaker drive unit with low frequency and high frequency transducers having co-axial low and high frequency voice coils

30

35

comprises a chassis 10 in the form of a conical basket having a front annular rim 11 connected to a rear annular member 12 by means of a number of ribs 13. The rear annular member 12 has an annular flange 14 and an annular seat 15. Secured to the flange 14 is a first magnetic structure 16 for the low frequency loudspeaker drive unit. The magnetic structure 16 comprises a magnet ring 17, which may for example be formed of barium ferrite, a front annular plate 18 which forms an outer pole and a member 19 which forms a backplate and inner pole 20. The plate 18, magnet ring 17 and member 19 are held together to provide a magnetic path interrupted by a non-magnetic air gap between the outer pole 18 and the inner pole 20. The poles are circular and form therebetween an annular air gap. The low frequency transducer or loudspeaker drive unit comprises a diaphragm 21 of generally frusto-conical form supported along the front outer edge thereof by a flexible surround 22 secured to the front rim 11 of the chassis 10. A tubular coil former 23 is secured to the rear edge of the diaphragm 21 and is arranged to extend co-axially of the air gap in the magnetic structure 16. The coil former carries a voice coil 24 positioned on the former such that the coil extends through the air gap. The coil is of sufficient axial length as to ensure that for normal excursions of the voice coil, the poles always lie within the length of the voice coil. A suspension member 25, in the form of a spider consisting of inner and outer rings interconnected by flexible legs or consisting of a corrugated sheet having annular corrugations, is secured between the coil former 23 and the annular seat 15 of the chassis 10 in order to ensure that the coil former, and voice coil carried thereby, are maintained concentric with the poles of the magnetic structure and out of physical contact with the poles during sound producing excursions of the diaphragm 21. The backplate and inner pole member 19 has a bore 26 extending co-axially thereof for the purpose of mounting a high frequency drive unit

27.

The high frequency transducer or drive unit 27 comprises a second magnetic structure consisting of a pot 28, a disc shaped magnet 29 and a disc shaped inner pole 30. The pot 28 has a cylindrical outer surface so dimensioned as to fit within the interior of the coil former 23 without making physical contact therewith. The pot is formed with a circular recess 31 to receive the magnet 29 and an annular lip 32 to form an outer pole. One circular pole face of the magnet 29 is held in engagement with the bottom wall of the recess 31 and the disc shaped inner pole 30 is held in engagement with the other circular pole face of the magnet such that the circular outer periphery of the inner pole 30 lies co-axially with and within the lip 32 forming the outer pole. A non-magnetic air gap extends between the inner and outer poles. A spacer ring 33 is secured to the front face of the pot 28. Preferably the magnet 29 is formed of neodymium iron boron which allows a very substantially enhanced magnetic field strength as compared with other available magnetic materials to be attained in the air gap between the poles. As a result, the overall size of the high frequency magnetic structure, for a required flux in the air gap, can be smaller than hitherto thereby allowing the high frequency drive unit to be positioned within the coil former of the low frequency drive unit immediately adjacent to the apex of the low frequency diaphragm 21. However it will be appreciated that the magnet 29 may be formed of other materials having magnetic properties substantially similar or superior to that of neodymium iron boron. A high frequency domed diaphragm 34 has an annular support 35 of annular corrugated form and this support is secured at its outer periphery to the spacer ring 33. Secured to the domed diaphragm 34 is a cylindrical coil former carrying a high frequency voice coil 36 such that the voice coil extends through the air

gap between the poles 30, 32 of the magnetic structure.

In order to centralise the high frequency unit relative to the low frequency unit, and in particular to ensure that the high frequency unit is coaxial with and does not interfere with motion of the low frequency voice coil a rod 37, preferably of non-magnetic material, is secured centrally to the rear face of the pot 28 and extends through the bore 26 of the low frequency magnetic structure. The high frequency drive unit tends to be held in engagement with the pole 20 of the magnetic structure 16 by magnetic attraction therebetween but is secured to the structure 16 by a threaded end portion 38 of the rod 37 extending through an aperture in a plate 39 positioned at the rear of the backplate 19 and a nut 40 threaded onto the end portion 38.

