Chapter 4. Theory - Enclosures

Sealed Enclosure

Within the piston operating range, loudspeaker vibrating assembly consists of mass Mmd, resistance Rms and compliance of the suspension Cms - Fig 4.1. These three components move with the same velocity Uc in respect to the box, which has velocity equal to 0. The first step is to draw Mmd, Rms and Cms connected in parallel between the velocity line U=Uc and U=0.

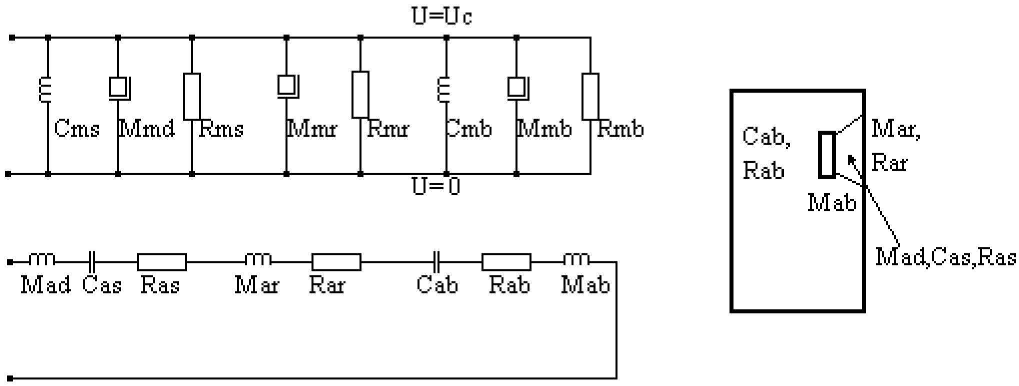


Fig 4.1

The front of the diaphragm radiates into the air in front of the box and the radiation impedance is represented by Mmr and Rmr connected again in parallel between U=Uc and U=0 lines. In this case, connection to Uc reflects the fact, that air immediately outside the box is excited by the diaphragm and connection to U=0 represents the fact, that the energy will eventually be sinked into the "still air".

The back side of the diaphragm is loaded by a thin, non-compliant layer of air represented by Mmb and then by compliance of the box with its losses - Cmb and Rmb connected in parallel between velocity lines. Upper end of the mass Mmb, vibrates with velocity Uc, and the other end, as we remember, must be connected to ground when mechanical mobility circuit is considered. The air in the box is compressed between the diaphragm, vibrating with velocity Uc, and the walls of the box, where velocity U=0 and this explains connection of Cmb and Rmb. It can be observed, that when the driver is mounted in the enclosure, its compliance Cas is connected in series with box compliance Cab, reducing total (system) compliance in accordance with the following formula: $C_{at} = C_{as} * C_{ab} / (C_{as} + C_{ab})$; where Cat is the system compliance. Masses Mar and Mab constitute what is known as "air load" $M_{at} = M_{ar} + M_{as}$. The air load increases total moving mass by up to 10% above the weight of the vibrating assembly. Now the system resonant frequency will determined by Cat and Mat and will be higher than the "free air" resonant frequency.

