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INTRODUCTION

For many years the Celestion Cabinet Handbook has been the musician's most useful single course of practical cabinet designs.

In this new Handbook we have covered the background and theory, both of cabinet and system design, in much greater detail. This Handbook encompasses all the key information you need to make the best use of your loudspeakers.

There are four sections:-

THEORY:	*The principles behind, and reasons for using, the main varieties of cabinet.*
APPLICATIONS:	*Which speakers and cabinets work best for lead and bass guitar, vocal/keyboard or PA use.*
PROJECTS:	*Detailed construction plans for 16 different cabinets.*
APPENDIX:	*Further data including formulae and driver cut-out dimensions.*

If you simply want to build a cabinet to suit your speaker and your application, or if you want to go fairly deeply into the theory and mathematics of designing your own box, there is something here for you.

SEALED CABINETS

Of the three simple cabinet designs, the sealed cabinet is the most basic and easy to build. Known also as an infinite baffle or acoustic suspension system, the design normally uses a single loudspeaker mounted on the front baffle of a completely airtight box.

Pros and Cons

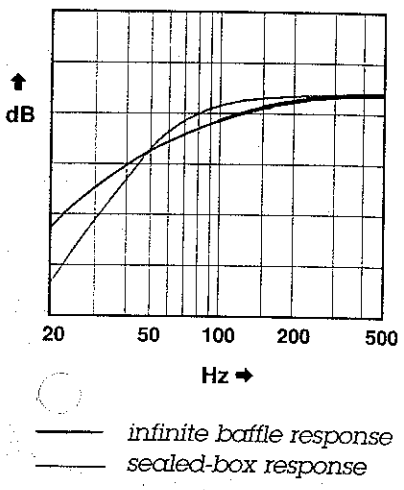
The sealed cabinet is simple to design and simple to build. It has been described as the best sounding, with the most controlled bass of any box design. It can be tuned for a very smooth response curve.

The major limitation of the sealed box in sound reinforcement applications is that it does little to enhance the bass performance, power handling or efficiency of the driver, compared to the ported or horn loaded boxes.

Principles

Only the sound radiating from the front of the speaker is relevant in the sealed box design. All the energy from the rear of the speaker is theoretically absorbed by the box.

It is the air in the cabinet that affects the system's performance. In a small box the air is difficult to compress, so it acts as a damper on the movement of the driver, therefore raising the resonant frequency of the system. As the box gets bigger the air inside the box can be compressed more easily, and so has less of a dampening effect on the movement of the driver.



infinite baffle response
sealed-box response

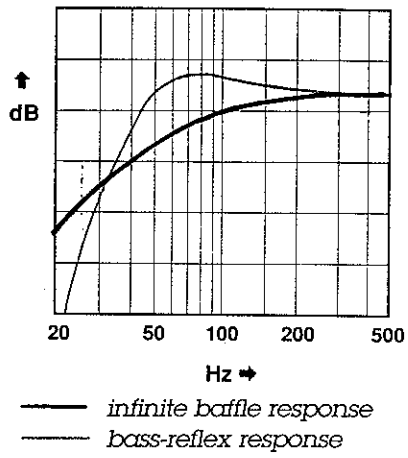
As the box size increases, the bass end is extended. When the total Q of the system Q_{tc} reaches a value of 0.7 there is the best combination of even response and extended bass. This is the 2nd Order Butterworth alignment. As Q_{tc} goes above 0.7, there is an increasing hump in the response just above the cut-off frequency. This may be desirable to give the effect of more bass, but variations of greater than 3 or 4 dB will upset the overall musical balance.

PORTED CABINETS

The ported or bass reflex cabinet is a simple box enclosure with a hole or port added on the front baffle. It is only marginally more complex to build than the sealed cabinet.

Pros and Cons

For most musician and PA uses, the ported cabinet offers the best option for building a clean sounding loudspeaker system that makes the most of the bass drivers used. The addition of the port can extend the driver's bass performance by almost a whole octave. It will also marginally improve the speaker's low



frequency power handling and efficiency. Whilst building the box is no more difficult than building a sealed box, the mathematics necessary for calculating the box and port sizes is fairly complicated. Unless this is done with some degree of accuracy, the system will perform unpredictably.

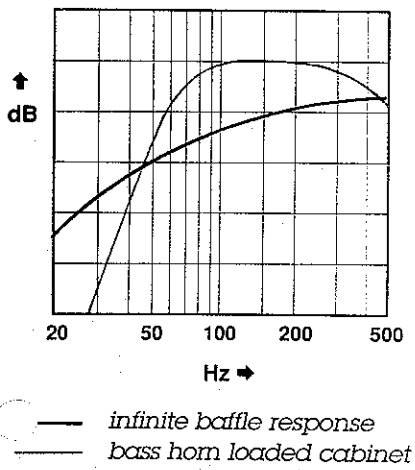
Principles

The energy from the front of the driver is radiated to the outside world as with the sealed box. But the sound from the back of the speaker also has an effect, as it vibrates the air in the port. This has a resonant frequency, like an organ pipe, adding to the sound output of the system. If the port is designed correctly, the additional energy will extend the bass performance of the speaker system, without adding distortion or sacrificing a smooth response.

HORN LOADED CABINETS

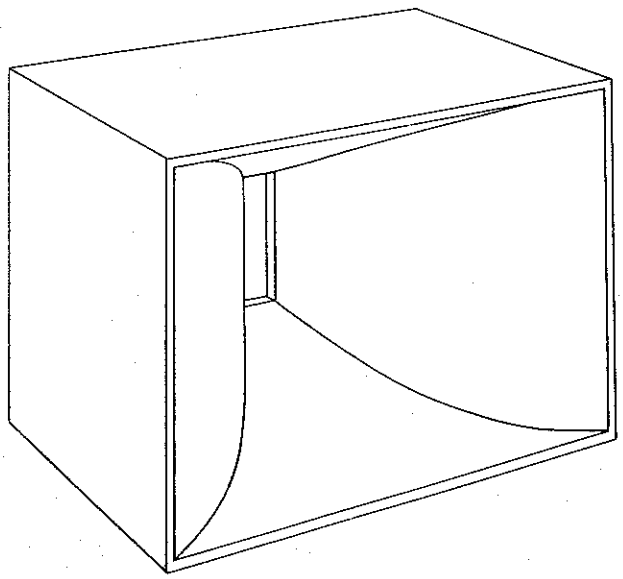
The horn loaded speaker system dates back to pre-electric days, with the large horns fitted to acoustic gramophones. The horn attempts to match the high acoustic impedance of the driver to the low impedance of the surrounding air, whilst dramatically increasing the effective radiating area of the driver.

These designs gained great popularity in the 1960s and 1970s for mid-range; and in modified forms, incorporating both horn and reflex principles, for bass.



Pros and Cons

Within its bandwidth, the horn loaded design significantly increases the efficiency of a bass driver. It is also highly rated for its ability to project bass into the auditorium. But it is not capable of extreme bass performance without the horn becoming unrealistically big. As drivers have increased in efficiency and power handling, they no longer necessarily need the assistance of a horn loaded box to give a reasonable bass output. The horn design demands a high level of woodworking skill, as large areas of plywood have to be bent into accurate curves.

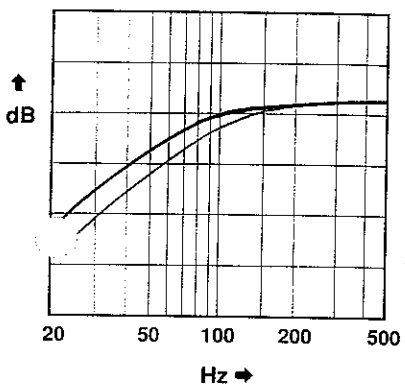


Principles

The energy from the driver is transmitted directly to a horn which forms a mathematical flare. The horn is designed to gradually alter the acoustic impedance from the high impedance of the driver to the low impedance of free air. The lowest frequency that the horn will reproduce is directly related to the size of the horn's mouth. For low frequency work the horn mouth has to be large, and therefore the horn itself must be long to achieve the gradual change in impedance.

OPEN BACKED CABINETS

With lead/rhythm guitar, there is no need to extend the bass response of the driver. Many cabinets and combos for this use are open backed, which places the driver into a convenient and secure casing.

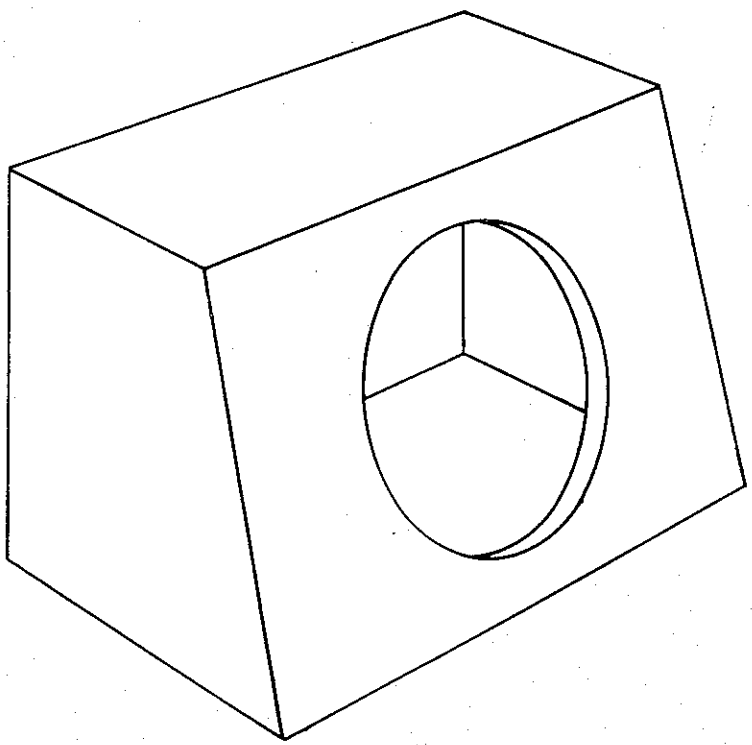


infinite baffle response
open back cabinet

Principles

Without any port or enclosed mass of air, there is no gain in the driver's bass performance. However, the box does perform a function beyond protection. If the driver is used without any cabinet at all, the sound coming from the rear of the speaker would cancel out some of the sound from the front of the driver, so reducing the amount of bass heard.

The sides of the open backed cabinet reduce this effect, and so the driver's bass performance is neither extended nor attenuated.



HF & HF-HORN CABINETS

HF drivers and HF horns need no assistance from the box to improve their performance. The cabinets for the HF systems are purely for protection and handling convenience, when transporting and setting up the system.

Impedance

A driver's impedance is its resistance to an AC signal. Loudspeaker impedances are normally quoted as a nominal value of either 4Ω, 8Ω or 16Ω, indicating the average impedance in an area above the driver's resonant frequency. Impedance is important for calculating crossover component values and working out the best way of connecting several drivers with a given amplifier.

Speakers can be connected together in parallel, series, or series/parallel. The performance of the speaker is unchanged, but the total impedance the amplifier sees will be different depending on which way the drivers are connected.

In series the total impedance increases as drivers are added, whereas if additional drivers are connected in parallel, the total impedance decreases.

Series/parallel offers the opportunity to even out the total impedance, when four or more drivers are used.

PASSIVE CROSSOVERS

The passive crossover filters the audio signal coming out of the amplifier into separate frequency bands. These bands feed each of the different driver sections within the loudspeaker system.

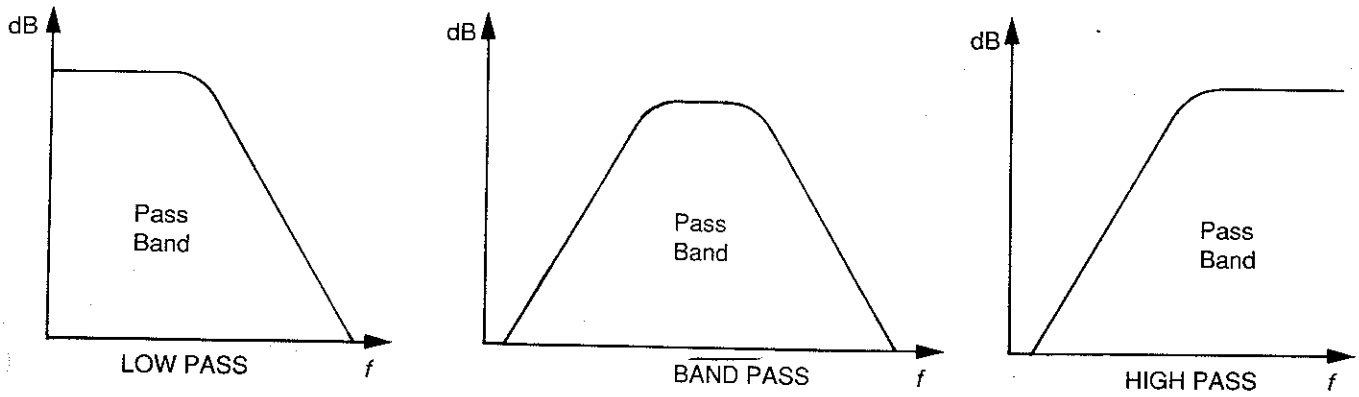
The passive crossover is normally either 2-way (LF + HF) or 3-way (LF + MF + HF) and the crossover points can be designed to suit the drivers used.

