

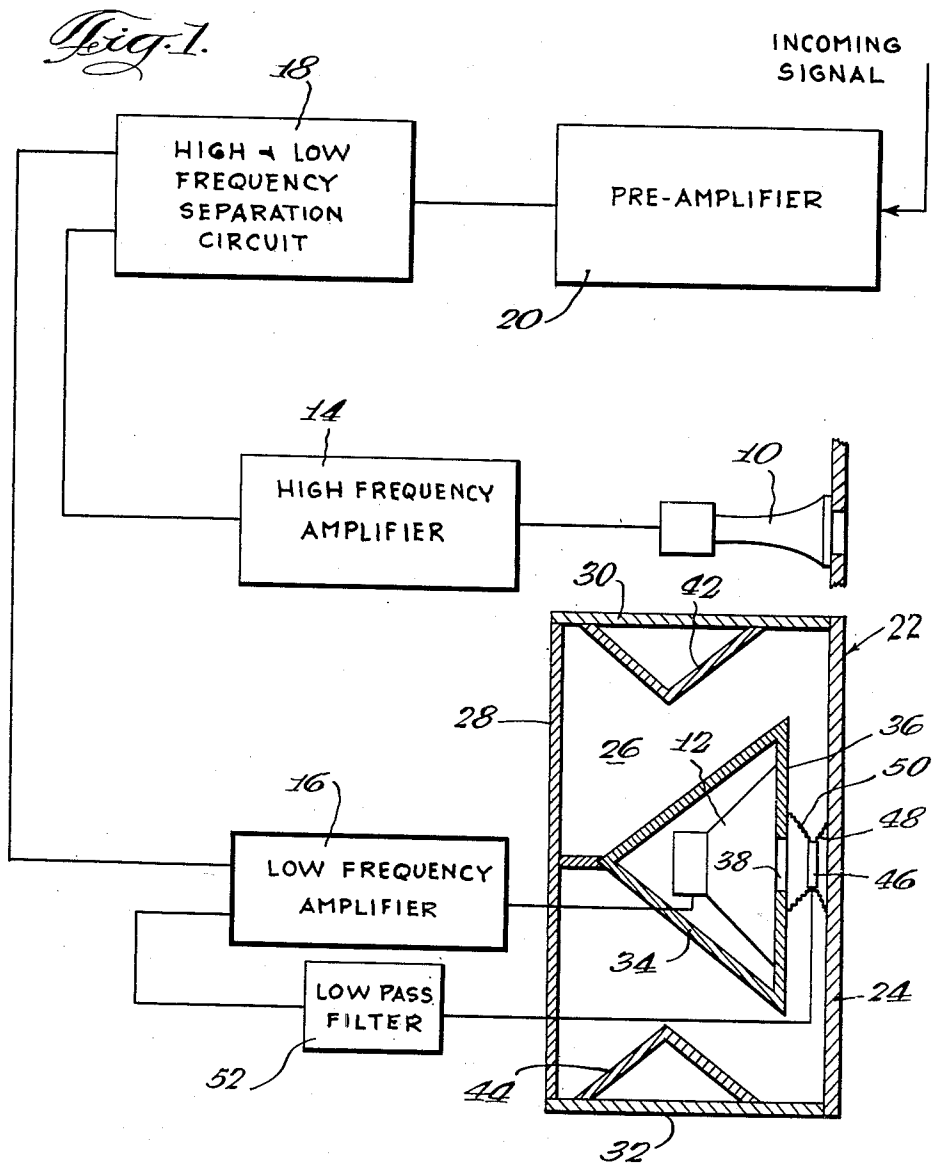
July 1, 1958

E. G. THURSTON
SOUND PRODUCING DEVICE

2,841,648

Filed Aug. 8, 1955

3 Sheets-Sheet 1



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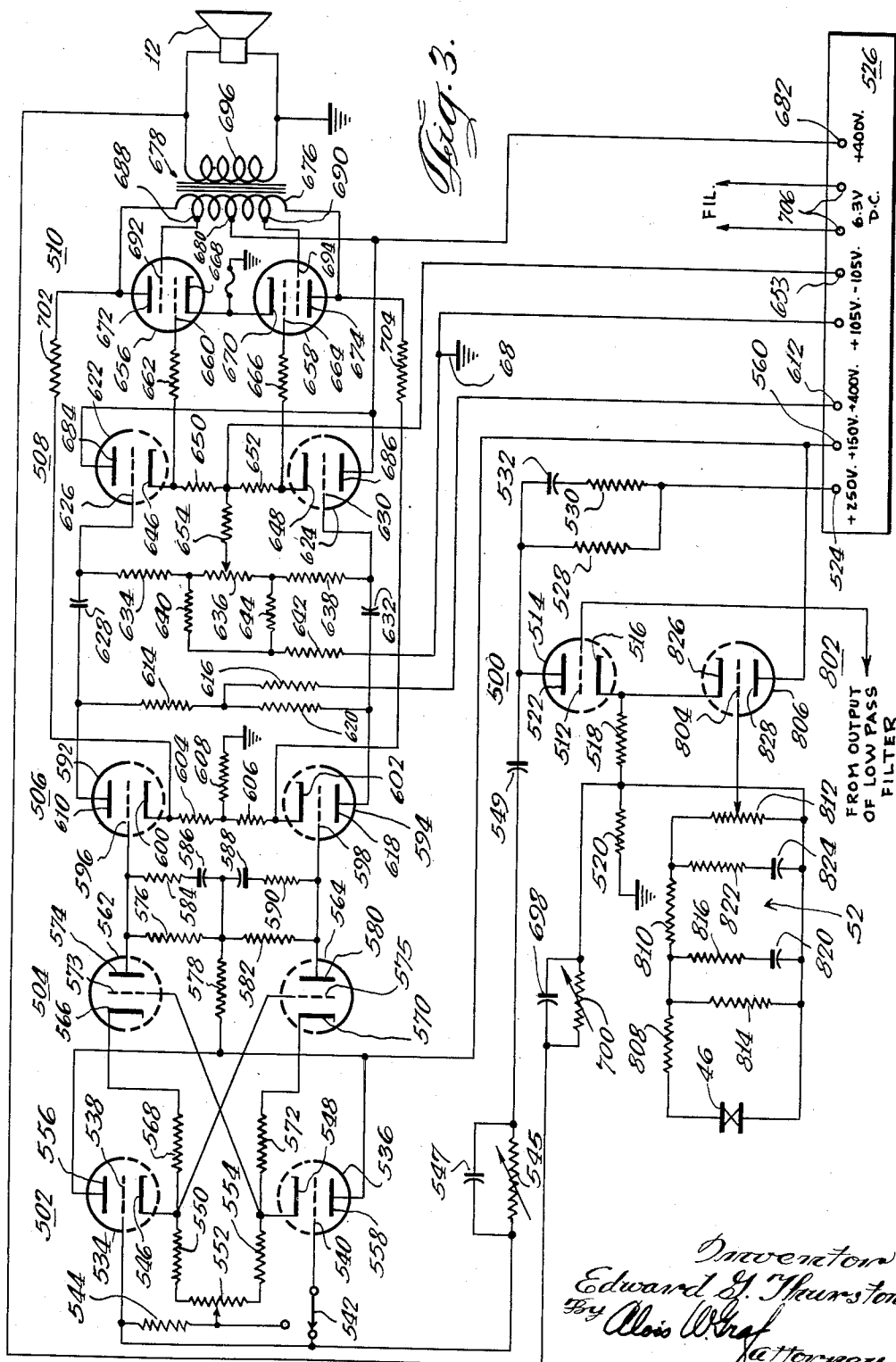
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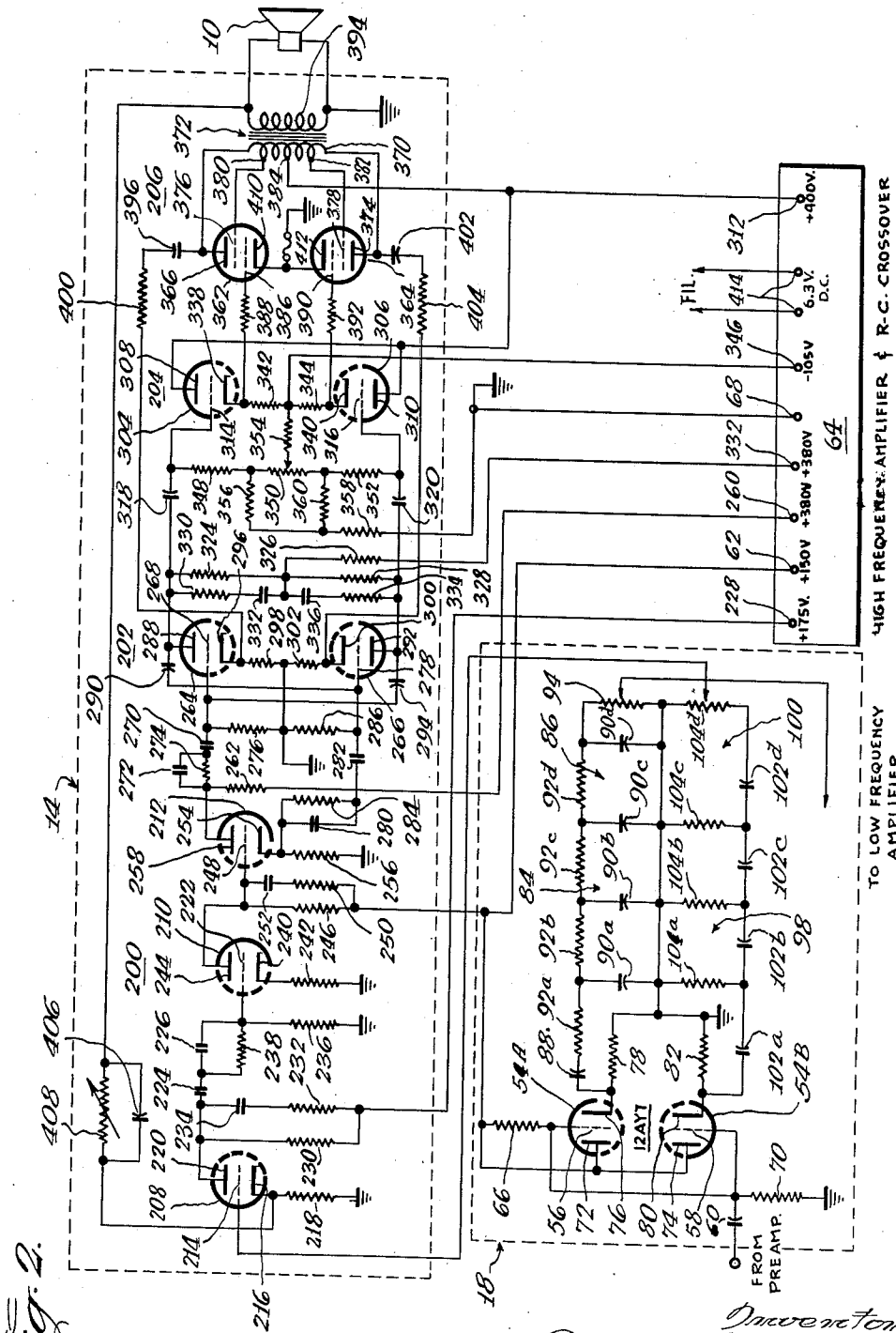
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SOUND PRODUCING DEVICE

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10 Claims. (Cl. 179—1)

The present invention relates generally to sound reproducing devices, and more particularly to devices for reproducing sound from electrical signals with high fidelity.

The fidelity of sound reproduction from electrical signals has greatly improved in recent years, partly because of improved loud speakers and partly because of improved devices for impressing the electrical signals upon loud speakers. Most of the presently used systems of reproducing sound utilize an amplifier provided with an output transformer, and a loud speaker connected to the output transformer. It is well-known that the frequency response of the amplifier and the distortion from the amplifier may be improved by providing a degenerative feedback loop from the output of the transformer to the input of the amplifier.

The loud speaker is also coupled to the air in the room in which it is disposed, and the frequency response of the speaker and the distortion by the speaker vary due to mechanical resonances, changes in the coupling between the speaker and the air, etc. No known system of feedback compensates for these effects, and hence only the design of the speaker can at present be employed to maximize the range of sound response and minimize the sound distortion from a given electrical signal.

One of the objects of the present invention is to improve the frequency response and distortion characteristics of loud speakers by providing a negative feedback loop from the output of the loud speaker to the input of the amplifier of the sound reproducing device.