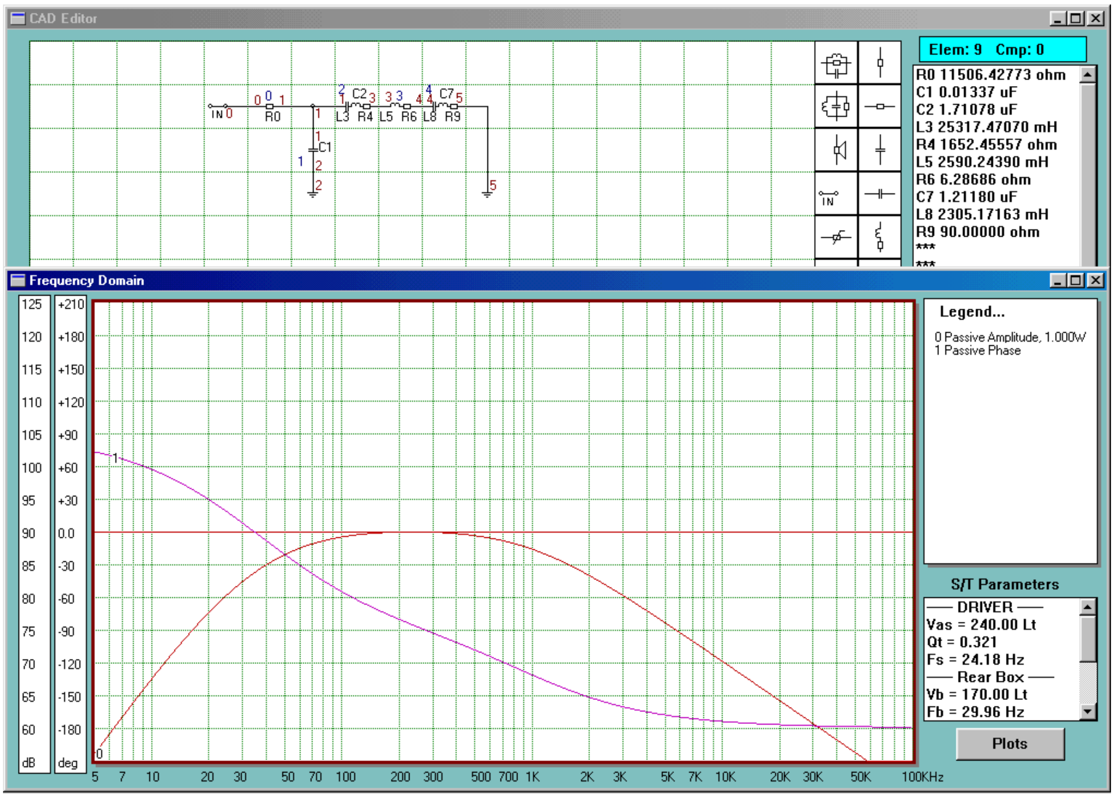


Fig 4.2 Sealed enclosure – acoustical impedance

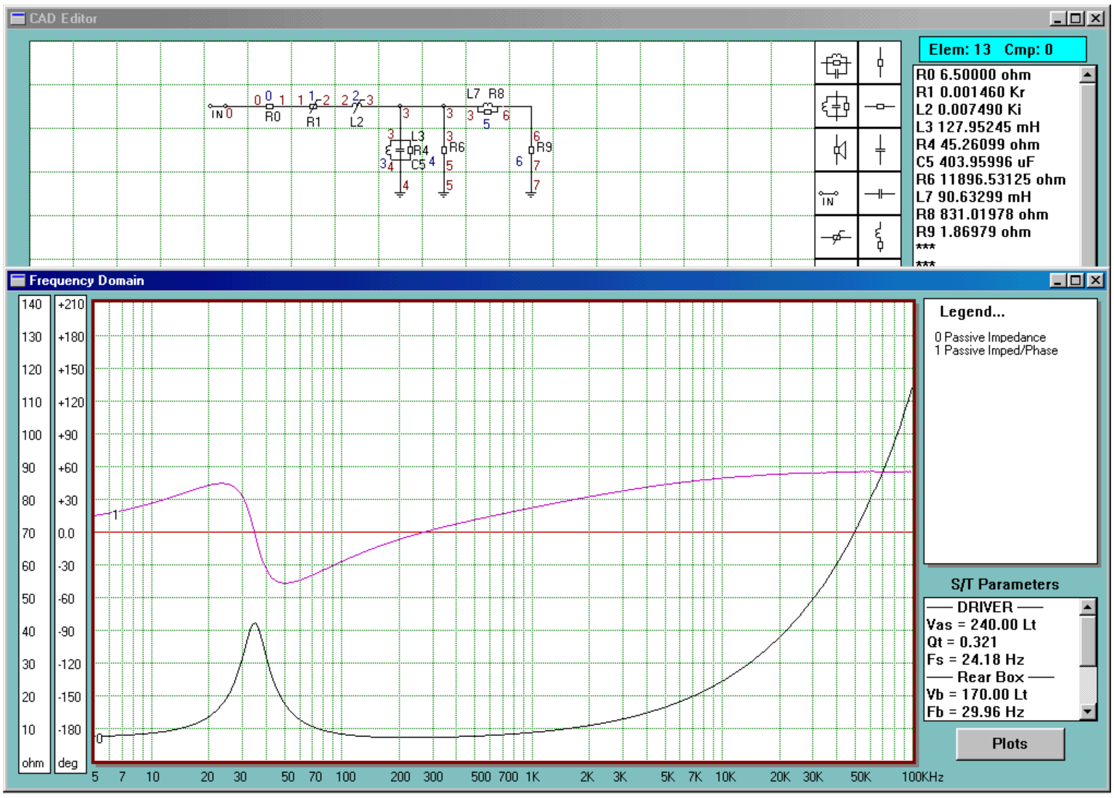


Fig 4.3 Sealed enclosure – electrical impedance

Assuming that walls of the enclosure are rigid, one would expect that absorption losses are small and the dominant enclosure losses are due to air leaks. There are many possible paths for the air to escape such as: back plate connectors, basket seal and - probably the worst offenders - pourus dust caps. These losses will affect enclosure Q-factor. It is more convenient to lump all possible losses due to various leaks into one element Rl and represent it on the acoustic impedance circuit as a resistor connected in parallel to Rab+Cab. This would provide an alternative, parasitic path for volume velocity (current - in acoustic impedance circuits) to trickle away from the circuit to the ground. Low Rl resistance would provide lower resistance path for volume velocity to be diverted from the radiating component (port), effectively reducing total system output. The acoustic impedance circuit is therefore more refined than the mechanical mobility representation and offers the user separate entries for absorption and leakage losses.

Fig 4.2 shows acoustical impedance representation adopted for the sealed enclosure model. The components are:

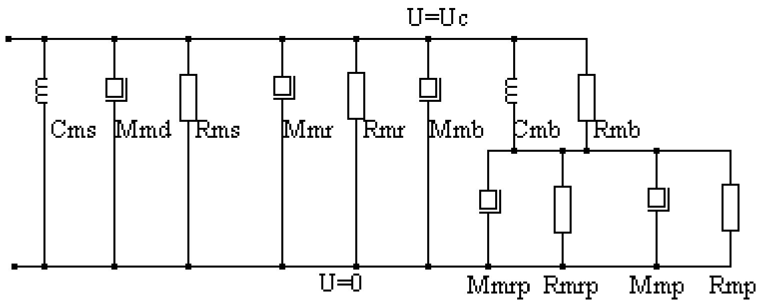
R0 = Rea, electrical DC resistance Re transformed to acoustical side.
C1 = Lea, voice coil inductance Le transformed to acoustical side.
C2 = Cas, equivalent compliance volume Vas transformed to acoustical side.
L3 = Mad, mass of the vibrating system Mms transformed to acoustical side.
R4 = Ras, vibrating assembly loss Rms transformed to acoustical side.