Connections to the low frequency voice coil 24 are provided by means of flexible leadout conductors 41 extending from the voice coil 24 to external connectors 42. Connections to the high frequency voice coil 36 are provided by flexible conductors 43 which extend along a recess in the outer wall of the pot 30, between the pot 30 and the inner pole 20 and thence through the bore 26 to external connectors (not shown). In order to allow the conductors to extend through the bore 26, the rod 37 has a diameter smaller than that of the bore 26 so as to leave an annular space through which the conductors 43 extend. Means, not shown, are provided between the pole piece 20 and the pot 28 to ensure that the rod lies co-axially with the bore 26. This means may be a disc secured to the pole piece 20 and having a central aperture of a diameter to receive the rod 37 in a sliding fit. The disc may be grooved to provide a passageway for the conductors 43 between the pole piece 20 and the pot 28. The rod 37 may be of circular, hexagonal or other section and the disc would be provided with a central aperture of matching

shape.

Instead of utilising a rod 37 of diameter smaller than that of the bore 26, if the rod is of hexagonal section its diameter may be of a size such that the rod is a sliding fit in the bore 26 to locate the high frequency drive unit co-axially of the pole piece 20 of the low frequency drive unit. Spaces between the faces of the hexagonal section rod and the wall of the bore 26 provide passageways for the conductors 43. Instead of using a plate 39 to secure the high frequency drive unit, a moulding may be used. The moulding would be located by means of a boss on the moulding entering the bore 26. The moulding may be so formed as to provide a mounting for other components such as the electronic components of a cross-over filter and terminals for electrical drive signals for the compound loudspeaker drive unit. As an alternative to the end 38 of the rod 37 being externally threaded, the end of the rod may be bored and threaded internally to receive a screw.

The construction described hereinbefore is particularly convenient in manufacture of the compound loudspeaker drive unit in that the high frequency drive unit is centralised relative to the low frequency drive unit prior to the high frequency drive unit reaching its final rest position on the pole piece 20. As a result the high frequency unit is prevented from engaging the low frequency voice coil during assembly of the compound loudspeaker drive unit. Furthermore this construction facilitates dis-assembly of the high frequency drive unit from the low frequency drive unit if and when any servicing of the units is necessitated without any need to demagnetise either of the magnetic assemblies.

If desired, an annular baffle 44 having a frusto-conical front surface is secured to the front of the high

frequency drive unit to provide a continuation of the surface of the low frequency diaphragm 21 towards the domed high frequency diaphragm.

- 5 It will be appreciated that with the high frequency drive unit positioned at or adjacent to the neck of the diaphragm of the low frequency drive unit, as in the above described construction of compound loudspeaker drive unit, the apparent sound source or acoustic centre of the high
- 10 frequency drive unit is substantially co-incident with the apparent sound source or acoustic centre of the low frequency drive unit. The radiation pattern or directivity of the low frequency drive unit is determined inter alia by the form of the low frequency diaphragm.
- 15 With the high frequency drive unit positioned adjacent to the neck of the low frequency diaphragm, the form of the low frequency diaphragm imposes its directivity upon the radiation pattern or directivity of the high frequency unit. Consequently at frequencies at which both drive
- 20 units contribute significant sound output, both drive units have substantially similar patterns of radiation or directivity. As a result the relative sound contributions from the two drive units as perceived by a listener are substantially unaffected by the listener being positioned
- 25 at off axis positions.

The low frequency conical diaphragm is shown in the drawing as being of conical form having an angle of flare which increases from the neck of the diaphragm toward the

30 outer periphery of the diaphragm. However it will be appreciated that the diaphragm may be of conical form having a uniform angle of flare. Also, the low frequency conical diaphragm may be of circular, elliptical or other section as desired.

35

The high frequency diaphragm is shown in the drawing as being of domed form. Such a diaphragm is suitable because

its acoustic centre may readily be located in close coincidence with that of the low frequency diaphragm, and because, in the frequency range where both drive units contribute significant sound output, its small size
5 relative to wavelength gives it, by itself, essentially non-directional sound radiation, allowing the effective directivity to be determined by the low frequency diaphragm. It will be appreciated that the high frequency diaphragm may alternatively be of any other form that
10 provides these characteristics.