One of the criteria of negative feedback circuits is that the feedback voltage must always be out of phase with the signal voltage for proper operation. If the feedback voltage becomes in phase with the signal voltage, an undesirable condition of sustained oscillation occurs. In order to provide a negative feedback circuit which is responsive to the acoustical output at the speaker, an electro-mechanical transducer must be disposed in the air adjacent to the speaker to generate the degenerative feedback voltage. Since with any practical mounting arrangement the distance from the speaker to the electro-mechanical transducer must be fixed, the phase of the feedback voltage will depend upon the frequency of the incident sound wave upon the electro-mechanical transducer. Thus as the frequency increases, the wavelength of the sound decreases and will approach in magnitude the fixed distance from speaker to electro-mechanical transducer. This will cause a progressive phase shift in the feedback voltage of the transducer relative to the input signal voltage of the amplifier so that even though the feedback and signal voltages were properly out of phase at low frequencies, they may become in phase at higher frequencies and oscillation will occur. Thus, a negative feedback loop, which merely disposes a microphone adjacent to the loud speaker and indiscriminately feeds the output voltage of the microphone to the input of the amplifier, will produce oscillations. Furthermore, such oscillations can occur at a frequency above the normal operating range of the speaker

unless proper precautions are taken to avoid them, and such an oscillatory condition may not only cause an unpleasant and undesirable sound but will also render the entire system incapable of high fidelity reproduction at any frequency.

It is a further object of the present invention to provide a sound reproducing device which employs an electro-mechanical transducer positioned adjacent to a loud speaker and means to feed back the response of the electro-mechanical transducer to the input of the speaker amplifier which prevents the feedback from becoming in phase with the signal to the input of the amplifier.

The inventor has found that it is possible to feedback a signal generated by an electro-mechanical transducer positioned adjacent to the loud speaker of a sound reproducing system if the frequency bandwidth of the feedback is limited. It is known that in the high fidelity reproduction of sound, it is usually the low frequency signals which are the most difficult to reproduce with a smooth response and low distortion. In the operation of low frequency, corner-loaded, horn type, loud speakers, such as that disclosed in the Patent No. 2,373,692 issued to Klipsch, the frequency response is approximately from 30 cycles per second to an upper limit of from 200 to 500 cycles per second and in this frequency range, the shortest wave length to be encountered, as far as substantial radiation is concerned, is between $2\frac{1}{2}$ and $5\frac{1}{2}$ feet. The upper limit of this frequency response is not only limited by the ability of the loud speaker and enclosure to substantially radiate sound at higher frequencies, but also by the fact that for high fidelity reproduction means are usually provided to purposely transfer electrical excitation from the low frequency speaker to another speaker or other speakers whose design permits better reproduction of higher frequency sounds. In general, it is desirable to cause the frequency of transfer of electrical excitation, or so called "crossover-frequency," to be substantially below the frequency at which the effective radiation of the low frequency speaker starts to decrease due to its own performance limitations at high frequencies and likewise substantially above that frequency at which the response of the high frequency speaker starts to decrease due to its inherent limitations at low frequencies. In practice, the low frequency speaker is usually capable of substantial radiation for at least one octave above the "crossover" frequency, and the high frequency speaker capable of substantial radiation for at least one octave below the crossover frequency.

The inventor has found that an electro-mechanical transducer, positioned from the vertex of the low frequency loud speaker by a distance not to exceed $\frac{1}{4}$ and preferably less than $\frac{1}{8}$ of a wavelength of sound in air at the crossover frequency of the low frequency speaker, may be used to generate a negative feedback signal which is fed into the input of the amplifier driving the speaker without introducing sufficient phase shift at any frequency to cause oscillations to develop, provided the response of the feedback circuit is properly attenuated above a frequency equal to three to four times the crossover frequency of the low frequency speaker.

The invention will be more fully understood, together with additional objects and advantages, from a further reading of this specification, particularly when viewed in the light of the drawings, in which:

Figure 1 is a schematic diagram of a device for reproducing sound from an electrical signal;

Figure 2 is a schematic electrical circuit diagram of the high and low frequency separation circuit and high frequency amplifier shown in Figure 1; and

Figure 3 is a schematic electrical circuit diagram illustrating the low frequency amplifier and feedback circuit shown in Figure 1.

The construction of the invention illustrated in the figures employs a plurality of speakers, such as a high frequency speaker 10 and a low frequency speaker 12, the high frequency speaker 10 being connected to the output of a high frequency amplifier 14, and the low frequency speaker 12 being connected to the output of a low frequency amplifier 16. A high and low frequency separation or "crossover" circuit 18 has separate outputs connected to the high frequency amplifier 14 and the low frequency amplifier 16, and a pre-amplifier 20 is connected to the input of the high and low frequency separation circuit 18. The incoming electrical signal is impressed upon the input of the pre-amplifier 20, this signal being supplied by a high fidelity signal source, such as a tape recorder, high frequency tuner, or the like.

The low frequency speaker 12 is disposed within a speaker enclosure 22 of the type described in the above referred to patent. The enclosure 22 has a solid front panel which is adapted to be disposed diagonally across a corner of a room. A pair of side panels 26 are attached to the edges of the front panel 24, a space being provided between the side panels 26 and walls of the room. The side panels 26 are secured to a rear support strip 28 which is adapted to be disposed in contact with the walls of the room at the corner thereof, and a cover 30 and base 32 extend from the rear support 28 to the front panel 24. A speaker housing 34 with an inner panel 36 confronting and parallel to the front panel 24 is secured between the side panels 26 and also attached to the support member 28. The inner panel 36 is provided with a circular throat opening 38, and a speaker 40 suitable, for example, for reproducing sounds from approximately 40 cycles per second to 500 cycles per second is secured to the inner panel 36. An angular shaped member 42 is secured to the cover 30 to form a flaring passage from the front panel 24 to the support member 28, and a similar member 44 is secured to the bottom 32 of the enclosure 22 for the same purpose. The enclosure here illustrated is a preferred construction, although the invention may be practiced with other suitable speaker enclosures, or even without an enclosure.

A microphone 46 is disposed between the throat opening 38 of the speaker housing 34 and the front panel 24 of the enclosure 22, said microphone being supported by suitable vibration isolators 48 and 50 which isolate it from mechanical vibrations occurring in the inner panel 36 or the front panel 24 of the housing 34. In one embodiment, the isolators 48 and 50 are resilient helical springs. The microphone 34 is electrically connected to the input of the low frequency amplifier 16 through a low pass filter 52.