L5 = Mar, air radiation of the front side of the diaphragm.
R6 = Rar, air radiation of the front side of the diaphragm.
C7 = Cab, enclosure compliance Vab transformed to acoustical side.
L8 = Mab, air load of the back side of the diaphragm.
R9 = Rab, absorption losses of the enclosure transformed to acoustical side.

Leakage losses Ral are not included in this circuit, but Ral can be connected in parallel with Cab+Rab. Fig 4.3 shows electrical impedance model of a sealed system.

Vented Enclosure

Vented enclosure provides different loading for the back of the diaphragm, as compared to the sealed box. The vibrating system and front loading of the diaphragm are represented on the mechanical mobility circuit the same way as for the sealed enclosure.

Introduction of the vent adds several more components such as: (1) mass of the air in the port Mmp and its losses Rmp and (2) radiation impedance of the port represented by Rmrp and Mmrp. The air in the port is treated as a mass because of its small volume and more importantly, because it is incompressible. Particles of air will move on both sides of the vent with the same velocity.



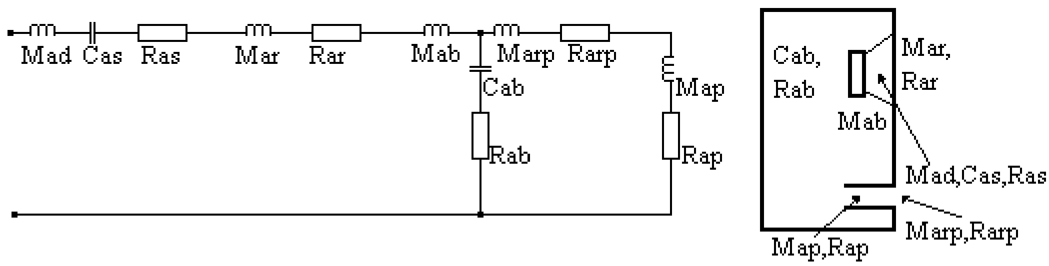


Fig 4.4

The air compressed in the box by the back side of the diaphragm has only one path to escape - pushing the air mass trough the vent. Therefore, the pressure path consists of series connection of Cmb, representing compliant air in the box and the four elements of the port. Since the air in the port is incompressible, the immediate layer of air in front of the box (radiation impedance) will be connected to the same velocity line as the entry to the port inside the box. The other end of the masses is connected to the U=0, or reference velocity as required in mechanical mobility circuits.