Pros and Cons

The passive crossover is simple to design and build. A high quality passive crossover can cope with systems of up to 500W peak power, and allows a complete loudspeaker system to be driven from a single amplifier channel. Because of the difficulty in getting very high power components, passive crossovers are not suitable for the largest systems. They also offer little flexibility for on-site alteration of relative levels or crossover frequencies.

Principles

All crossovers operate as a combination of high pass and low pass filters. The signal can be rolled off at 6dB/octave (1st order), 12dB/octave (2nd order), 18dB/octave (3rd order) or at even steeper filter rates. The roll-off needs to be reasonably steep to filter out enough of the unwanted frequencies. But as the filter rate increases, so does the crossover's complexity and internal phase shifts. Normally the 2nd Order (12dB/octave) crossover is considered the best compromise for musician and PA systems.



ACTIVE CROSSOVERS

Active, or electronic, crossovers filter the signal before, rather than after it gets to the power amplifier. Normally available as commercial rack mounting units, most have controls to adjust both the crossover frequency and level. Some also include variable filter rates and built-in limiters.

Pros and Cons

The active crossover works at line levels, using normal low-power components, making it easier to manufacture a high quality, complex, active crossover. As it is connected between the mixer and amplifier, there is no restriction to the size of amplifier you can use. However, the need for a separate amplifier channel for each frequency band makes the active system more expensive to implement than the passively driven one.

LEAD GUITAR

Speakers for lead and rhythm guitars are an extension of the instrument itself with a tonal character of their own. The loudspeaker system is designed for a distinctive sound that enhances the style of the player. The system should have a tight and well projected sound, which is normally achieved by using a 12" or 10" driver in a sealed or open backed cabinet. The driver will be one of the range of paper edged (PE) models, as these each have a distinctive sound and high output.

Larger and more powerful systems can be built by increasing the quantity of 10" or 12" drivers to 2 or 4. Whilst being bigger, heavier and less convenient to transport, these boxes have greater efficiency and disperse the mid/high signals better. At the other end of the scale, a single 8" driver is ideal for a compact practice speaker.

BASS GUITAR

Bass guitar speakers should be designed to produce a powerful, smooth and undistorted sound that extends as deep as possible. The drivers need to deal with a lot of energy, so systems must use at least a single 15" or 18" driver, mounted in a ported or sealed cabinet. The alternative is to use 4 x 10" or 12" drivers or a pair of 15" units. Cloth edged (CE) are required for bass guitar as they have an extended, uniform response.

FULL RANGE VOCAL/KEYBOARD

Vocal/keyboard speakers should be designed to produce an undistorted, wide range performance that projects well. Pairs of 10" or 12" drivers in a ported or sealed box will give good mid-range performance and dispersion with some protection against feedback.

Cloth edged (CE), with their clean, powerful performance, are the first choice for these types of systems. For greater clarity at the top end, add an HF unit to the system. HF drivers will extend the response of the system to 15kHz, with improved dispersion control at the higher frequencies.

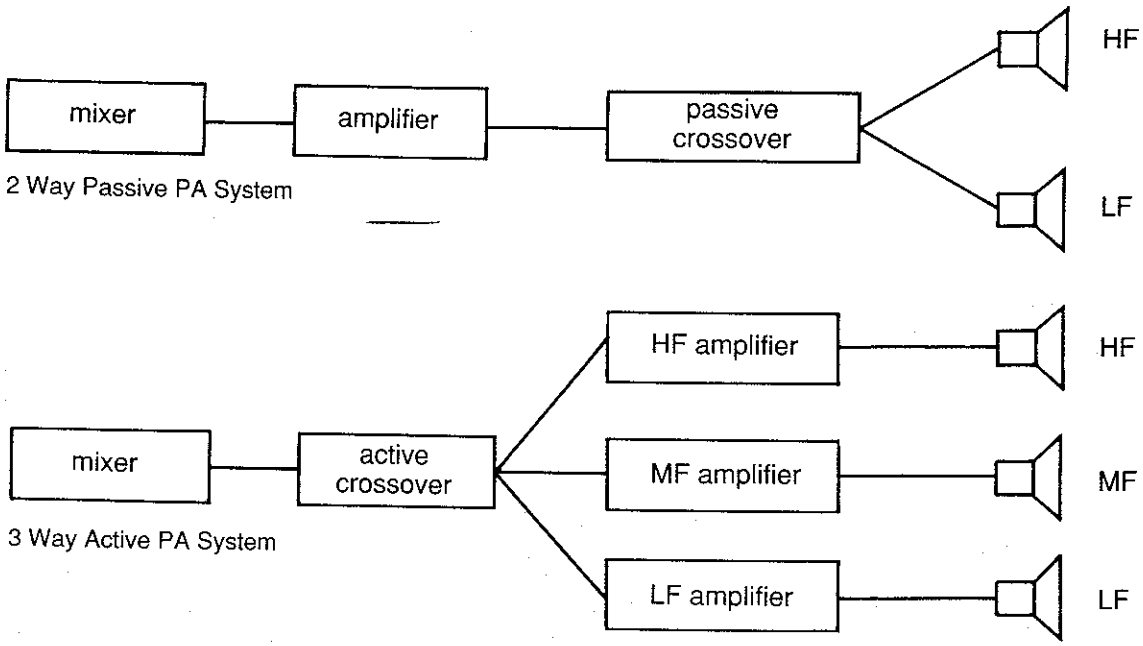
PA SYSTEMS

PA speaker systems are specifically designed for reproducing live and recorded music cleanly and accurately, with control over the direction of the sound. These systems are used for front-of-house, in-fills and stage monitors in live music re-inforcement, and as the main sound system for clubs and discos.

The smallest systems may include an LF and HF driver in a single cabinet, but generally PA systems are built up from several cabinets or modules, each covering one particular part of the frequency range.

Passive or active crossovers are used to split the frequency range for each of the modules.

A PA system can be 2-way (LF & HF) or 3-way (LF, MF & HF). Occasionally, further ultra LF or HF modules are added to make a 4-way system. By breaking up the audio spectrum into smaller bands, the drivers and cabinets can be optimised to reproduce a specific frequency range.



Low-Frequency Module

The LF modules handle the frequency range from around 50Hz up to the 700Hz-3kHz range. It should use 12", 15" or 18" drivers in sealed, ported or horn loaded cabinets. The module's upper response limit varies according to driver size and cabinet type. As the driver gets bigger, the more limited its mid range performance becomes. Horn loaded cabinets further reduce the mid-frequency output of the bass unit.

As a guide, here are the highest recommended crossover frequencies for the various driver/cabinet options.

Driver Diameter	Sealed/Ported Cabinet	Horn Loaded Cabinet
12"	3kHz	2kHz
15"	1kHz	700 Hz
18"	500Hz	300Hz

Mid-Frequency Module

Large PA systems use 15" or 18" bass drivers which have an upper frequency limit of between 300 Hz and 1kHz. As no HF unit will work down to these frequencies, a speaker must be added to cover the important mid-range signals.

Mid-range systems use either 5", 8", 10" or 12" cone drivers in a sealed or horn loaded cabinet or alternatively, a compression driver and horn. They crossover from the bass unit and work up to the 5 kHz to 10kHz range, depending on the drivers used.

As low frequency extension is unimportant, the sealed cabinet with its tight driver control, is a good choice for small and medium systems. A horn loaded 12" driver will go down lower and is ideal for matching up to 15" or 18" horn loaded bass cabinets.

The compression driver is the most efficient and acoustically powerful of all the mid-range systems. It is the classic mid-range unit for the larger PA systems with control over directivity, and a high frequency response extending up to 10kHz.

The usable band width of each mid-range system is dependent on the size of the drivers used. The larger drivers can come in at a lower frequency but have less HF output.

Driver/Cabinet Type	Lower Crossover Frequency	Upper Crossover Frequency
5" sealed cabinet	1.5kHz	10kHz
8" sealed cabinet	1kHz	7kHz
10" sealed cabinet	600Hz	5kHz
12" sealed cabinet	300Hz	3kHz
12" horn loaded Compression Driver	200Hz 700Hz	2kHz 8kHz

High-Frequency Module

High frequency drivers take over from the LF or MF driver and extend the response up to the 15kHz region. The HF drivers work on a slightly different principle to cone drivers. They are extremely efficient but have limited power handling. Alone an HF cone or diaphragm will produce a very narrow beam of sound. This dispersion must be controlled and widened by using a horn of some variety.

Smaller drivers tend to use a horn that is integral with the unit and come in three main types:

1. HF Bullets *radiate a tight conical beam of sound deep into the auditorium. To achieve good horizontal dispersion several bullets must be used in a horizontal array. For 'short throw' applications the horizontal dispersion can be much improved by the use of an acoustic lens in front of the driver.*

2. HF Slot *drivers radiate a wide horizontal beam and are useful for 'short throw' applications such as monitors, in-fills and PAs in small venues.*

3. Radial Horns *give good horizontal dispersion and are used in much the same situations as the slot drivers, but with increased frequency range.*

Large compression drivers need to have horns bolted onto them. Horns have a 'cut-off' frequency and should not be used below this frequency, in fact it is best to use them from an octave above this frequency. There are two main types of horn.

1. Radial Horns *give good wide dispersion in the horizontal plane, but very limited dispersion in the vertical plane.*

2. Constant Directivity Horn (CD Horn) *gives a constant beam width in both the horizontal and vertical planes. They will not 'throw' the sound as far as a radial horn.*

BOX CONSTRUCTION NOTES

The cabinet should be built as a solid and non-resonant box, with well sealed and secured joints.

Chipboard is the least expensive panel material, but it is easily damaged and not as durable as plywood. For the horn designs, plywood is essential as it is the only type of panel material that can be easily curved.

The panel joints can be simple butt-joints, screwed and glued, with reinforcing battens. More sophisticated joints can be used if you have the woodworking skills. Whatever the joint type, it is important that it is both secure and airtight. The wood thickness is specified on each of the projects. Use number 10 screws of the appropriate type for the wood, positioned not more than 150mm apart.

To reduce panel resonances, screw and glue bracing battens on all the larger (more than 0.5 m) panels.

Mid-frequency standing waves inside the cabinet can be reduced by glueing or stapling acoustic wadding to the internal surfaces of all the panels. This wadding should be at least 25mm thick. Glass fibre and rock wool are suitable materials.

The cabinet volume is calculated by multiplying the internal height, width and depth of the cabinet. If the measurements are in feet, the result is in ft^3 (cubic feet); if measurements are in decimetres then the result will be in litres. (Note: 1 ft^3 = 28.3 litres.)

Electrical connectors should be high quality 1/4" jacks, 4 mm binding posts or XLRs. Solder on flying leads, then mount the socket and make airtight using a sealing compound.

The drivers can be mounted to the front or back of the baffle. Front mounting makes a very simple job of dropping the speaker in or out of the cabinet. In either case, use mounting bolts and 'T' nuts to fix the driver to the baffle. Speaker clamps can also be used, which will secure both the driver and a speaker grille.

There is a wide range of speaker cabinet accessories available from specialist suppliers. Wheels, handles, grilles and corners, all add to convenience and durability. These should be fitted carefully, so as not to weaken the box or create air leaks.

GENERAL PURPOSE BASS

TYPE: *Ported bass, using 10", 12", 15" or 18" drivers*

APPLICATION: *Bass end for PA, keyboard and vocal, with optional HF Driver/crossover for full-range.*

CONSTRUCTION: *Simple.*

MATERIAL: *18mm ply.*

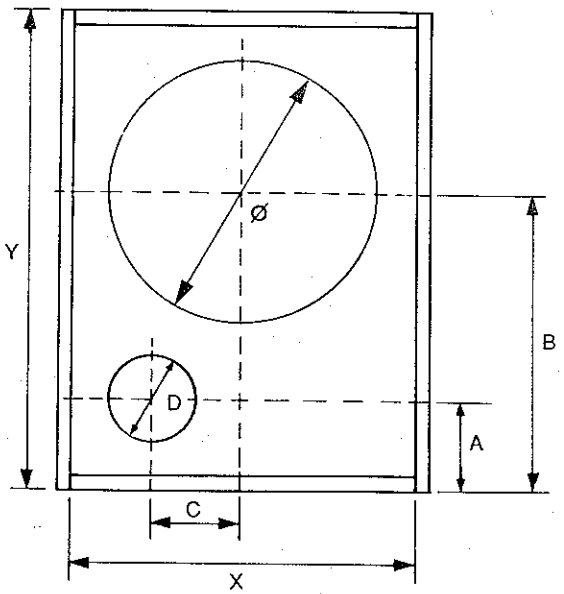
COMMENTS: *The following designs give dimensions for 10", 12", 15" and 18" drivers. For each speaker size (except the 10") there are three separate sets of dimensions. Each option produces a different shape box with the same internal volume. An HF Driver/crossover can be added to the 10" and 12" systems.*

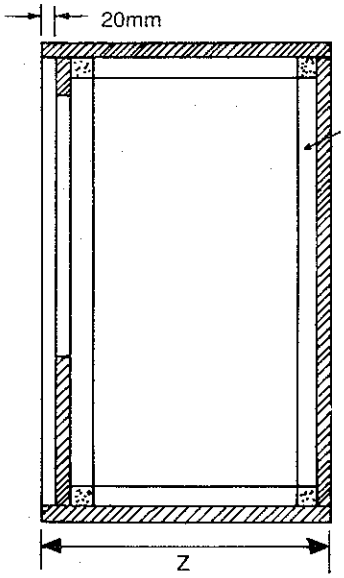
For two bass drivers, double the cabinet width and duplicate the port.