The high and low frequency separation circuit 18 is shown in detail in Figure 2. This circuit employs a single vacuum tube having two triode sections 54A and 54B. The grids 56 and 58 of these sections 54A and 54B, respectively, of the vacuum tube are interconnected and also connected to the preamplifier 20 through a capacitor 60. The grids 56 and 58 are also connected to one of the positive terminals 62 of a power source 64 through a resistor 66, and to the negative terminal 68 of the power source 64, which is ground, through a resistor 70. The plates 72 and 74 of the sections 54A and 54B are also interconnected and directly connected to the positive terminal 62 of the power source 64. The cathode 76 of vacuum tube 54A is connected to the ground terminal 68 through a resistor 78, and the cathode 80 of vacuum tube section 54B is connected to this terminal 68 through a resistor 82.

A low-pass filter 84 is connected across the resistor 78. This low-pass filter 84 consists of four L-type resistor capacitance filters 86 connected in cascade and connected to the cathode 76 of vacuum tube section 54A by a condenser 88. Each of the L-type filters 86 has a condenser 90a, 90b, 90c or 90d and a resistor 92a, 92b, 92c or 92d, connected in series. The resistor 92a is connected to the condenser 88, and the resistors 92a, 92b, 92c and 92d are connected in series, the junctions of these resistors being

connected to ground by condensers 90a, 90b, 90c and 90d, respectively. A voltage divider 94 is connected in parallel with condenser 90d of the final filter network 86, and the voltage divider 94 has a tap 96 which is connected to the input of the low frequency amplifier 16.

A high-pass filter 98 is connected in parallel with the resistor 82. This filter 98 consists of four L-type condenser-resistor networks 100 connected in cascade. Condenser 102a is connected to the cathode 80 and in series with condensers 102b, 102c and 102d. The junctions between these condensers are connected to ground by resistors 104a, 104b and 104c, respectively and a resistor 104d is connected from condenser 102d to ground and provided with a tap which is connected to the input of the high frequency amplifier 14.

In the particular construction of the invention described throughout this disclosure, the vacuum tube sections 54A and 54B are sections of type 12AY7 tube, condenser 60 has a capacity of 0.25 mfd., resistor 70 has a resistance of 100,000 ohms, resistor 66 a resistance of 600,000 ohms, condenser 88 a capacity of 0.05 mfd., resistors 92a, 92b, 92c and 92d resistances of 90,000 ohms, condensers 90a, 90b, 90c and 90d capacities of 1235 mmfd., resistors 78 and 82 a resistance of 2150 ohms, resistor 94 a resistance of 1000 ohms, condensers 102a, 102b, 102c and 102d have capacities of 0.0061 mfd., and resistors 104a, 104b, 104c and 104d a resistance of 1000 ohms. The potential drop across the terminals 62 and 68 of the power source 64 is 150 volts.

The high frequency amplifier 14 has a voltage amplifier 200, phase inverter 202, push-pull driver 204, and push-pull power amplifier stager 206 connected in cascade. The high frequency speaker 10 is connected to the output of the power amplifier 206, and the input of the voltage amplifier 200 is connected to the tap of resistor 104d in the high and low frequency separation circuit 18.

The voltage amplifier 200 has three triode vacuum tube sections 208, 210, and 212 connected in circuits which are connected in cascade. Vacuum tube section 208 has a grid 214 directly connected to the tap of resistor 104d of the high and low frequency separation circuit 18. The cathode 216 of vacuum tube section 208 is connected to the negative terminal 68 of the power source 64 through a cathode resistor 218. The plate 220 of vacuum tube section 208 is connected to the grid 222 of vacuum tube section 210 through serially connected condensers 224 and 226. The plate 220 of vacuum tube section 208 is also connected to a positive terminal 228 of the power supply 64 through a resistor 230, and a resistor 232 and condenser 234 connected in series are connected in parallel with the resistor 230.

The grid 222 of vacuum tube section 210 is also connected to the ground terminal through a grid resistor 236, and a resistor 238 is connected between the grid 222 and the junction between condensers 224 and 226. The cathode 240 of vacuum tube section 210 is also connected to the ground terminal through a cathode resistor 242. The plate 244 of vacuum tube section 210 is connected to the positive terminal 62 of the power source 64 through a plate resistor 246, and directly connected to the grid 248 of vacuum tube section 212. A resistor 250 and condenser 252 connected in series are also connected in parallel with resistor 246. The cathode 254 of vacuum tube section 212 is connected to the ground terminal through a resistor 256 and the plate 258 of vacuum tube section 212 is connected to a positive terminal 260 of the power source 64 through a resistor 262.

In the voltage amplifier 200, the vacuum tube sections 208, 210 and 212 are sections of type 12AY7 tubes. Terminal 228 has a positive potential of plus 175 volts, and terminal 260 has a positive potential of 380 volts with respect to the negative terminal 68 of the power source. Resistor 218 has a resistance of 350 ohms, resistor 230 has a resistance of 47,000 ohms, resistor

232 a resistance of 4,700 ohms, condenser 234 a capacitance of 0.005 mfd., condenser 224 a capacitance of 0.1 mfd., condenser 226 a capacitance of 0.004 mfd., resistor 238 a resistance of 4,700 ohms, resistor 236 a resistance of 150,000 ohms, resistor 242 a resistance of 910 ohms, resistor 246 a resistance of 47,000 ohms, resistor 250 a resistance of 4,700 ohms, condenser 252 a capacitance of 0.0005 mfd., resistor 256 a resistance of 24,000 ohms, and resistor 262 a resistance of 24,000 ohms.

The phase inverter 202 employs two triode vacuum tube sections 264 and 266, section 264 having a grid of 268 connected to the plate 258 of vacuum tube section 212 through serially connected condensers 270 and 272. A resistor 274 is connected in parallel with resistor 272, and a resistor 276 is connected between the grid 268 and the ground terminal. Vacuum tube section 266 has a grid 278 which is connected to the cathode 254 of vacuum tube section 212 through serially connected condensers 280 and 282. A resistor 284 is connected in parallel with condenser 280, and a resistor 286 is connected between the ground terminal and the grid 278. Vacuum tube section 264 has a plate 288 which is connected to the grid 278 of vacuum tube section 266 through a condenser 290, and vacuum tube section 266 has a plate 292 connected through a condenser 294 to the grid 268 of the vacuum tube section 264. Vacuum tube section 264 has a cathode 296 connected to the ground terminal through a resistor 298, and vacuum tube section 266 has a cathode 300 connected to the ground terminal through a resistor 302.

