The main theme of this chapter is the design of multifilm hydrophone. Flexure mode devices with multifilm/multielement constructions are already reported in the open literature [92][102]. In a flexure bimorph configuration, two piezoelectric films are sandwiched together and are bonded to a non-piezoelectric substrate. According to the external electrical connections, two configurations are possible for bimorph devices. In series bimorph the polymer films are connected electrically in series, whereas in parallel bimorphs they are electrically parallel. In the construction of bimorphs, the thickness and mechanical properties of the bonding layer must be considered to determine the performance of the bimorph. In some cases, instead of two films, more number of piezoelectric layers are laminated resulting in a structure known as multimorph.
The multifilm designs described here are not bimorphs, but a variant of this extended to the (3,1) drive design. These are made up of two independently mounted PVDF films coupled to each other mechanically. The two multifilm designs described here are:

1. MF 01
2. MF 02

The major difference between these two designs lies in the distinct approaches for the mounting of the films.

6.1 MF 01

A cross-sectional view of the hydrophone design is shown in Fig. 6.1. A circular phosphor bronze sheet of diameter 5.5 cm and thickness 1 mm serves as the diaphragm for transferring the impinging acoustic energy to the active element. A perspex annular ring with sides threaded and a groove at the top for a rubber O-ring, is fixed over a cylindrical enclosure. A perspex cap with its insides threaded and a groove at the bottom for a second O-ring, forms the upper part of the head assembly. The diaphragm is placed over the perspex ring with O-rings on both sides, and is tightened properly with the cap, so that the diaphragm is pressed uniformly. An opening of approximately 5 cm is provided at the centre of the cap for exposing the diaphragm to the external pressure field. A brass driver pin of length 2 cm and diameter 1 mm is fixed at the centre of the diaphragm. At the other end of the pin a rectangular sheet of copper of 1 cm × 0.5 cm is soldered. To both sides of this strip two PVDF films of 5 cm × 1 cm × 52 μm are adhered. The films are stretched independently and the terminal electrodes are connected.
Fig. 6.1: A cross-sectional view of MF 01.

C : PERSPEX CAP
D : PHOSPHOR BRONZE DIAPHRAGM
T : THREADINGS
R : PERSPEX ANNULAR RING
O : RUBBER 'O' RINGS
P : DRIVER PIN
F1, F2 : PVDF FILMS
E : WATER TIGHT ENCLOSURE
separately. Hence this assembly can be considered as having two parallel fixed films attached to a phosphor bronze diaphragm through a driver pin.

The principle of working of this design is similar to the refined model except that the present design uses two films which are excited by the same incident acoustic pressure. With this arrangement the voltage outputs will be developed across the films simultaneously, which can be extracted through the terminal electrodes.

In order to facilitate different combination of the film outputs, the tail assembly of the enclosure is made similar to the top one, except that the opening at the top assembly is absent at the bottom cap. Underwater connector is used for taking the cumulative output. So the hydrophone's tail part can be opened and the outputs of the films can be suitably combined and tapped to the underwater connector. As in the earlier designs MOSFET preamplifier AMP 4002 is also connected at the output with an extended cable length of 25 metres.

The response of this hydrophone was evaluated in air and water for individual films and for their series combination. B&K 8104 was used as the reference transducer in air and the sensitivity of the unknown transducer was calculated using comparison method. Fig. 6.2 illustrates the response of the hydrophone in air for individual films and for their series combinations in the frequency region of 300 Hz to 2.5 kHz.

Evaluation of the hydrophone performance in water was carried out at the Lake Facility. UW 15 was used as the projector and ITC 1042 as the reference
Fig. 6.2: Frequency response of MF-01 in air for a single film and for its series combination with a second one.
hydrophone. Fig. 6.3 depicts its response for individual films and their series combinations, in water.

The response of the hydrophone with the individual films (F1 or F2) was similar and hence only one of the responses is shown.

6.2 MF 02

MF 02 is similar to the MF 01 except that it uses two opposed films instead of two parallel films as in MF 01. Fig. 6.4 describes a sketch of this reformed multifilm version. Here also the head and tail assemblies are similar to MF 01 with a difference in the structure of the mounting of polymer films. In the head assembly, it also uses a phosphor bronze diaphragm of diameter 5 cm and thickness 1 mm, which is squeezed in between two rubber O-rings. One end of a driver pin is attached to the centre of the diaphragm and the other end to a 'L' shaped structure as shown. This structure has length 7 cm, breadth 1 cm and thickness 1.5 mm, is made of perspex and is terminated with a rectangular perspex sheet of 1.5 cm × 1 cm × 1.5 mm. To this rectangular sheet two polarised PVDF films of 5 cm × 1 cm × 52 µm are glued as shown. The films are stretched independently and the outputs are taken across them individually. So the whole assembly can be considered to be having two opposed polymer films attached to a phosphor bronze diaphragm through a perspex structure.

When the diaphragm vibrates due to the external acoustic pressure, the perspex structure coupled to it will also vibrate in accordance. This will make one of the films to expand and the other to contract. Corresponding to these strains on
Fig. 6.3: Frequency response of MF 01 in water with single film and its series combination with a second one.
Fig. 6.4: A cross-sectional view of MF 02.
the films, voltages will be developed across them simultaneously. The outputs are extracted through the separate output electrodes and are suitably combined.

Response of the hydrophone was evaluated in air and water. Figs. 6.5 and 6.6 show its response in air and water respectively for the individual films and for their series combination.

The purpose of both the designs described above is to increase the sensitivity of the hydrophone by adding up the voltages developed across the films due to a given incident acoustic pressure. While comparing the different plots furnished, it is clear that the procedure adopted for adding up of the voltages developed in two different films of both the hydrophone designs achieved the desired results. Of the two multifilm designs, MF 02 behaved in a better way than MF 01, particularly where the band of operation is concerned. But the design of MF 01 is more compact and simpler than MF 02, as mounting of the film is not complex.

It may be possible to enhance the sensitivity further by increasing the number of films. But it is to be noted that, when the number of films increases, their effective electrical impedance will also increase, as they are connected electrically in series. This increased impedance will drastically dampen the resultant output, if necessary precautions like suitable means to convert the signal path from high impedance to low impedance etc. are not taken. The graph shown in Fig. 6.7 is the impedance plot of MF 02, which throws light on the impedances of individual films and for their series combination in the frequency range of 300 Hz to 4 kHz. It can be inferred from the plot that the trend of increasing impedance is higher at lower frequencies.
Fig. 6.5: Frequency response of MF 02 in air for individual films and for their series combinations.
Fig. 6.6: Frequency response of MF 02 in water for individual films and for their series combinations.
Fig. 6.7: Frequency versus Impedance plot of MF 02.