SPEAKER SIZE	VOL. (Litres)	OPTION 1						OPTION 2						OPTION 3								Port Length
		X	Y	Z	A	B	C	X	Y	Z	A	B	C	X	Y	Z	A	B	C	D	Ø	
10"	30	315	540	245	120	360	0	-	-	-	-	-	-	286	477	294	80	290	0	76	230	-
12"	50	374	634	280	130	411	0	369	497	350	85	300	100	339	558	338	90	335	0	102	283	62
15"	100	470	790	338	140	482	0	464	616	427	110	380	130	427	695	412	120	420	0	152	355	159
18"	150	539	898	380	160	560	0	530	700	480	120	420	150	489	790	463	140	490	0	152	420	117

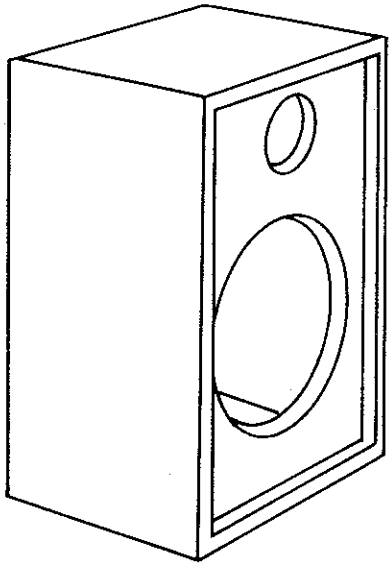
Dims. in millimetres

Material 18mm ply





VOCAL/PA



TYPE: *Sealed full range, using 12" driver and HF driver (bullet or slot type).*

APPLICATION: *Vocals or small PA.*

CONSTRUCTION: *Simple.*

MATERIAL: *18mm ply ½ sheet.*

COMMENTS: *The cabinet must be air tight. A passive crossover can be mounted internally.*

STAGE MONITOR

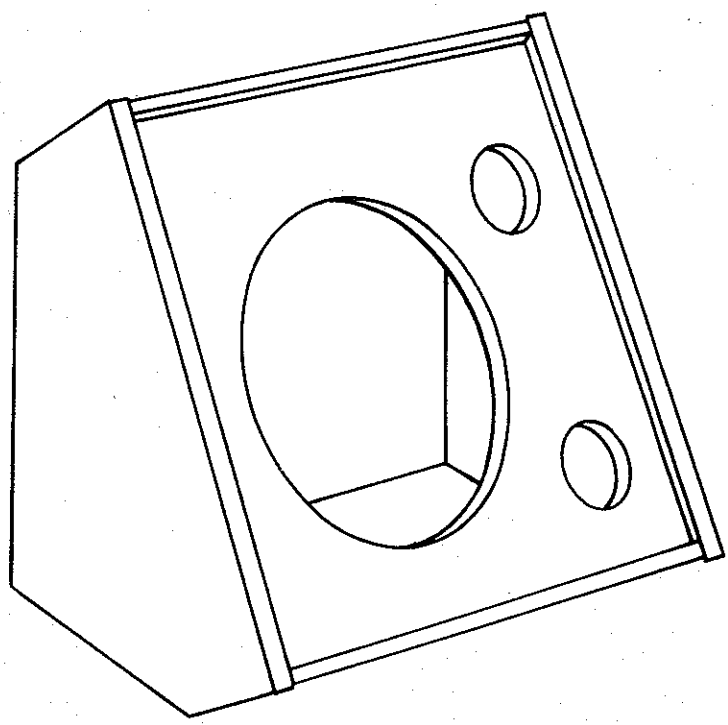
TYPE: *Ported full range, using 12" driver and HF driver (bullet or slot type).*

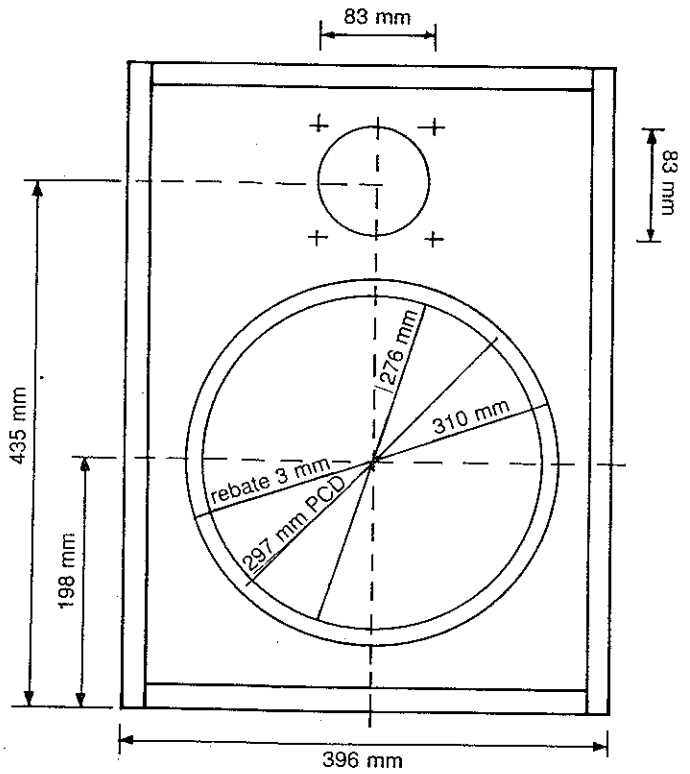
APPLICATION: *Stage monitor of instruments and vocals.*

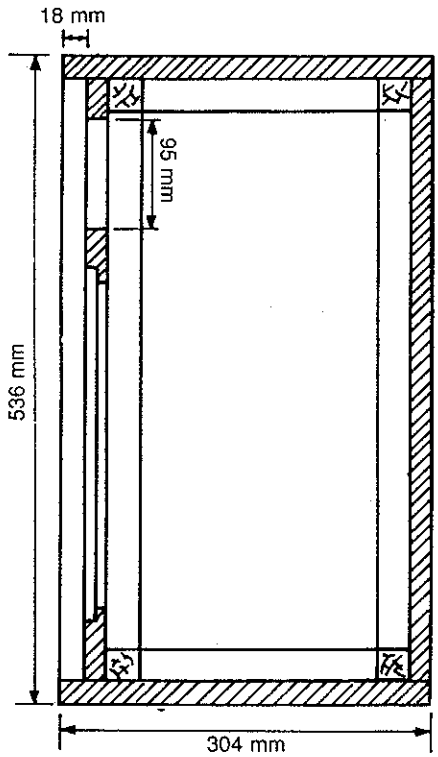
CONSTRUCTION: *Simple.*

MATERIAL: *18mm ply ½ sheet.*

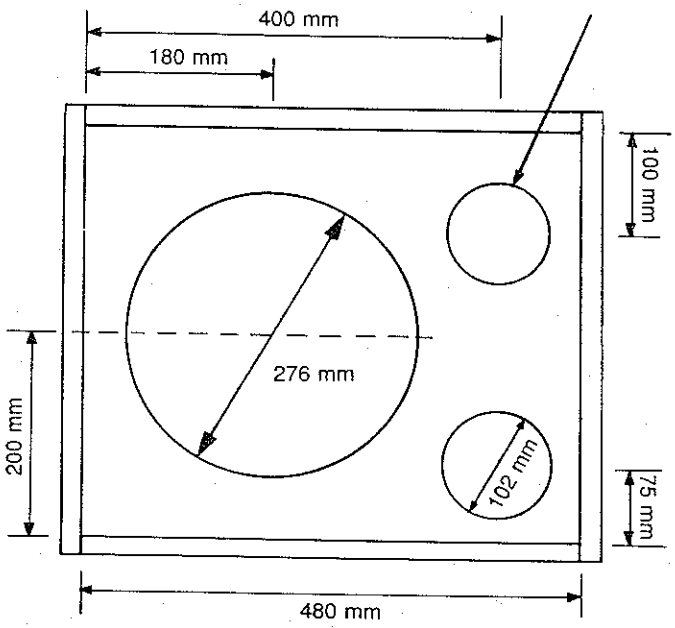
COMMENTS: *The cabinet is designed to work at several different angles. Care should be taken in measuring and cutting the angled sides.*

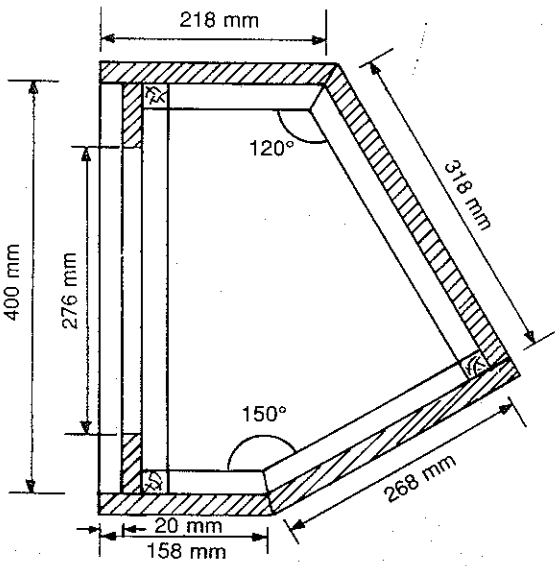






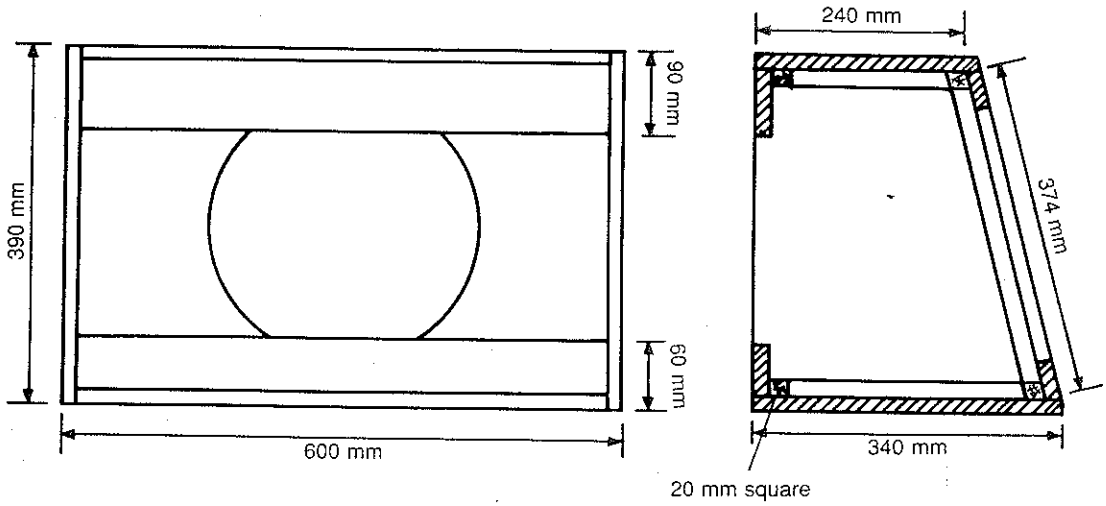
See drive unit cut-out details

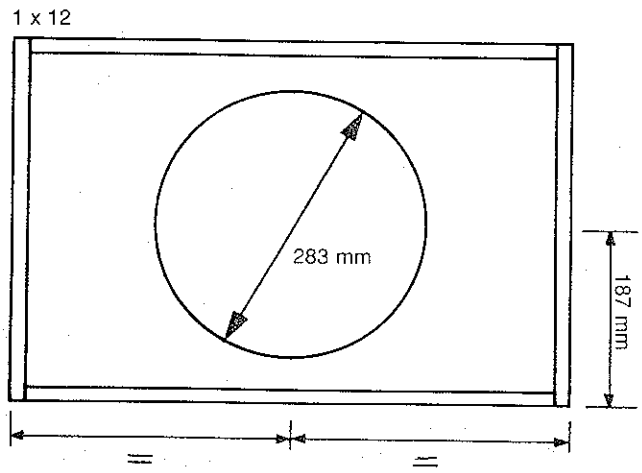


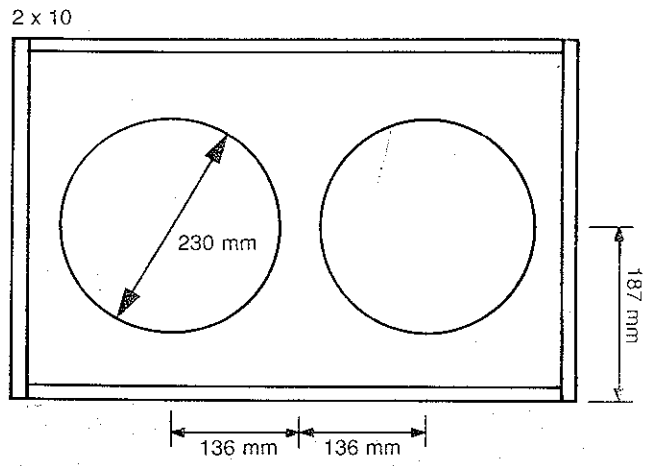


LEAD/RHYTHM GUITAR

TYPE:	*Open backed using 2 x 10" or 1 x 12" drivers (PE type).*
APPLICATION:	*Lead or rhythm guitar speaker.*
CONSTRUCTION:	*Simple.*
MATERIAL:	*15mm, ½ sheet.*
COMMENTS:	*Check the side angles and strength of the joints.*