The driver stage 204 utilizes a vacuum tube having two triode sections 304 and 306 connected in a push-pull cathode follower circuit. The vacuum tube sections 304 and 306 have plates 308 and 310, respectively, that are interconnected and connected to a positive terminal 312 of the power source 64. The tube sections 304 and 306 also have grids 314 and 316, respectively, the grid 314 being connected to the plate 288 of vacuum tube section 264 through coupling condenser 318, and the grid 316 connected to the plate 292 of vacuum tube section 266 through coupling condenser 320. The plate 288 of vacuum tube section 264 is connected to a positive terminal 322 of the power source 64 through series connected resistors 324 and 326, and the plate 292 of vacuum tube section 266 is also connected to the positive terminal 322 by a resistor 328 connected to the junction of resistors 324 and 326. In addition, a resistor 330 is connected in series with condenser 332, and these are connected in parallel with resistor 324; and a resistor 334 and condenser 336 are connected in series, and these are connected in parallel with the resistor 328.

The vacuum tube sections 304 and 306 have cathodes 338 and 340 which are interconnected by resistors 342 and 344, the junction between the resistors 342 and 344 being connected to a negative terminal 346 of the power supply 64. The grids 314 and 316 are interconnected by a resistor 348, voltage divider 350, and resistor 352 connected in series, and a resistor 354 is connected between the tap of the voltage divider 350 and the junction of the resistors 342 and 344. The junction between resistor 348 and the voltage divider 350 is connected to the ground terminal through a resistor 356 and a potentiometer 358, and the junction between the voltage divider 350 and the resistor 352 is connected to the junction between the resistor 356 and potentiometer 358 by a resistor 360.

The power amplifier 206 employs a pair of vacuum tubes 362 and 364 connected in a push-pull circuit. The vacuum tube 362 has a plate 366 which is connected to one end of the primary winding 370 of an output transformer 372, the other end of the primary winding 370 being connected to a plate 374 of vacuum tube 364.

Vacuum tubes 362 and 364 are also provided with screen grids 376 and 378, respectively, and the screen grids are connected to taps 380 and 382, respectively, on the primary winding 310 of the transformer 372. The transformer primary winding 370 is also provided with a center tap 384 which is directly connected to a positive terminal 312 of the power source 64.

Vacuum tube 362 has a control grid 386 which is connected to the cathode 338 of vacuum tube section 304 through a resistor 388; and vacuum tube 364 has a control grid 390 connected to the cathode 340 of vacuum tube section 306 through a resistor 392. The transformer 372 has a secondary 394, one end of which is grounded, and the high frequency speaker 10 is connected across the secondary 394 of the transformer 372. Vacuum tube 362 has a cathode 410, and vacuum tube 364 has a cathode 412, the cathodes 410 and 412 being interconnected and connected to the ground terminal.

Two negative feedback systems are provided in the high frequency amplifier 14. The first is provided from the plates 366 and 374 of vacuum tubes 362 and 364 to the cathodes 296 and 300 of vacuum tube sections 264 and 266, respectively. These negative feedback circuits consist of a condenser 396 connected in series with a resistor 400 between the plate 366 and the cathode 296; and a condenser 402 connected in series with a resistor 404 between the plate 374 and the cathode 300. The second of these negative feedback systems consists of a condenser 406 connected in parallel with the adjustable resistor 408 and this combination is connected between the ungrounded end of the secondary 394 of the transformer and the cathode 216 of vacuum tube section 203 in the voltage amplifier 200.

Vacuum tube 362 has a cathode 410, and vacuum tube 364 has a cathode 412, the cathodes 410 and 412 being interconnected and connected to the ground terminal.

In the exemplary construction of the invention described herein, vacuum tube sections 264 and 266 are sections of a 5814 tube, as are vacuum tube section 304 and 306. Vacuum tubes 362 and 364 are type KT-66 tubes. The potentials of the power source 64 measured with respect to the ground terminal are: terminal 322 plus 380 volts, terminal 346 minus 105 volts, and terminal 312 plus 400 volts. The power supply 64 also has a pair of terminals 414 which supply 6.3 volts D. C. which is connected to the filaments of all of the tubes in the high and low frequency separation circuit 18, high frequency amplifier 14, and low frequency amplifier 16, these connections being conventional and not illustrative. The following table sets forth the values of the condensers and resistors used in the phase inverter 202, driver 204, and power amplifier stage 206.

Table 1

Resistor 262	ohms	24,000
Resistor 274	do	1,000
Resistor 284	do	1,000
Condenser 272	mfd	0.002
Condenser 280	mfd	0.002
Condenser 270	mfd	0.1
Condenser 282	mfd	0.1
Resistor 276	ohms	150,000
Resistor 286	do	150,000
Condenser 290	mmfd	1.5
Condenser 294	mmfd	1.5
Resistor 298	ohms	2,500
Resistor 302	do	2,500
Condenser 332	mmfd	40
Resistor 328	ohms	50,000
Resistor 334	do	5,000
Resistor 360	do	4,700
Potentiometer 350	do	10,000
Resistor 404	do	70,000

Table 1—Continued

Condenser 396	mfd	0.25
Resistor 400	ohms	70,000
Condenser 402	mfd	0.25
Resistor 408	ohms	20,000
Condenser 406	mfd	0.00025
Resistor 330	ohms	5,000
Resistor 324	do	50,000
Condenser 336	mmfd	40
Resistor 326	ohms	5,000
Resistor 356	do	4,700
Variable resistor 358	do	10,000
Resistor 352	do	150,000
Resistor 354	do	4,700
Resistor 342	do	24,000
Resistor 344	do	24,000
Resistor 388	do	1,000
Resistor 392	do	1,000

The low frequency amplifier 16 employs a voltage amplifier 500, a push-pull cathode follower 502, a phase inverter 504, a voltage amplifier 506, a driver 508, and a push-pull power amplifier 510. The output from the low frequency section of the high and low frequency separation circuit 18 is transmitted to the low frequency amplifier 16 from the tap 96 of resistor 94 which is connected to a grid 512 of a vacuum tube section 514 in the voltage amplifier 500. The vacuum tube section 514 also has a cathode 516 which is connected to the ground terminal through series connected resistors 518 and 520. The plate 522 of vacuum tube section 514 is connected to a positive terminal 524 of a power source 526 through a resistor 528. The resistor 528 is connected in parallel with a resistor 530 and condenser 532 connected in series.