15

20

25

30

35

**CLAIMS**

1. A compound loudspeaker drive unit comprising a first transducer operable to generate sounds in a relatively low frequency range and a second transducer (27) operable to generate sounds in a relatively high frequency range, said relatively low and relatively high frequency ranges overlapping in a cross-over region; said first transducer having a conical diaphragm (21) flaring outwardly and forwardly from a neck; characterised in that said second transducer (27) is located in or adjacent to the neck of the conical diaphragm (21) of the first transducer in such a position that effective acoustic centres of the first and second transducers are coincident and that in said cross-over region the flaring of the conical diaphragm (21) imposes a directivity upon the radiation of sound from the second transducer (27) whereby the directivities of the first and second transducers are matched over frequencies in the cross-over region where both transducers make significant contributions to the sound output of the drive unit and in that the second transducer (27) has a magnetic structure including a permanent magnet (29) formed of a neodymium iron boron compound.
2. A compound loudspeaker drive unit comprising a first transducer operable to generate sounds in a relatively low frequency range and a second transducer (27) operable to generate sounds in a relatively high frequency range, said relatively low and relatively high frequency ranges overlapping in a cross-over region; said first transducer having a conical diaphragm (21) flaring outwardly and forwardly from a neck; characterised in that said second transducer (27) is located in or adjacent to the neck of the conical diaphragm (21) of the first transducer in such a position that effective acoustic centres of the first and second transducers are coincident and that in the cross-over region the flaring of the conical diaphragm (21) imposes a directivity upon the radiation of sound



from the second transducer (27) whereby the directivities of the first and second transducers are matched over frequencies in the cross-over region where both transducers make significant contributions to the sound output of the drive unit and in that the second transducer (27) has a magnetic structure including a permanent magnet (29) producing a magnetic flux in an air gap, the permanent magnet (29) being formed of a material having magnetic properties similar or superior to those of a neodymium iron boron compound.

3. A compound loudspeaker drive unit as claimed in claim 1 or 2 further characterised in that the second transducer (27) includes a high frequency diaphragm (34) operable to generate sounds in the relatively high frequency range and which has a form such that sound radiated thereby without the acoustic loading of the low frequency diaphragm (21) would be substantially non-directional for frequencies in the crossover region.

4. A compound loudspeaker drive unit as claimed in claim 3 further characterised in that the high frequency diaphragm (34) is of domed form.

5. A compound loudspeaker drive unit comprising a low frequency moving coil drive unit (16, 21, 23, 24) for generating sound in a relatively low frequency range and a high frequency moving coil drive unit (27) for generating sound in a relatively high frequency range; said high frequency drive unit (27) including magnetic means (28, 29, 30, 32) interacting with a high frequency voice coil (36) thereof, characterised in that the magnetic means (28, 29, 30, 32) includes a permanent magnet (29) formed of a neodymium-iron boron compound.

6. A compound loudspeaker drive unit comprising a low frequency moving coil drive unit (16, 21, 23, 24) for



generating sound in a relatively low frequency range and a high frequency moving coil drive unit (27) for generating sound in a relatively high frequency range; said high frequency drive unit (27) including magnetic means (28, 29, 30, 32) interacting with a high frequency voice coil (36) thereof, characterised in that the magnetic means (28, 29, 30, 32) includes a permanent magnet (29) producing a magnetic flux in an air gap, the permanent magnet (29) being formed of a material having magnetic properties similar or superior to those of a neodymium iron boron compound.

7. A loudspeaker as claimed in claim 5 or 6 further characterised in that the high frequency drive unit (27) has a first apparent sound source and the low frequency drive unit has a second apparent source; and in that the high frequency drive unit (27) is disposed co-axially with the low frequency drive unit (16, 21, 23, 24) and is disposed in an axial direction relative to said low frequency drive unit such that said first and second apparent sources are substantially coincident.

8. A compound loudspeaker drive unit as claimed in claim 5 or 6 further characterised in that the low frequency drive unit comprises a substantially frusto-conical low frequency diaphragm (21) flaring outwardly in a forward direction from a neck thereof; a low frequency voice coil (24) connected to said neck of the diaphragm (21); and first magnetic means (16) providing a magnetic flux interacting with the low frequency voice coil (24) whereby electrical energisation of the low frequency voice coil (24) is effective to impart movement to the diaphragm (21) to produce sounds in a relatively low frequency range; and in that the high frequency loudspeaker drive unit (27) is positioned adjacent to said neck of the low frequency diaphragm (21) and comprises a high frequency diaphragm (34) carrying the high frequency voice coil (36); and in



that the permanent magnet (29) provides a magnetic flux interacting with the high frequency voice coil (36) whereby electrical energisation of the high frequency voice coil (36) is effective to impart movement to the
5 high frequency diaphragm (34) to produce sounds in a relatively high frequency range overlapping said relatively low frequency range in a cross-over band.