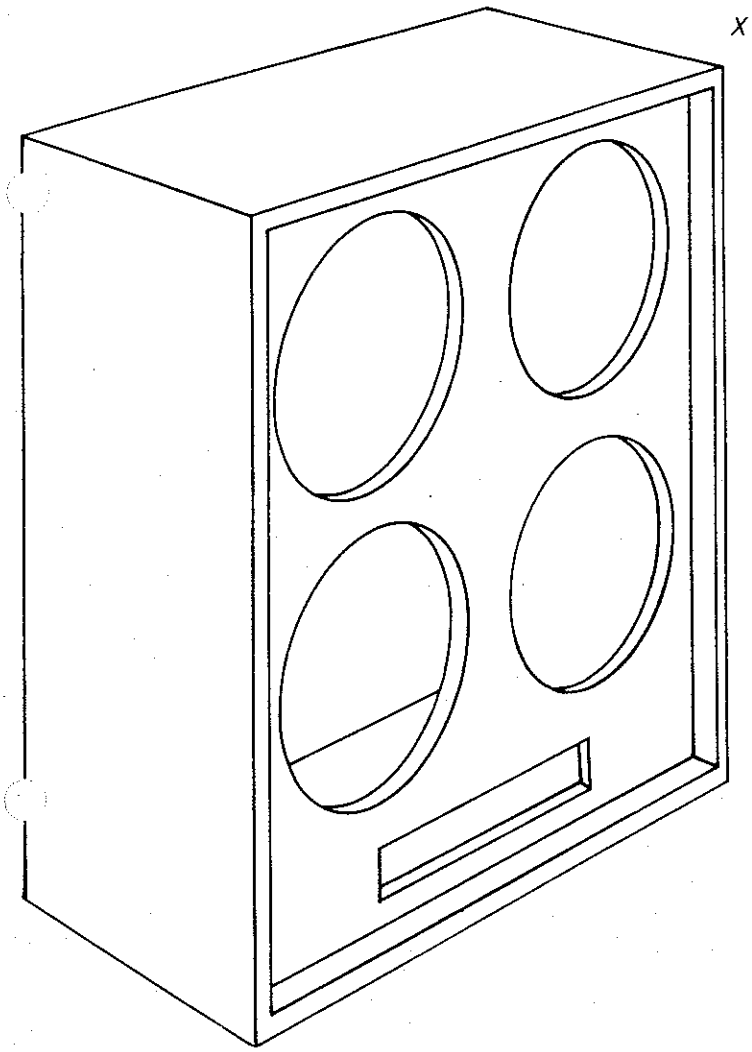


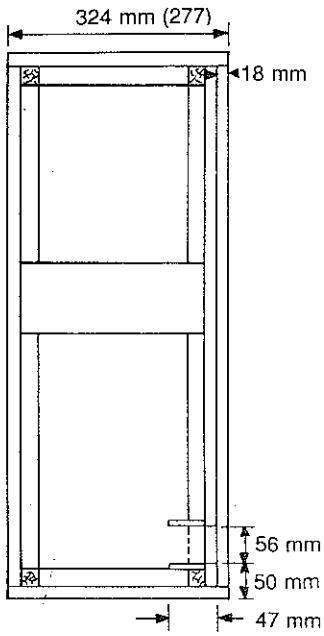


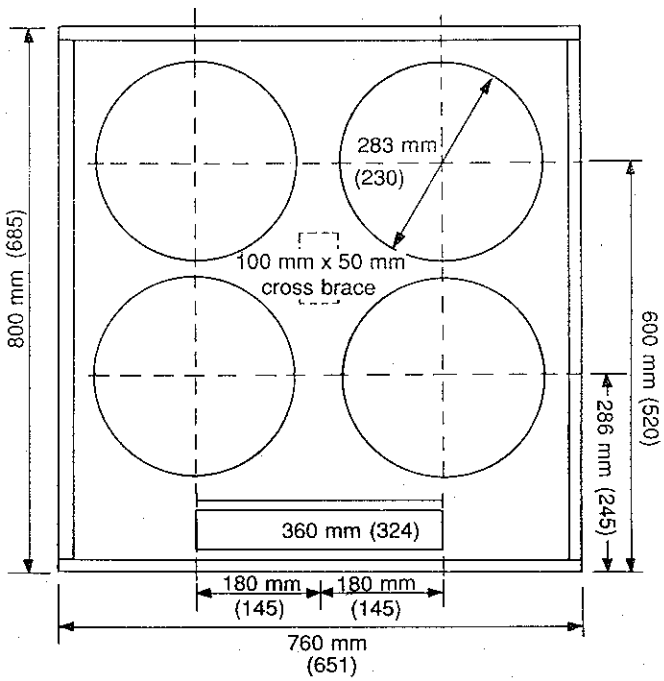


GUITAR/BASS GUITAR

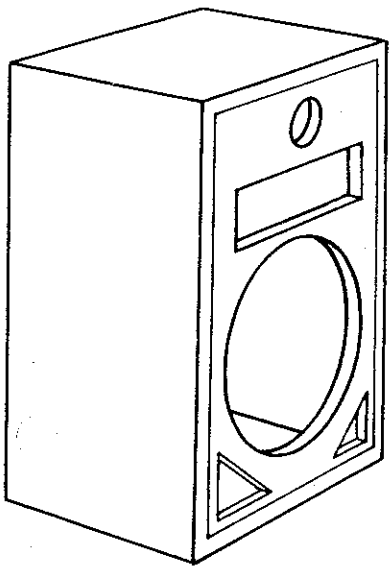
TYPE:	*Ported bass using 4 x 12" drivers or 4 x 10" drivers (CE type), sealed cabinet 4 x 12" or 4 x 10" drivers (PE type).*
APPLICATION:	*Lead (PE) or bass guitar (CE).*
CONSTRUCTION:	*Simple.*
MATERIAL:	*18mm, 1 sheet.*
COMMENTS:	*The port is only required when using cloth edge (CE) drivers for bass guitar. Dimensions in brackets are for 4 x 10" cabinet.*



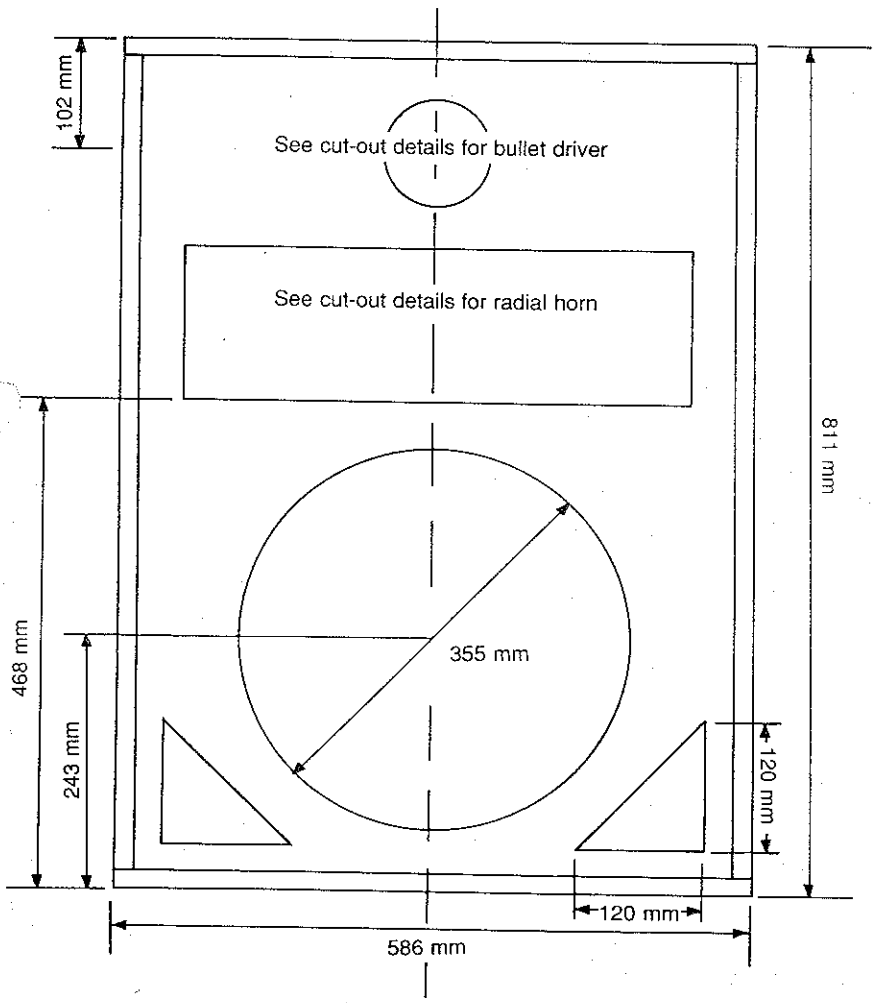


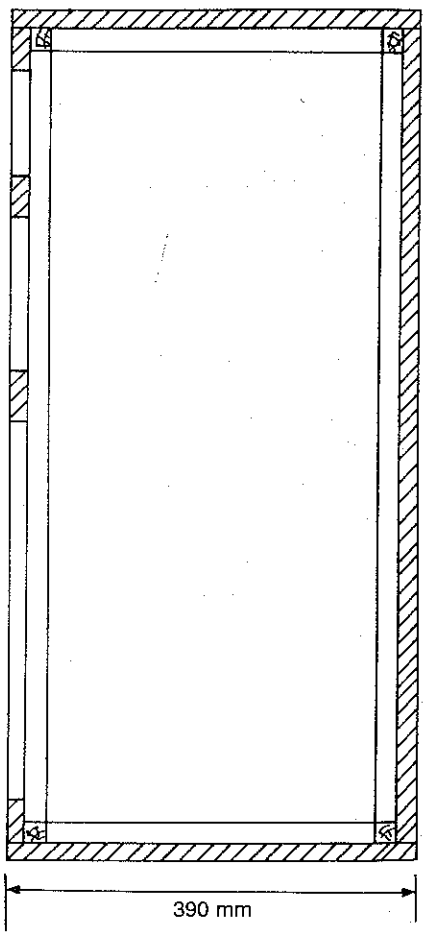


3-WAY CABINET

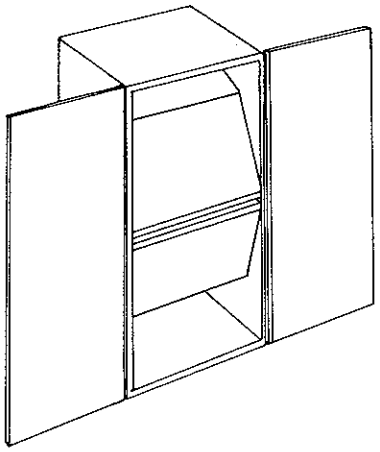


TYPE:	*Ported full-range cabinet, using 15" driver, Compression driver with radial horn and HF Bullet.*
APPLICATION:	*Keyboards, PA for small to medium size venues.*
CONSTRUCTION:	*Simple.*
MATERIAL:	*18mm ply 1 sheet.*
COMMENTS:	*All joints should be rigid and airtight. Side and rear panels should be braced. Passive crossover can be mounted internally.*