The push-pull cathode follower 502 employs a vacuum tube having a pair of triode sections 534 and 536. The two sections 534 and 536 have grids 538 and 540, respectively, which are interconnected through a double pole single throw switch 542 normally positioned to form this connection. The grid 540 is also connected to the grid 538 through a resistor 544 when the switch 542 is in its other position for purposes of balancing the input circuit of the cathode follower 502. Grid 538 is also connected to the plate 522 of vacuum tube section 514 through a resistor 545 and condenser 537 connected in parallel and a condenser 549. The vacuum tube sections 534 and 536 are also provided with cathodes 546 and 548, respectively, and these cathodes are interconnected through resistor 550, voltage divider 552 and resistor 554 connected in series. The tap of the voltage divider 552 is connected to the grid 538 through the resistor 554. The vacuum tube sections 534 and 536 have plates 556 and 558, respectively, which are interconnected and connected to a positive terminal 560 of the power source 526.

The phase inverter 504 is also provided with a vacuum tube having a pair of triode sections 562 and 564. The cathode 566 of vacuum tube section 562 is connected to the cathode 546 of vacuum tube section 534 through a resistor 538; and the cathode 570 of vacuum tube section 564 is connected to the cathode 548 of vacuum tube section 536 through the resistor 572. The grid 573 of vacuum tube section 562 is directly connected to the cathode 548 of vacuum tube section 536; and the grid 575 of vacuum tube section 564 is directly connected to the cathode 546 of vacuum tube section 534. The plate 574 of vacuum tube section 562 is connected to the positive terminal 560 through serially connected resistors 576 and 578, and the junction of resistors 576 and 578 is connected to the plate 580 of vacuum tube section 564 through a resistor 582. A resistor 584 and a condenser 586 connected in series are connected in parallel with the resistor 576; and a condenser 588 and a resistor 590 connected in series are also connected in parallel with the resistor 582.

The amplifier 506 has a vacuum tube with a pair of triode sections 592 and 594. Vacuum tube section 592 has a grid 596 connected to the plate 574 of vacuum tube section 562; and vacuum tube section 594 has a grid 598 connected to the plate 580 of vacuum tube section 564. The cathodes 600 and 602 of vacuum tube sections 592 and 594, respectively, are interconnected by serially connected resistors 604 and 606, and the junction of said resistors is connected to ground through a resistor 608. Vacuum tube section 592 has a plate 610 which is connected to a positive terminal 612 of the power source 526 through serially connected resistors 614 and 616, and vacuum tube section 594 has a plate 618 connected to the junction of resistors 614 and 616 by a resistor 620.

The driver 508 employs a vacuum tube with a pair of vacuum tube sections 622 and 624. Vacuum tube section 622 has a grid 626 connected to the plate 610 of vacuum tube section 592 through condenser 628, and vacuum tube section 624 has a grid 630 connected to the plate 618 of vacuum tube section 594 through a condenser 632. The grids 626 and 630 are also interconnected by serially connected resistor 634, potentiometer 636, and resistor 634 and potentiometer 636 is connected to the ground by serially connected resistors 640 and 642 and the junction between resistors 636 and 638 by a resistor 644. Vacuum tube section 622 also has a cathode 646 which is interconnected with the cathode 648 of vacuum tube section 624 by a pair of serially connected resistors 650 and 652, and the junction between the resistors 650 and 652 is connected to the tap of resistor 636 by a resistor 654 and to a negative terminal 653 of the power supply 526.

The power amplifier 510 employs a pair of vacuum tubes 656 and 658 connected in a push-pull circuit. The grid 660 of vacuum tube 656 is connected to the cathode 646 of vacuum tube section 622 through a resistor 662, and the grid 664 of vacuum tube 658 is connected to the cathode of 648 of vacuum tube section 624 through a resistor 666. Vacuum tube 656 has a cathode 668, and vacuum tube 658 has a cathode 670, both of these cathodes being connected to ground through a fuse 671. Vacuum tube 656 has a plate 672, and vacuum tube 658 has a plate 674; and these plates are connected to the ends of the primary 676 of a transformer 678. The primary 676 is provided with a center tap 680 which is connected to a positive terminal 682 to the power source 526, this positive terminal 682 also being connected to the plates 684 and 686 of vacuum tube sections 622 and 624, respectively. The primary 676 of the transformer 678 also has a pair of taps 688 and 690 which are connected to the screen grids 692 and 694, respectively.

The transformer 678 has a secondary 696 which is connected to the speaker 12 and to the ground terminal at one end. The other end of the secondary 696 is connected to the junction of resistors 518 and 520 in the voltage amplifier 500, thus forming a feedback loop, a parallel connected condenser 698 and variable resistor 700 being serially connected in the feedback loop. A resistor 702 connected to the plate 672 of vacuum tube 656 and to the cathode 600 of vacuum tube section 592 and a resistor 704 connected to the plate 674 of vacuum tube 658 and to the cathode 602 of vacuum tube section 594 provide an additional feedback loop from the power amplifier 510 to the amplifier 506.

In the particular construction of the invention described throughout this disclosure, vacuum tube section 514 is one section of a type 12AY7 vacuum tube, vacuum tube sections 534 and 536 are portions of a type 5814 vacuum tube, vacuum tube sections 562 and 564 are portions of a type 5751 vacuum tube, vacuum tube sections 592 and 594 are sections of a type 5814 vacuum tube, vacuum tube sections 622 and 624 are sections of a type 5814 vacuum tube, and vacuum tubes 656 and 658 are type KT-66 tubes. The power source 526 delivers plus

250 volts to terminal 524, plus 150 volts to terminal 560, plus 400 volts to terminal 612, minus 105 volts to terminal 653, and plus 400 volts to terminal 682, all of these voltages being measured relative to ground and power supplies 64 and 526 having common grounds. In addition, the power source 526 has terminals 706 which carry 6.3 volts D. C. and are connected to the filaments in the conventional manner.