The mechanics of the above process can be easily demonstrated on a physical model of a vented box. Connecting a small (1.5V) battery across vented box terminals, we can displace the cone in or out of the box. Small air-flow detecting device (candle) positioned in front of the port will show significant air movements, in the direction opposite to the diaphragm. The volume of air displaced by the cone should be similar to the volume of air leaving the port. If the difference is significant, than leakage losses are significant (small Rl).

The above experiment clearly shows the pressure (current) path in the mechanical mobility model, so it should now be easy to explain why the compliance of the box is connected in-series with port elements. It is observable, that Cmb and Mmp+Mmrp form series resonant circuit in the mechanical mobility representation. The circuit will act as a “selective short circuit” for the volume velocity Uc, shorting it to U=0 (ground) at the circuit resonant frequency. Because of the circuit losses, the short is not perfect, but velocity Uc will be much reduced. In the practical system this situation translates into much reduced cone excursion at the box resonant frequency.

Acoustical impedance representation shows Cas and Map+Marp forming parallel resonant circuit. Electrical circuit theory advocates that very little energy (current) needs to be fed into the circuit for it to resonate and for the current (volume velocity) in the resonant circuit to be still very high. Therefore, volume velocity in the "feeding" branch, which contains diaphragm output will be very small and volume velocity in the resonant circuit containing port will be high. This effect, although the strongest on the resonant frequency Fb, will extend over some narrow frequency range and on the low-end side creates extended system output. It is the enclosure/port resonance effect, that is being exploited here to augment system output at low frequency.

A number of tuning arrangements (alignments) can be performed on the vented system. Usually, there will be one "optimal" tuning and a number of other alignments, depending on how much deviation from optimum one is prepared to tolerate. Tuning the box lower than optimum, will still provide significant output from the port around the box/port resonant frequency, but a "saddle" on the system frequency response will start to show up above Fb due to driver's roll-off.

The acoustic impedance model created using the "dot method" can be again enhanced by adding enclosure leakage losses represented by Rl and connected in parallel to Rab+Cab.

Fig 4.5 shows acoustical impedance representation adopted for the vented enclosure model. The components are:

R0 = Rea, electrical DC resistance Re transformed to acoustical side.
C1 = Lea, voice coil inductance Le transformed to acoustical side.
C2 = Cas, equivalent compliance volume Vas transformed to acoustical side.
L3 = Mad, mass of the vibrating system Mms transformed to acoustical side.
R4 = Ras, vibrating assembly loss Rms transformed to acoustical side.
L5 = Mar+Mab, air radiation of the front side of the diaphragm + air load of the back side of the diaphragm.
R6 = Rar, air radiation of the front side of the diaphragm.
C7 = Cab, enclosure compliance Vab transformed to acoustical side.
R8 = Rab, absorption losses of the enclosure transformed to acoustical side.
R9 = Ral, leakage losses of the enclosure
L10 = Marp, port radiation.
R11 = Rarp, port radiation.
L12 = Map, mass of the air in the port.
R13 = Rap, frictional losses in the port.

Fig 4.6 shows electrical impedance model of a vented system.