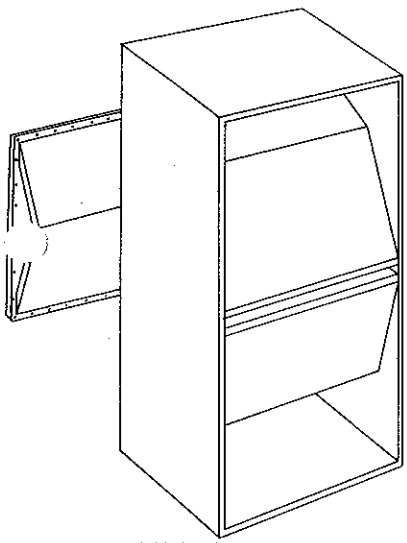


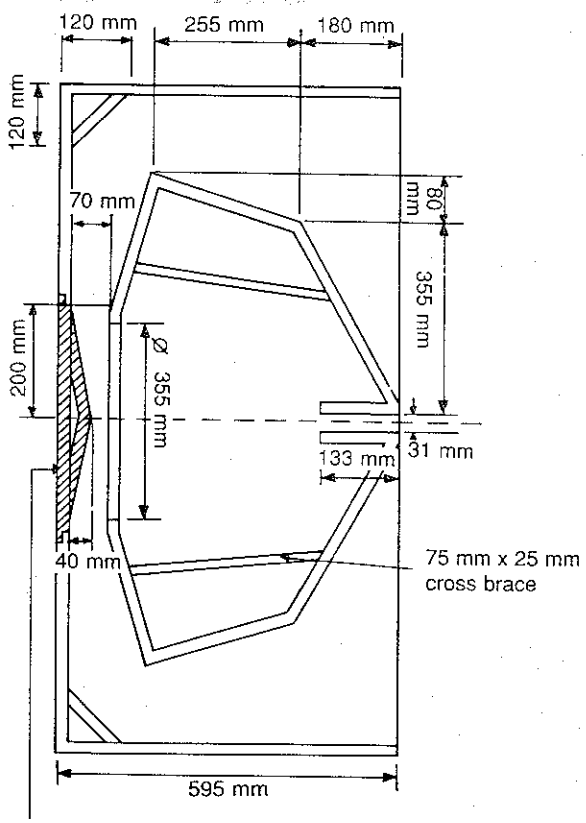
W-BIN CABINET

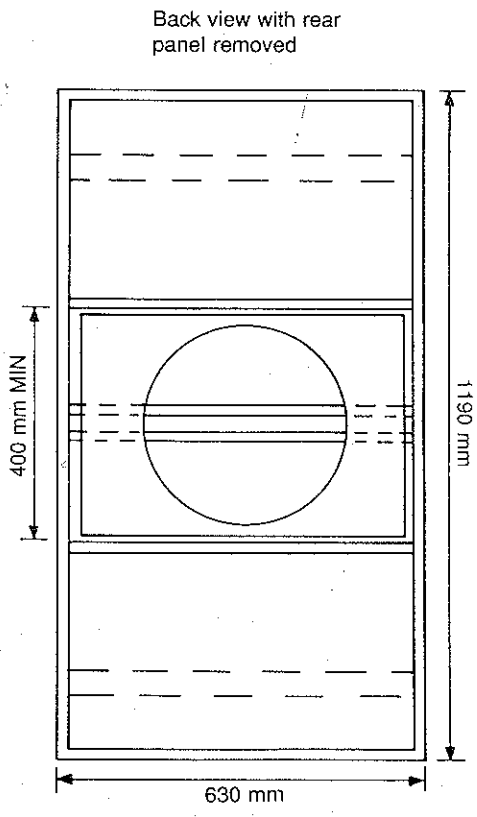


PA BASS

TYPE:	*W-Bin using 15" driver.*
APPLICATION:	*Bass-end for PA and disco.*
CONSTRUCTION:	*Medium.*
MATERIAL:	*18mm, 1 3/4 sheets.*
COMMENTS:	*Side panels should be grooved or battened to fix the internal panels at the correct angle. This design is especially effective in the mid-bass region (100Hz upwards). The bass extension can be improved by using several units together, or adding side flaps ('barn doors').*



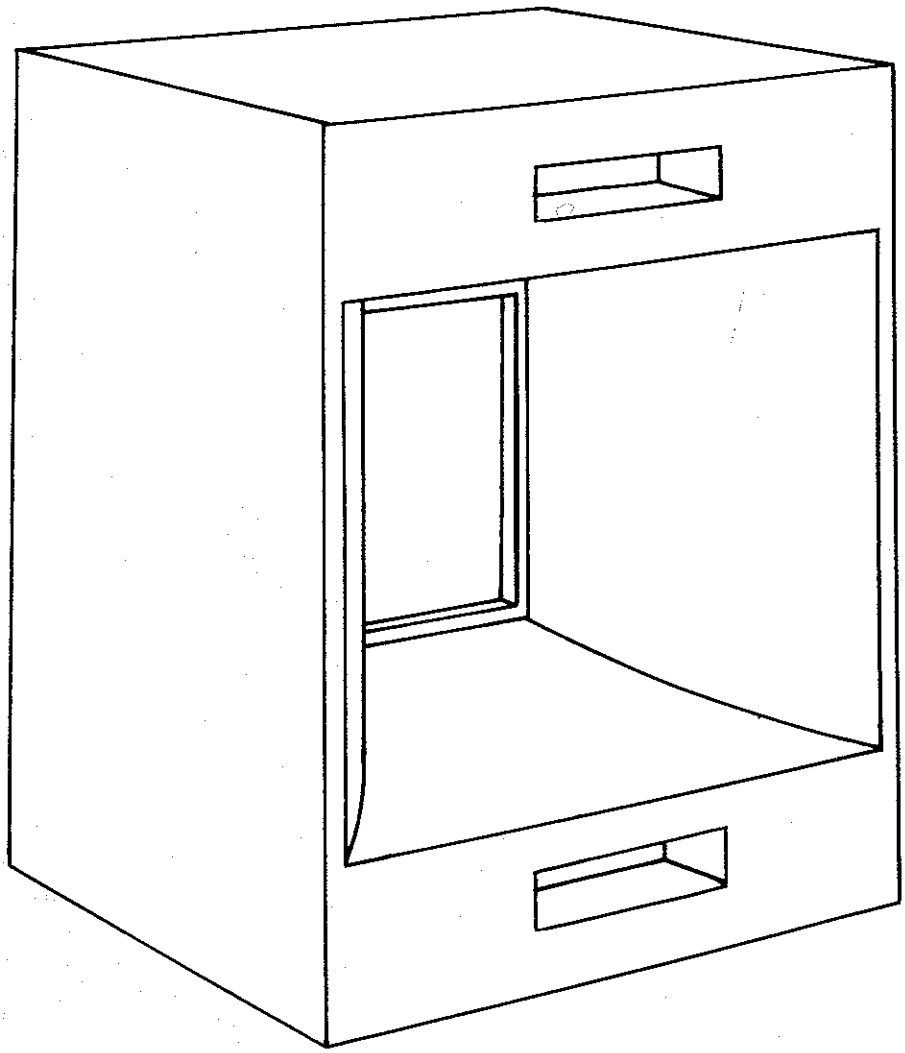


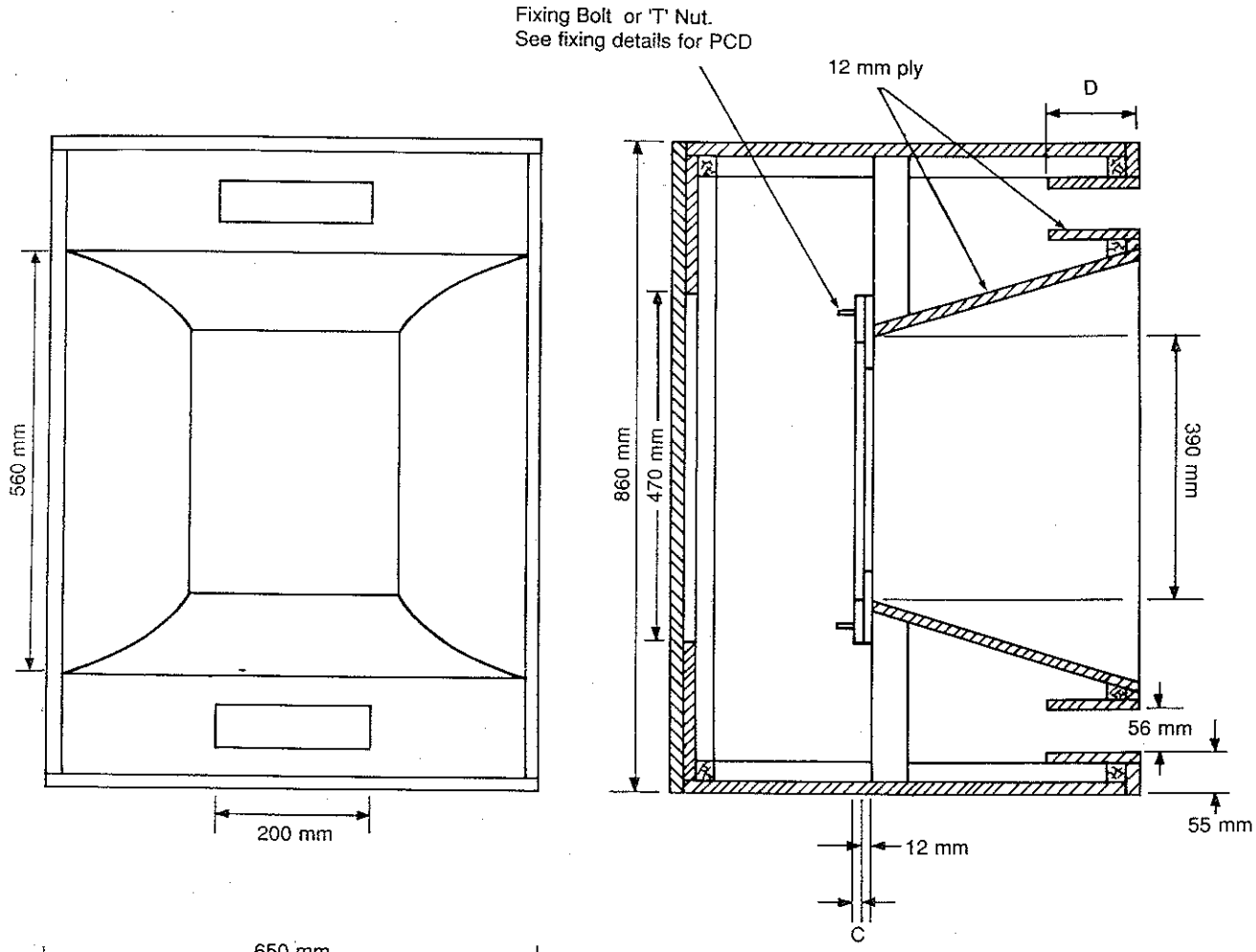


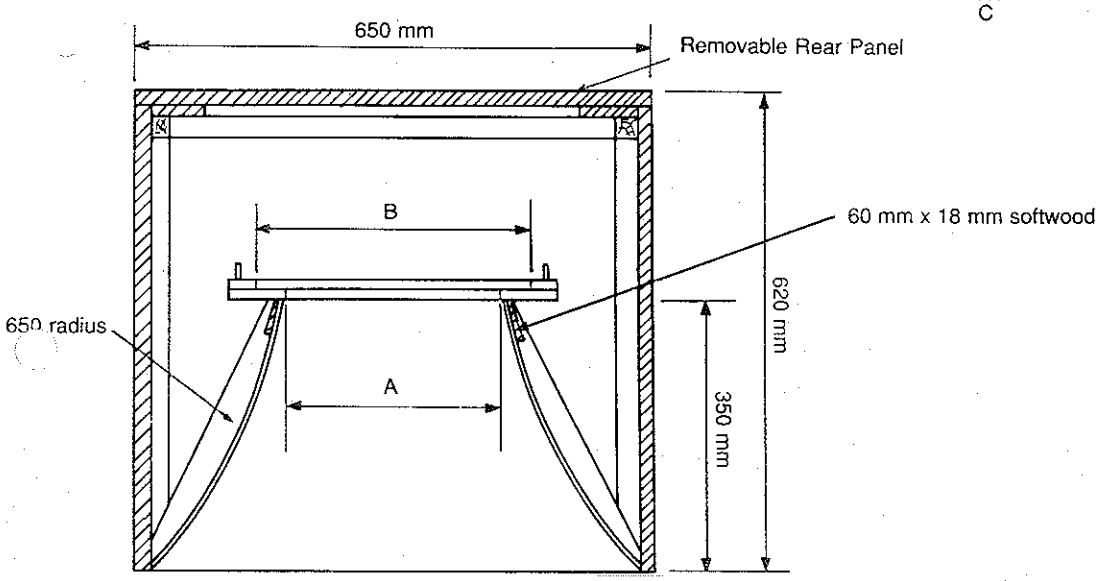
HORN LOADED REFLEX CABINET

PA BASS

TYPE:	*Horn loaded, reflex cabinet using 15" or 18" driver*
APPLICATION:	*Bass-end for small/medium PA or disco.*
CONSTRUCTION:	*Complex.*
MATERIAL:	*18mm ply, 1½ sheets* *12mm ply, ½ sheet* *3mm ply, 1 sheet*
COMMENTS:	*This cabinet requires accurate bending of the horn walls. It must be extremely rigid and airtight. The curve is achieved by laminating four pieces of 3mm ply together and bending them around a softwood frame. The removable back should also be made airtight.*