The resistors and condensers employed in the low frequency amplifier 16 are given in the following table.

Table II

Resistor 528	ohms	47,000
Resistor 530	do	5,000
Condenser 532	mfd	0.005
Condenser 549	mfd	0.1
Resistor 545	ohms	3,000
Condenser 547	mfd	0.005
Resistor 544	ohms	1,000
Resistor 550	do	2,400
Resistor 552	do	2,000
Resistor 554	do	2,400
Resistor 568	do	3,300
Resistor 572	do	3,300
Resistor 578	do	24,000
Resistor 576	do	200,000
Resistor 582	do	200,000
Resistor 584	do	22,000
Condenser 586	mfd	0.0001
Condenser 588	mfd	0.0001
Resistor 590	ohms	22,000
Resistor 604	do	3,500
Resistor 606	do	3,500
Resistor 608	do	9,000
Resistor 614	do	100,000
Resistor 620	do	100,000
Resistor 616	do	10,000
Resistor 640	do	4,700
Resistor 644	do	4,700
Resistor 642	do	10,000
Condenser 628	mfd	0.25
Condenser 632	mfd	0.25
Resistor 634	ohms	510,000
Resistor 636	do	10,000
Resistor 638	do	510,000
Resistor 654	do	4,700
Resistor 650	do	24,000
Resistor 652	do	24,000
Resistor 662	do	1,000
Resistor 666	do	1,000
Resistor 702	do	100,000
Resistor 704	do	100,000
Condenser 698	mfd	0.00037
Resistor 700	ohms	25,000

The microphone 46 is a crystal microphone and mounted in front of the throat opening 38 in the speaker enclosure 22 at a distance no greater than 1½ feet from the vertex of the speaker cone. The microphone 46 is connected to the cathode 516 of the voltage amplifier 500 through the low pass filter 52 and a cathode follower 802. One terminal of the microphone 46 is directly connected to the junction between resistors 518 and 520 in the voltage amplifier 500, and the other terminal of the microphone 46 is connected to a grid 804 of a vacuum tube section 806 in the cathode follower circuit 802 through series connected resistors 808, 810, and a portion of a voltage divider 812. The voltage divider 812 is connected between the resistor 810 and the junction of resistors 518 and 520. A resistor 814 is connected between the junction of resistors 808 and 810 and the junction of resistors 518 and 520, and a resistor 816 and condenser 820 connected in series are connected in parallel with resistor 814. In like manner, a resistor 822 and a condenser 824 are connected in series and the combination

is connected in parallel with the voltage divider 812. It is thus clear that the filter 52 is a "step" filter.

In the particular construction described herein, vacuum tube section 806 is one section of a type 12AY7 vacuum tube, the other section being used in the voltage amplifier 500. The crystal microphone is of conventional construction and is responsive to sounds having a frequency from approximately 20 cycles per second to 12,000 cycles per second. The size of the various components in the low pass filter 52 are set forth in the following table.

Table III

Resistor 808	ohms	1,000
Resistor 810	do	1,000
Resistor 814	megohms	2.2
Resistor 816	ohms	500,000
Condenser 820	mfd	0.0006
Resistor 822	ohms	180,000
Condenser 824	mfd	0.00015
Potentiometer 812	ohms	1,000

The vacuum tube section 806 has a cathode 826 which is directly connected to the cathode 516 of vacuum tube section 514. Vacuum tube section 806 also has a plate 828 which is connected to the positive terminal 560 of the power source 526.

The signal source impresses the electrical signals to be reproduced upon the pre-amplifier 20 which amplifies the incoming signal without phase shift and without changing the relative amplitude of the high frequency and low frequency components of the signal. The pre-amplifier 20 has not been specifically disclosed, since many suitable pre-amplifiers having flat frequency responses are available and well-known. The high and low frequency separations circuit effectively reduces the high frequency components of the signal which is transmitted to the low frequency amplifier 60 to negligible amplitude, the frequency range impressed upon the low frequency amplifier 16 being approximately 30 cycles per second to an upper limit of 500 cycles per second, and in the particular construction described herein this frequency range is from 30 cycles per second to approximately 200 cycles per second. The upper limit of the frequency range impressed upon the low frequency amplifier is determined by the characteristics of the speaker enclosure 22, since speaker enclosures of the type described herein produce sounds having frequency responses with an upper limit falling off rapidly in the vicinity of 300 to 500 cycles per second, depending upon the design of the enclosure.

The design of the high pass filter 98 of the high and low frequency separation circuit 18 is determined by the characteristics of the high frequency amplifier 14 and high frequency speaker 10. In addition, however, the lower limit of the frequency range of the signals impressed upon the high frequency amplifier should approximately equal the upper limit of the frequency range of the signals impressed upon the low frequency amplifier 16 in order to cover the entire frequency range with the two speakers 10 and 12.

The low frequency amplifier 16 has a flat frequency response over the range of the signals impressed upon it from the output of the low pass filter 84 of the high and low frequency separations circuit 18, and thus the response of the low frequency speaker 12 also covers this range. It is possible that a relatively high frequency oscillation could occur in the feedback loop including the speaker 12, microphone 46, and low frequency amplifier 16, say in the vicinity of 1500 to 2500 cycles per second, since in the design of the low frequency amplifier there is no reason to provide a cut-off at the high frequency end of its response. The low pass filter 52 attenuates the high frequency components of the signals fed back in this feedback loop. This low pass filter 52 is a "step type" filter, and the filter must not introduce excessive phase shift. For this reason, the maximum "roll

off" or attenuation of the overall filter 52 must not exceed 10 db per octave, or excessive phase shift will be introduced in this feedback loop. The filter 52 must attenuate signals in excess of three to four times the crossover frequency to avoid oscillations.

As a result of introducing the feedback loop including the speaker 12, microphone 46, low pass filter 52, and low frequency amplifier 16, a cleaner reproduction of the low frequency, or base, response in a high fidelity system is achieved. Further, no sensation of "boominess" occurs.

The man skilled in the art will devise many utilities and modifications of the present invention beyond those specifically disclosed herein. It is therefore intended that the scope of the present invention be not limited by the foregoing disclosure, but rather only by the appended claims.