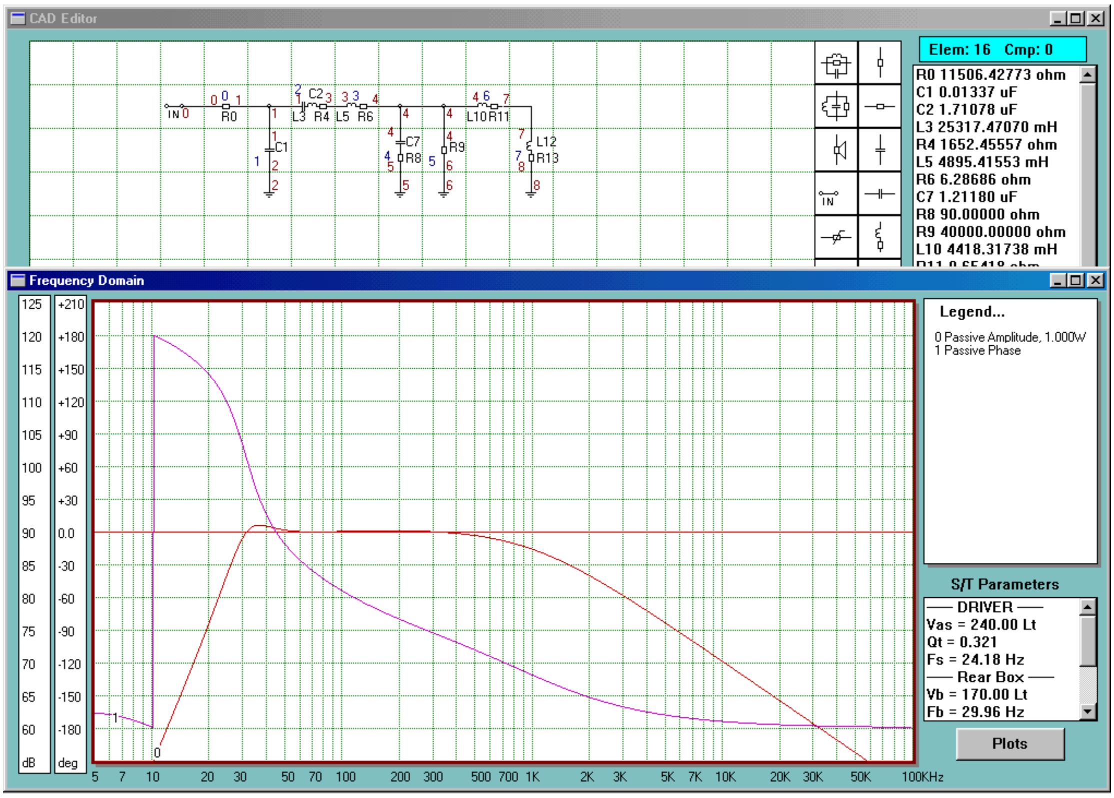


Fig 4.5 Vented enclosure – acoustical impedance

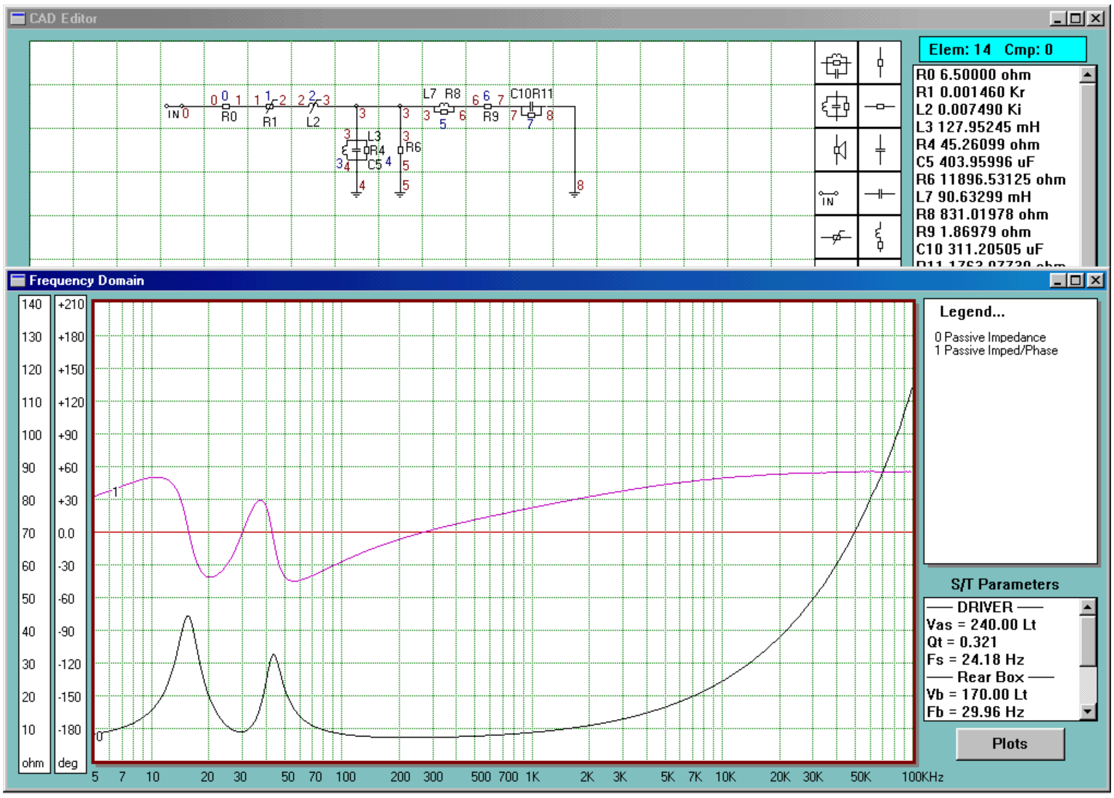


Fig 4.6 Vented enclosure – electrical impedance