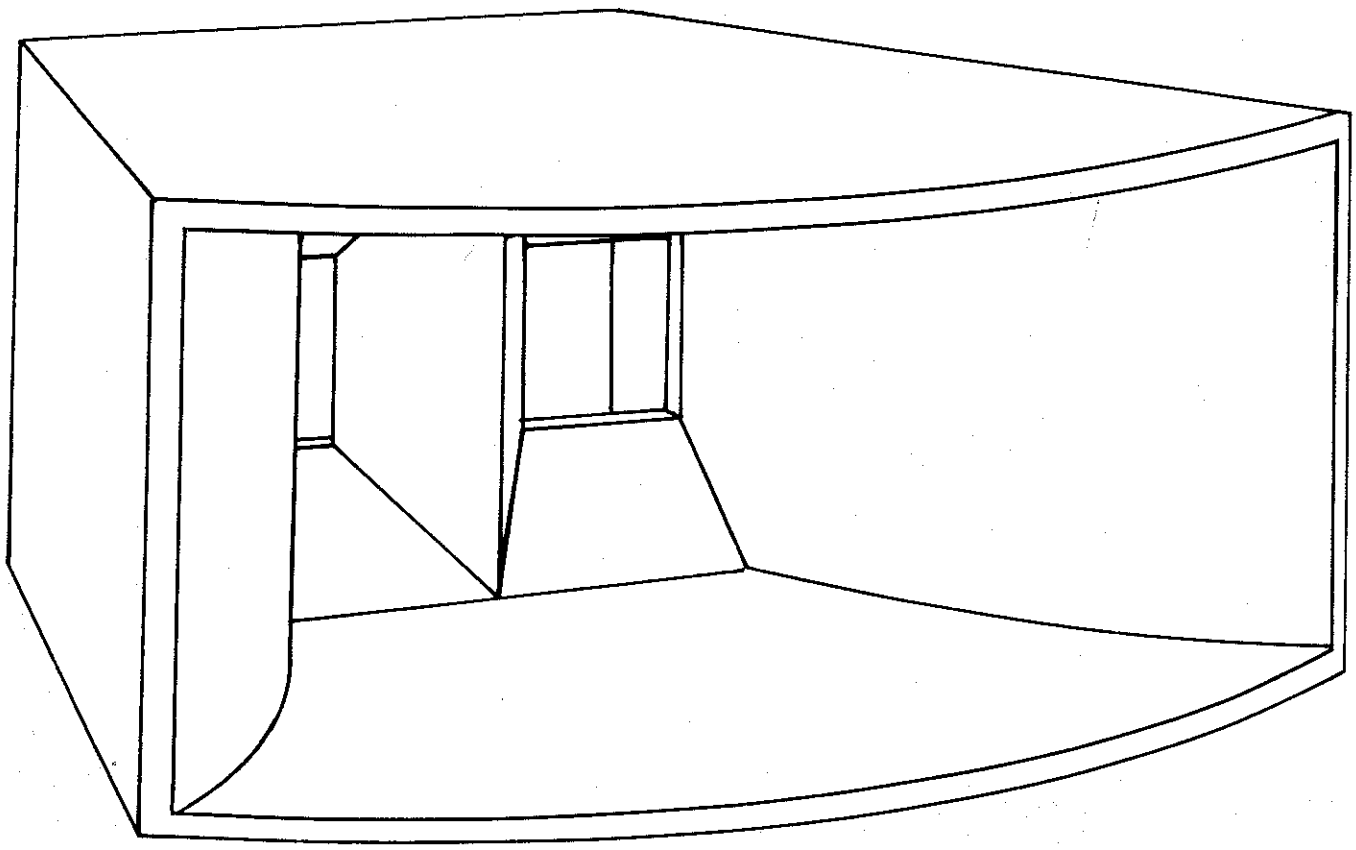


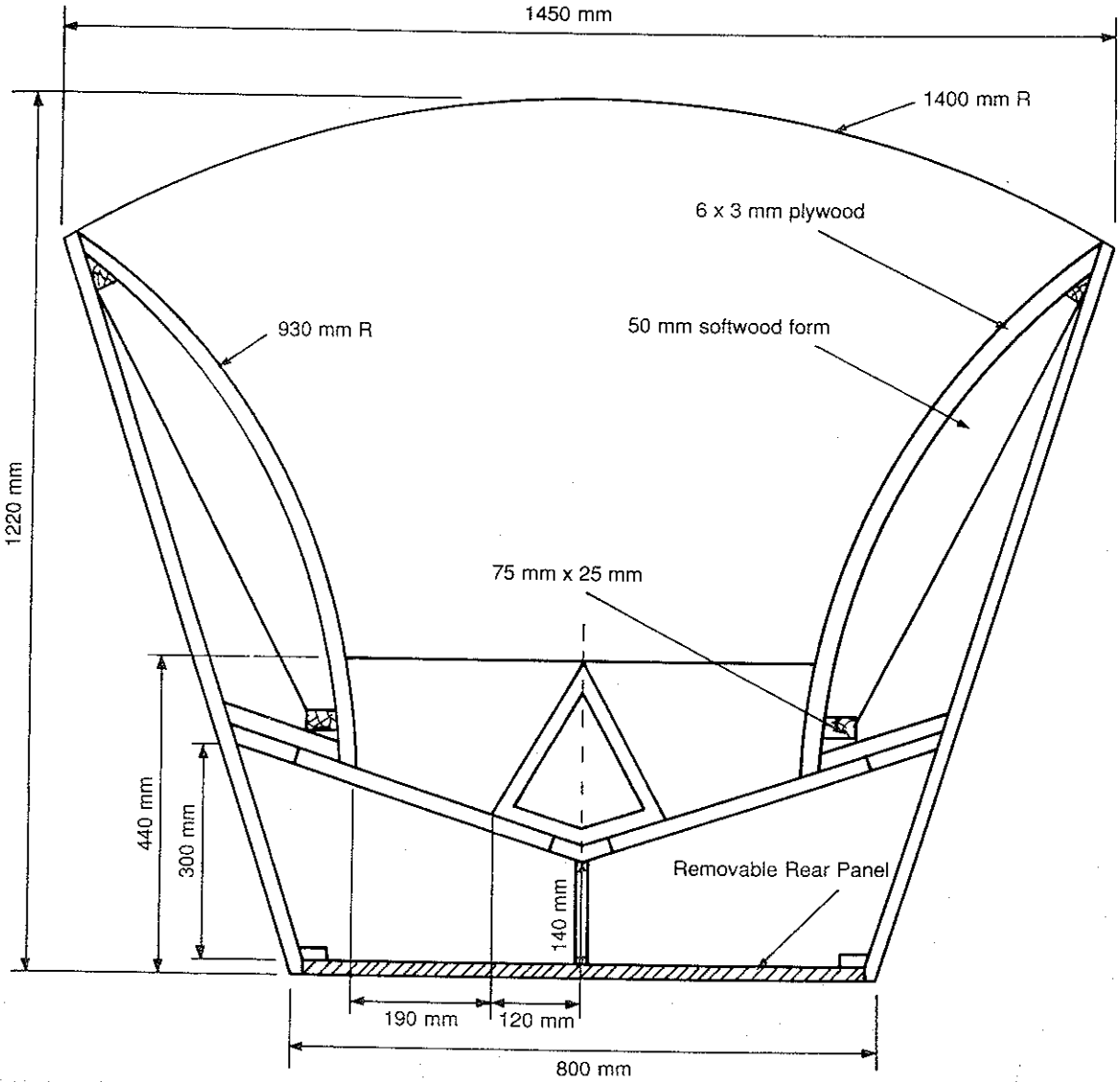
	A	B	C	D
15" Speaker	270	345	12	42
18" Speaker	320	410	18	86

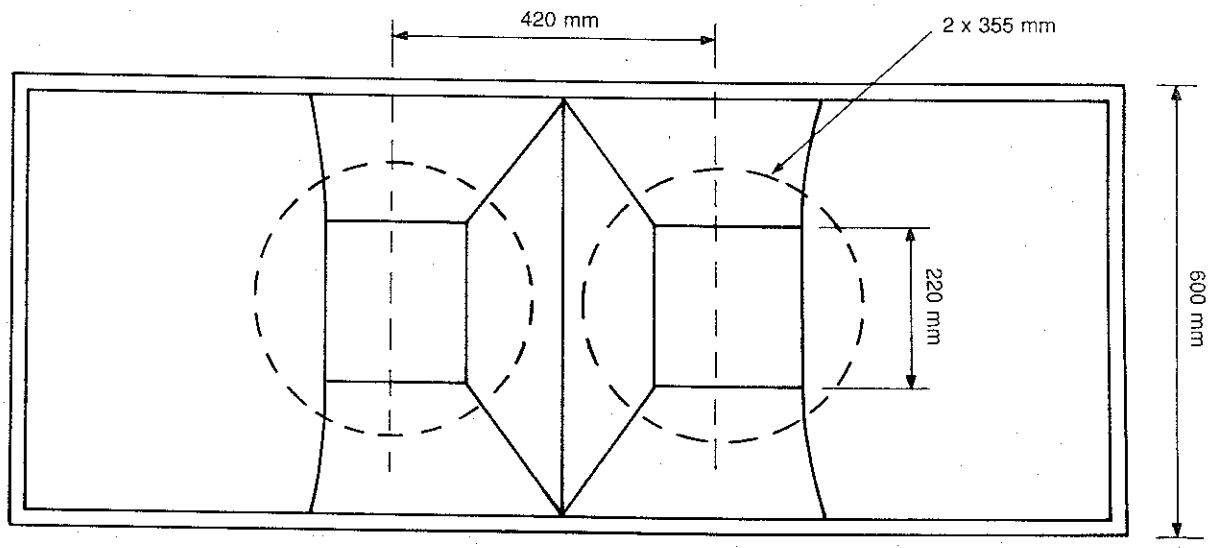
2 x 15" HORN CABINET

PA BASS

TYPE:	*Horn loaded using 2 x 15" drivers.*
APPLICATION:	*Bass-end for large PA.*
CONSTRUCTION:	*Complex.*
MATERIAL:	*25mm, 2 sheets* *18mm, ½ sheet* *3mm ply, 2 sheets*
COMMENTS:	*This cabinet requires accurate bending of the horn walls. It must be extremely rigid and airtight. The curve is achieved by laminating six pieces of 3mm ply together and bending them around ~~a soft~~wood frame. The removable back should also be made airtight.* *This cabinet may be used in multiples to give adequate bass extension.*

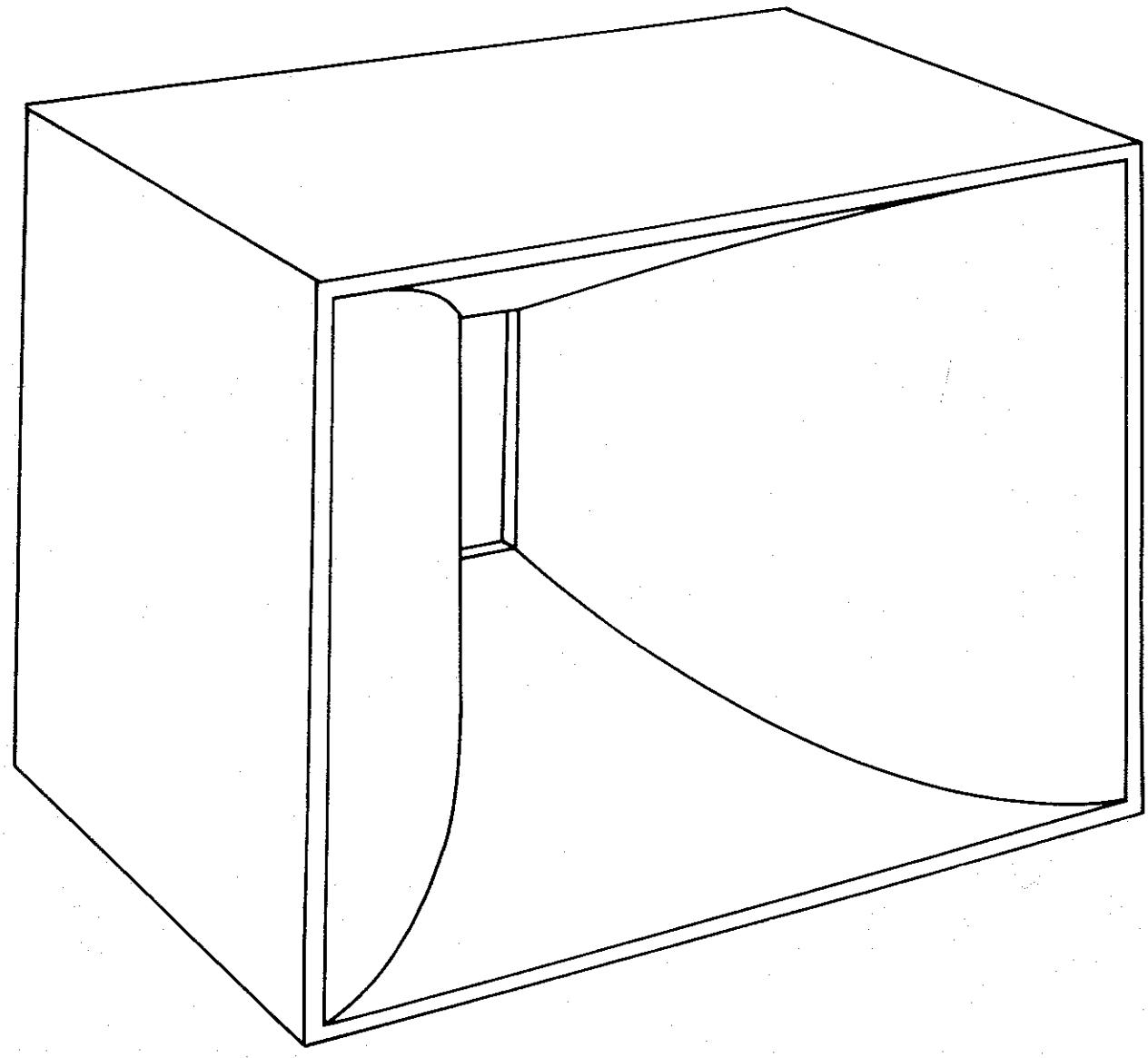


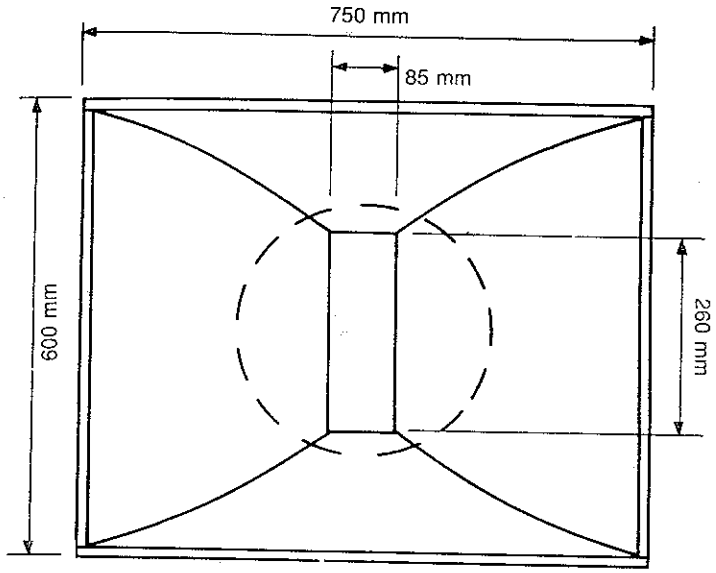

1450 mm
1400 mm R
6 x 3 mm plywood
930 mm R
50 mm softwood form
1220 mm
75 mm x 25 mm
440 mm
300 mm
140 mm
Removable Rear Panel
190 mm
120 mm
800 mm