The invention claimed is:

1. A sound reproducing device comprising a speaker arranged to operate up to a certain crossover frequency, an amplifier having an input adapted to be connected to a signal source and an output connected to the speaker, a microphone confronting the speaker at a distance from $\frac{1}{8}$ to $\frac{1}{4}$ wavelength of said crossover frequency, and connected to the input of the amplifier, and means to attenuate the frequency components produced by the microphone above several times said crossover frequency.

2. A sound reproducing device comprising a speaker arranged to operate up to a certain crossover frequency, an amplifier having an input adapted to be connected to a signal source and an output electrically connected to the speaker, a microphone confronting the speaker and spaced therefrom by a distance ranging from $\frac{1}{8}$ to $\frac{1}{4}$ wavelength of said crossover frequency, and a low pass filter attenuating frequencies above 1000 cycles per second electrically connected between the microphone and the input of the amplifier.

3. A sound reproducing device comprising a high and low frequency separation circuit having an input adapted to be connected to an audio source and high and low frequency outputs, said separation circuit having a predetermined crossover frequency, a first amplifier having an input electrically connected to the low frequency output of the separation circuit, a first speaker connected to the first amplifier, a second amplifier connected to the high frequency output of the separation circuit, a second speaker connected to the second amplifier, a microphone confronting the first speaker and spaced therefrom between $\frac{1}{8}$ and $\frac{1}{4}$ wavelength of said crossover frequency, and a low pass filter electrically connected between the microphone and the input of the first amplifier, said filter attenuating frequencies several times those of said crossover frequency.

4. A sound reproducing device comprising a high and low frequency separation circuit having a selected crossover frequency including a pair of cathode follower stages having vacuum tubes with interconnected control grids, interconnected plates, and cathodes, the first of said stages having a plate to cathode circuit including a first resistor and the second of said stages having a plate to cathode circuit including a second resistor, a low pass filter connected across the first of said resistors having a low frequency output, a high pass filter connected across the second of said resistors having a high frequency output, a first amplifier having an input electrically connected to the low frequency output of the separation circuit, a first speaker connected to the first amplifier, a second amplifier connected to the high frequency output of the separation circuit, a second speaker connected to the second amplifier, a microphone confronting the first speaker and spaced therefrom by $\frac{1}{8}$ to $\frac{1}{4}$ wavelength of said crossover frequency, and a low pass filter electrically connected between the microphone and the input of the first amplifier, said filter attenuating frequencies above three to four times said crossover frequency.

5. A sound reproducing device comprising a high and low frequency separation circuit operating relative to a certain crossover frequency and having an input adapted to be connected to an audio source and high and low frequency outputs, a first amplifier having an input electrically connected to the low frequency output of the separation circuit, a first speaker connected to the first amplifier, a second amplifier connected to the high frequency output of the separation circuit, a second speaker connected to the second amplifier, a microphone confronting the first speaker and spaced therefrom by $\frac{1}{8}$ to $\frac{1}{4}$ wavelength of said crossover frequency, and a low pass filter attenuating frequencies higher than said crossover frequency, said filter being electrically connected between the microphone and the input of the first amplifier and having at least two low pass networks connected in cascade, each of said networks including two resistors and a capacitor connected in series, and a third resistor connected in parallel with the capacitor and one of the resistors, the following low pass network being connected across the third resistor.

6. A sound reproducing device comprising a high and low frequency separation circuit operating relative to a certain crossover frequency and having an input adapted to be connected to an audio source and high and low frequency outputs, a first amplifier having at its input a pair of stages, the second of said stages being a cathode follower stage, each stage including a vacuum tube with a plate, a grid, and a cathode, the cathodes of said tubes being interconnected and the grid of the first of said stages being connected to the low frequency output of the separating circuit, a speaker enclosure having a front panel and an inner panel having a throat opening therein, a first speaker mounted within the enclosure confronting the throat opening and facing the front panel, a second amplifier connected to the high frequency output of the separation circuit, a second speaker connected to the second amplifier, a microphone disposed between the front panel and the inner panel of the enclosure confronting the throat opening and electrically connected to the input of the first amplifier, said microphone being from the speaker a distance equal to $\frac{1}{4}$ to $\frac{1}{8}$ wavelength of said crossover frequency, and a low pass filter electrically connected between the microphone and the grid of the second stage of the first amplifier, said filter attenuating frequencies above three to four times the crossover frequency.

7. A device for reproducing sound from a signal source comprising a speaker enclosure including a front panel and an inner panel spaced rearwardly of said panel and having a throat opening therein, a speaker mounted rearwardly of the opening in the enclosure, an amplifier having an input adapted to be connected to a signal source and an output connected to the speaker, a microphone disposed between the front panel and the inner panel confronting the throat opening and electrically connected to the input of the amplifier, and means to attenuate the frequency components produced by the microphone above 1000 cycles per second.

8. A device for reproducing sound from a signal source comprising a speaker enclosure including a front panel, and an inner panel spaced rearwardly of said front panel and having a throat opening therein, a speaker mounted rearwardly of the opening in the enclosure, an amplifier having an input adapted to be connected to a signal source and an output connected to the speaker, a microphone, vibration isolation means attached to the front panel and the microphone and between the inner panel and the microphone to mount said microphone between the front panel and the inner panel confronting the throat opening, and a low pass filter attenuating frequencies above 1000 cycles per second electrically connected between the microphone and the input of the amplifier.

9. In a sound reproducing system having a plurality of loud speakers, the combination of high and low fre-

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quency separation circuits having a certain crossover frequency, an amplifier connected to said circuits, a low frequency speaker connected to said amplifier, a microphone positioned in front of said speaker a distance equal to $\frac{1}{8}$ to $\frac{1}{4}$ wavelength of said crossover frequency, and a low frequency filter connected between said microphone and the input to said amplifier, said filter precluding the transmission of frequencies greater than from three to four times said crossover frequency.

10. In a sound reproducing system having a plurality of loud speakers, the combination of high and low frequency separation circuits having a certain crossover frequency, an amplifier connected to said circuits, a low

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frequency speaker connected to said amplifier, a microphone positioned in front of said speaker a distance equal to $\frac{1}{8}$ to $\frac{1}{4}$ wavelength of said crossover frequency, a negative feedback circuit interconnecting said microphone and the input of said amplifier, said latter circuit including means for effectively eliminating frequencies appreciably higher than said crossover frequency.

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