9. A compound loudspeaker drive unit as claimed in claim
10 8 further characterised by an annular baffle member (44) effective to provide a continuation of the surface of the low frequency diaphragm (21) toward the high frequency diaphragm (34).

15 10. A compound loudspeaker drive unit as claimed in any preceding claim further characterised in that the high frequency drive unit (27) is manufactured separately from said low frequency drive unit (10, 16, 21, 23, 24); in that a pole piece (20) of the low frequency drive unit has
20 a central bore (26) extending therethrough; in that the high frequency drive unit (27) is manufactured with a rod (37), preferably of non-magnetic material, secured thereto and projecting rearwardly therefrom; and in that said rod (37) is entered into said bore (26) in assembly
25 of the high frequency drive unit onto the pole piece (20) and engages within said bore (26) to locate the high frequency drive unit (27) relative to the low frequency drive unit during and after assembly of the units.

30 11. A compound loudspeaker drive unit as claimed in any one of claims 1 to 9 further characterised in that the high frequency drive unit (27) is manufactured separately from said low frequency drive unit (10, 16, 21, 23, 24) and is secured to a pole piece (20) of magnetic means (16)
35 of the low frequency drive unit and in that a pole piece (20) of the low frequency drive unit has a central bore (26) extending therethrough, in that the high frequency



drive unit (27) is manufactured with a rod (37), preferably of non-magnetic material, secured thereto and extending therefrom centrally in a rearward direction and in that the rod is entered into the bore (26) in mounting the high frequency drive unit on the pole piece (20) and engages within said bore to locate the high frequency drive unit (27) relative to the low frequency drive unit during and after assembly of the units.

10 12. A compound loudspeaker drive unit as claimed in claim 11 further characterised by means (39, 40) to secure the free end of the rod (37) to the low frequency drive unit.

15 13. A compound loudspeaker drive unit as claimed in claim 12 further characterised in that the means (39, 40) to secure the free end of the rod (37) comprises a moulding formed to act as a mounting for other components of the loudspeaker.

20 14. A compound loudspeaker drive unit as claimed in claim 1 or 2 further characterised by conductors (43) providing connections to a voice coil (36) of the high frequency drive unit (27), and in that said conductors (43) extend from said voice coil (36) through a bore (26) in a pole piece (20) of magnetic means (16) for the low frequency drive unit.

30 15. A compound loudspeaker drive unit as claimed in claim 11 further characterised by conductors (43) providing connections to a voice coil (36) of the high frequency drive unit (27), and in that said conductors (43) extend from said voice coil (36) through the bore (26) in the low frequency drive unit in a space between the rod (37) and a wall of the bore (26).

35

16. A compound loudspeaker drive unit comprising a first transducer operable to generate sounds in a low frequency



range and a second transducer (27) operable to generate sounds in a high frequency range, said low and high frequency ranges overlapping in a cross-over region; said first transducer having a conical diaphragm (21) flaring
5 outwardly and forwardly from a neck; characterised in that said second transducer (27) is located in or adjacent to the neck of the conical diaphragm (21) of the first transducer in such a position that effective acoustic centres of the first and second transducers are coincident
10 and that in the cross-over region the flaring of the conical diaphragm (21) imposes a directivity upon the radiation of sound from the second transducer (27) whereby the directivities of the first and second transducers are matched over frequencies in the cross-over region where
15 both transducers make significant contributions to the sound output of the drive unit; in that the second transducer comprises a magnet structure consisting of a first element (28) mounted on a central pole piece (20) of the first transducer and having a cylindrical outer wall
20 dimensioned to be located with a clearance within means (23) mounting a low frequency voice coil (24) to the neck of the low frequency diaphragm (21); in that a disc shaped permanent magnet member (29) formed of a neodymium iron boron compound is located in a cylindrical recess (31) in
25 said first element (28); in that a disc shaped pole piece (30) is mounted on a face of the permanent magnet member (29) and an annular pole piece (32) is mounted on the first element to define, with the disc shaped pole piece, an air gap; and in that a high frequency voice coil (36)
30 of the second transducer (27) interacts with magnetic flux produced in the air gap by said disc shaped permanent magnet member (29).

17. A compound loudspeaker drive unit constructed and
35 arranged to operate substantially as hereinbefore described with reference to the accompanying drawing.