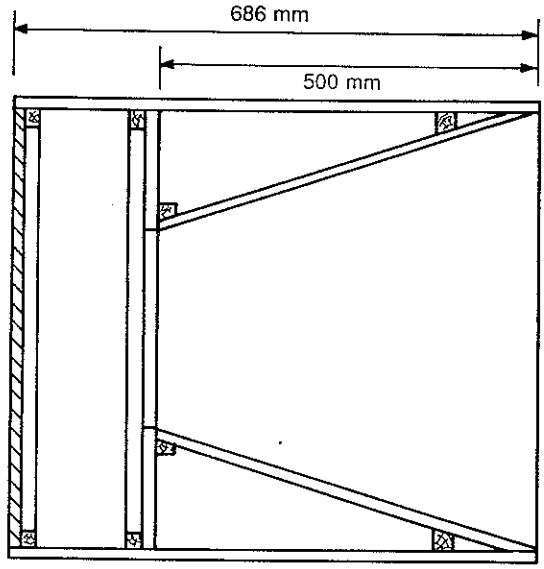

420 mm
2 x 355 mm
220 mm
600 mm

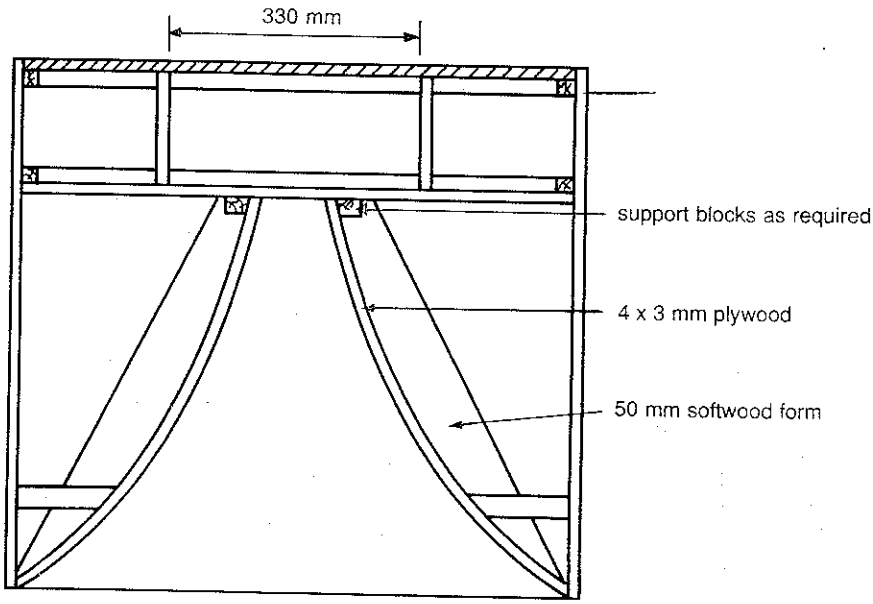
1 x 12" HORN CABINET

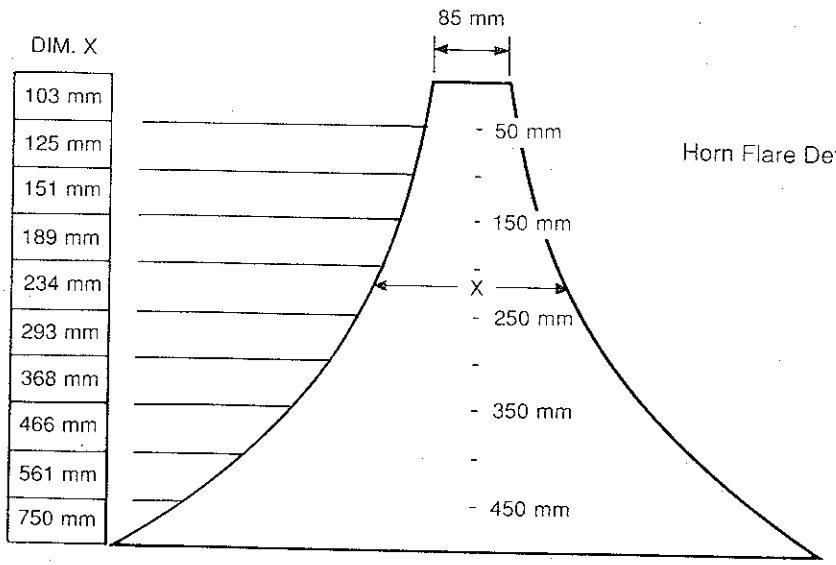
TYPE:	*Horn loaded using 1 x 12" driver*
APPLICATION:	*Low/mid-range for PA systems. Covers the 200Hz to 2kHz region.*
CONSTRUCTION:	*Complex.*
MATERIAL:	*18mm, 1 ¼ sheets* *3mm ply, ¾ sheet*
COMMENTS:	*This cabinet requires accurate bending of the horn walls. It must be extremely rigid and airtight. The curve is achieved by laminating four pieces of 3mm ply together and bending them around a softwood frame.* *The removable back should also be made airtight.*







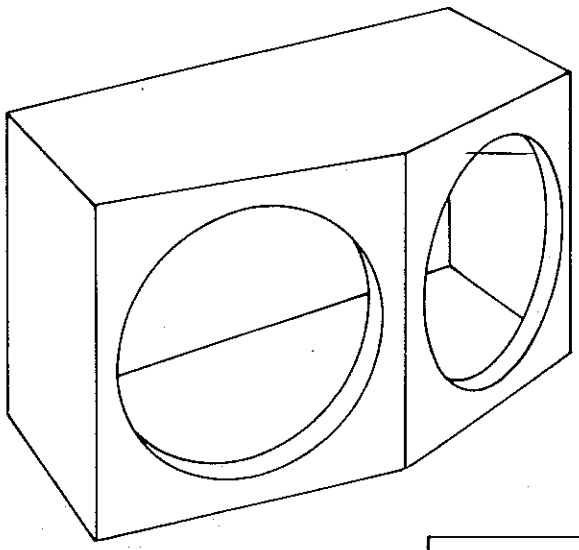


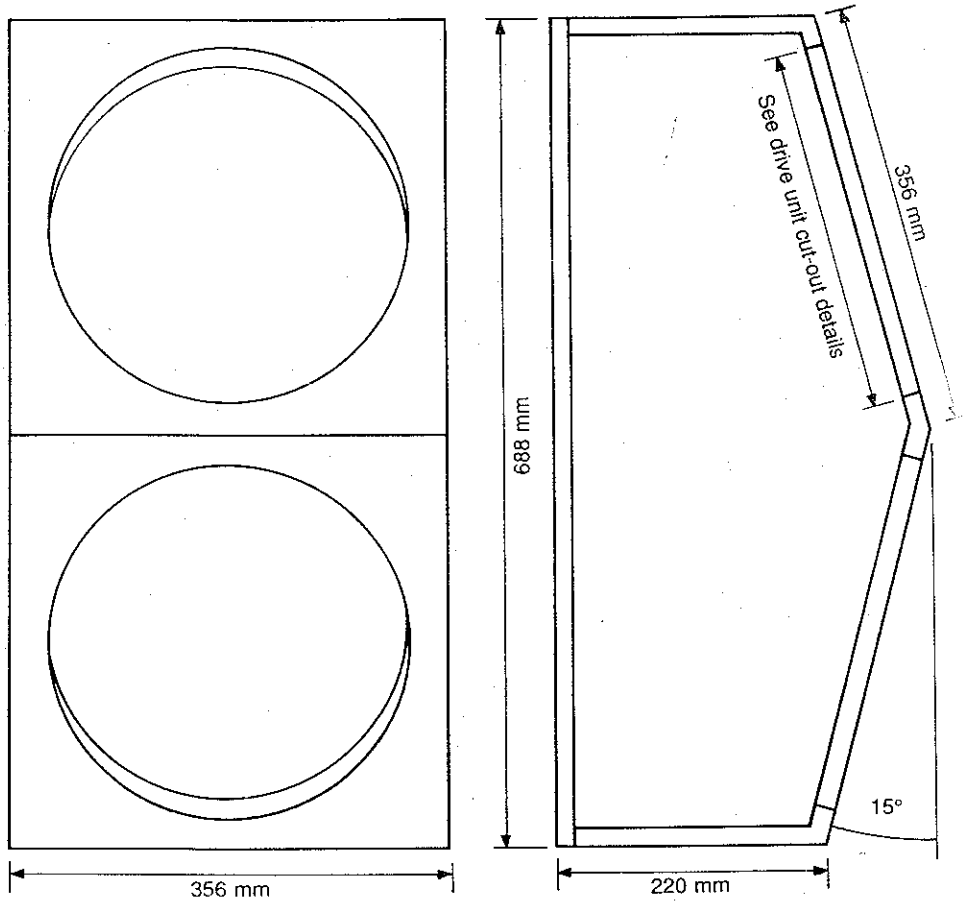


Horn Flare Details

PA MID-RANGE CABINET

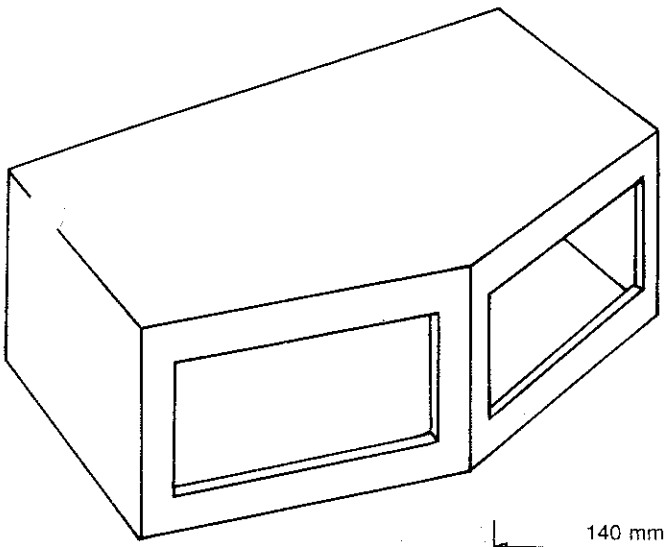
TYPE:	*Angled sealed cabinet using 2 x 10" or 2 x 12" drivers.*
APPLICATION:	*Mid-range for medium PA systems.*
CONSTRUCTION:	*Simple.*
MATERIAL:	*18mm, ½ sheet.*
COMMENTS:	*The internal volume is not critical. Use the mounting hole diameter suitable for the driver used.*

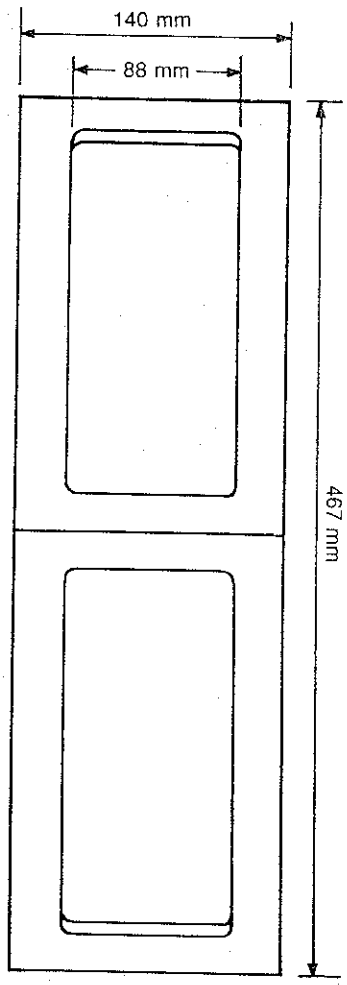


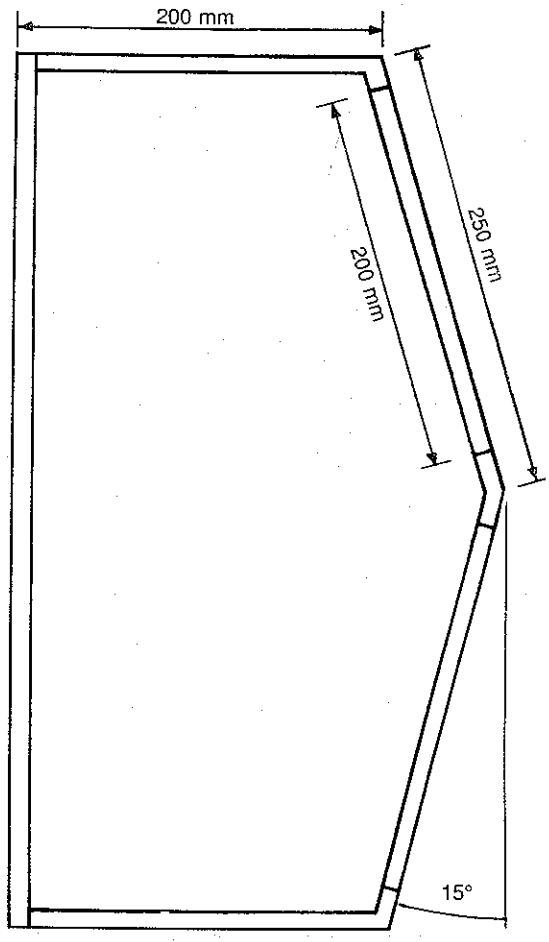


PA HF CABINET

TYPE:	*Angled protection/mounting cabinet using 2 x HF horn drivers.*
APPLICATION:	*High frequency for small/medium PA systems.*
CONSTRUCTION:	*Simple.*
MATERIAL:	*12mm, ¼ sheet.*
COMMENTS:	*This box is for protecting and mounting the HF unit, it does not have to be airtight. A passive crossover can be mounted internally.*



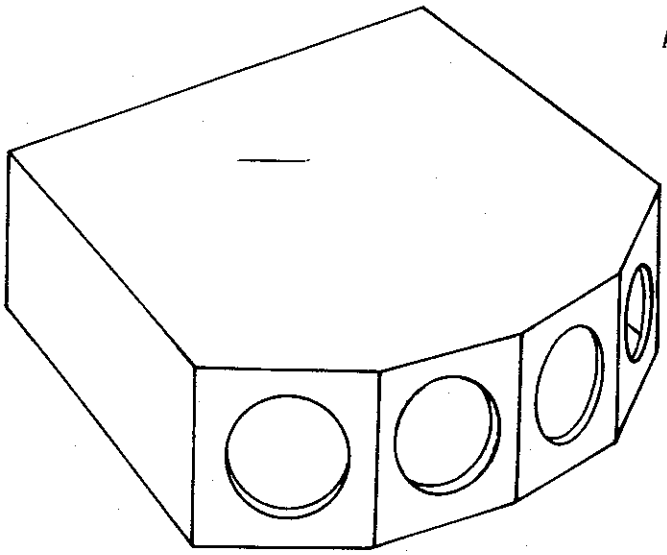


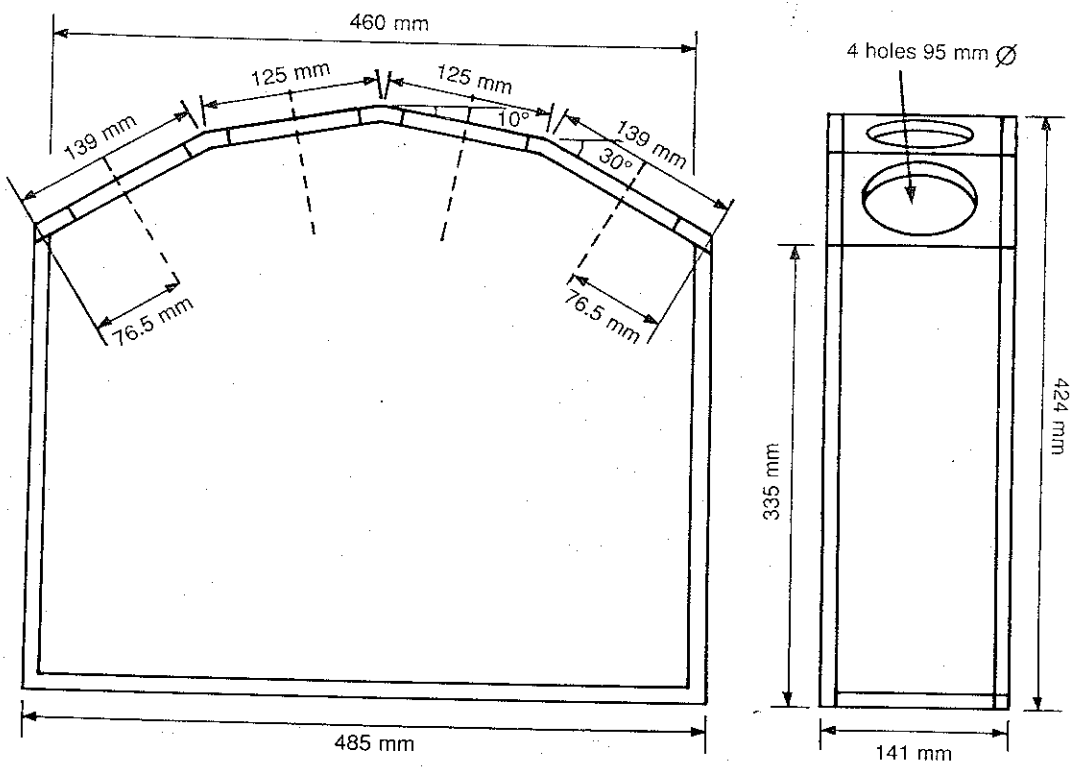


PA HF CABINET

TYPE:	*Angled protection/mounting cabinet using 4 x HF bullets.*
APPLICATION:	*High frequency for medium/large PA systems.*
CONSTRUCTION:	*Simple.*
MATERIAL:	*12mm, ¼ sheet.*
COMMENTS:	*This box is for protecting and mounting the HF unit, it does not have to be airtight. A passive crossover can be mounted internally.*

It allows for wide dispersion HF coverage.

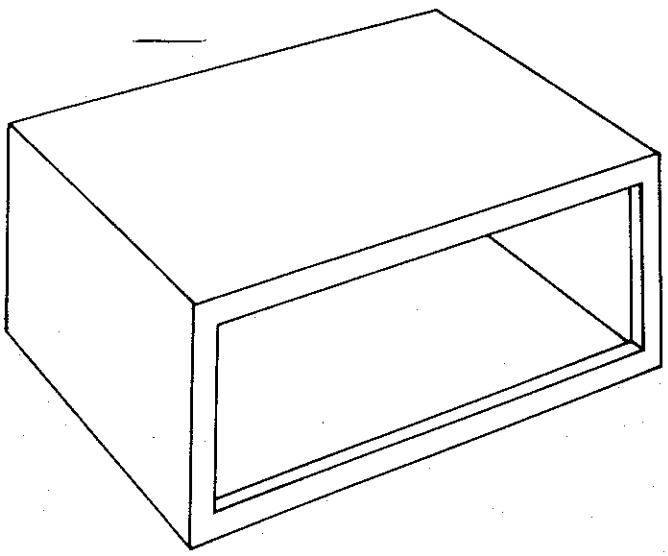


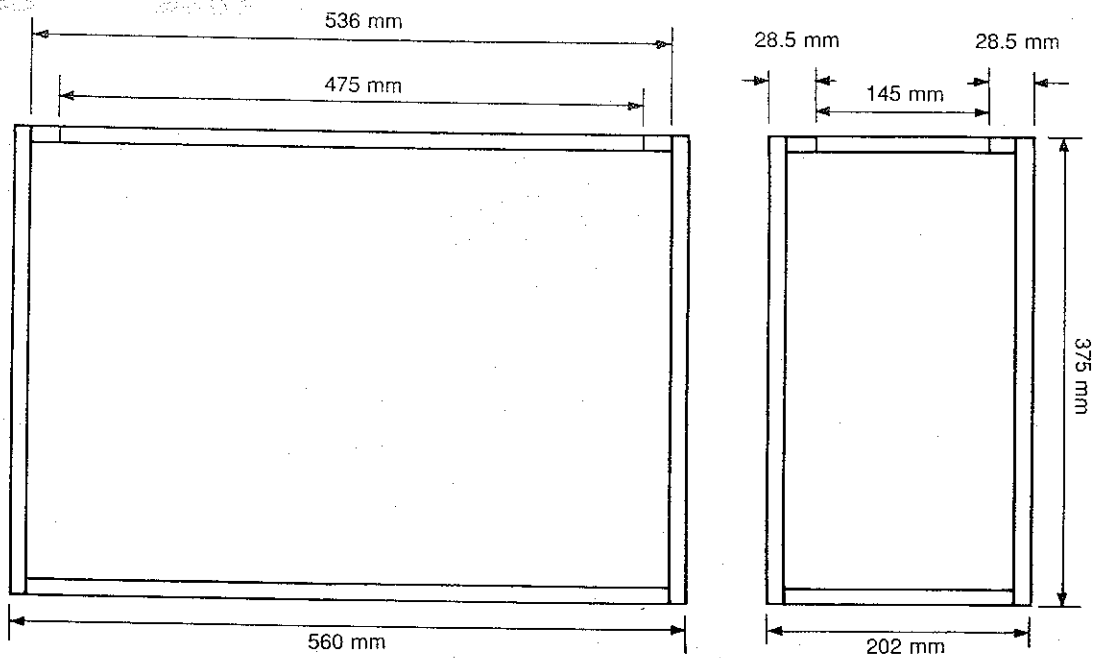


PA MID/HF HORN CABINET

TYPE:	*Protection/mounting cabinet using a mid/HF compression driver and horn.*
APPLICATION:	*Mid/high frequency for large PA systems.*
CONSTRUCTION:	*Simple.*
MATERIAL:	*12mm, 1/4 sheet.*
COMMENTS:	*This box is for protecting and mounting the HF unit, it does not have to be airtight. A passive crossover can be mounted internally.*

Use softwood battens to reinforce the cabinet and support brackets to take the weight of the compression driver.





CROSSOVERS

The passive crossover should be built using a pre-drilled PC board (Veroboard) as a base. If the speaker is going to be transported a lot, then it is worth gluing or cable-tying the components to the board.

Follow the circuit diagram carefully and test by connecting up to the drivers and running the system at very low levels. Also check that the drivers are all connected in the correct phase.

Component Values:

	2-WAY 3kHz		3-WAY 600Hz + 4kHz		3-WAY 1kHz + 7kHz	
	8 Ω	16 Ω	8 Ω	16 Ω	8 Ω	16 Ω
C_1	6.8	3.3	33	22	22	10
C_2	3.3	1.82	14.7	6.8	8.2	4.7
C_3	10	4.7	6.8	3.3	3.3	2.2
C_4			2.2	1.2	1.47	0.82
L_1	0.8	1.5	4	8	2.5	4.7
L_2	0.3	0.5	0.8	1.5	0.45	1
L_3			1.7	3.5	1	2
L_4			0.3	0.7	0.2	0.4

Capacitors should be 20% tolerance, reversible (non-polarised) types with a ripple current of at least 1000 mA. The voltage rating should be enough to cope with the amplifier power.

Values given are all in μF (micro farads)

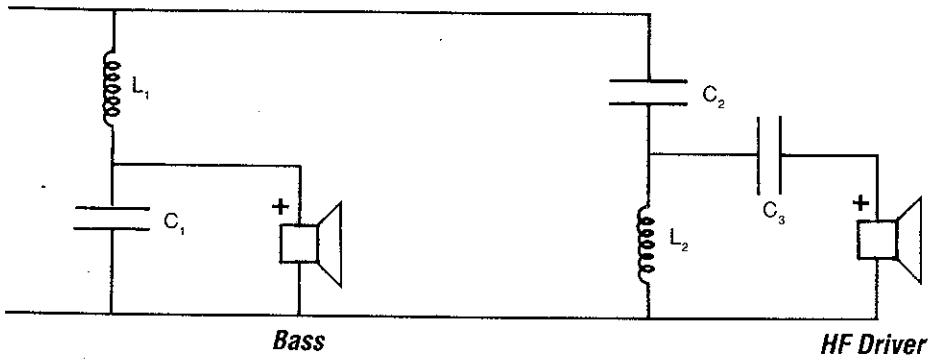
Capacitor Voltage Rating:

Input Power (RMS)	Capacitor Voltage Rating
100W	40V
200W	60V
300W	70V
400W	90V

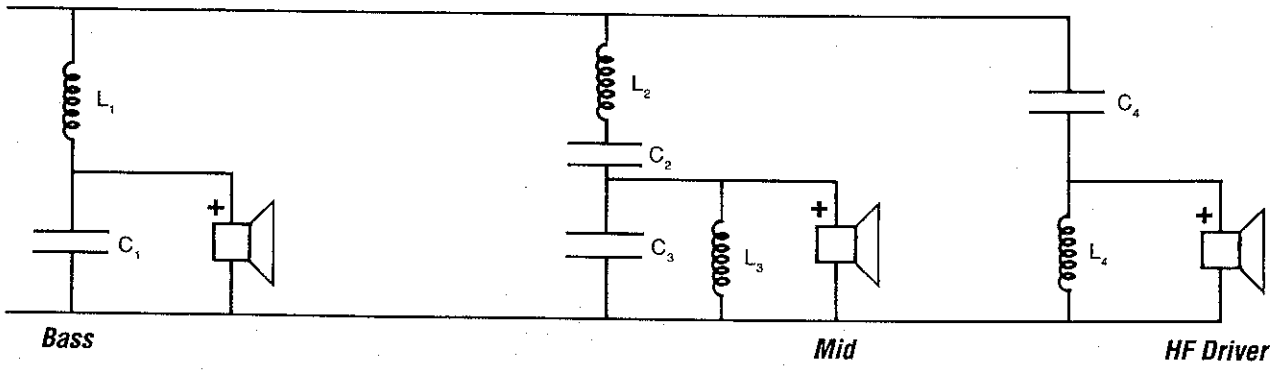
Inductors should be 5% tolerance, air-cored with a DC resistance less than 0.6 Ω.

Values given are all in mH (millihenries).

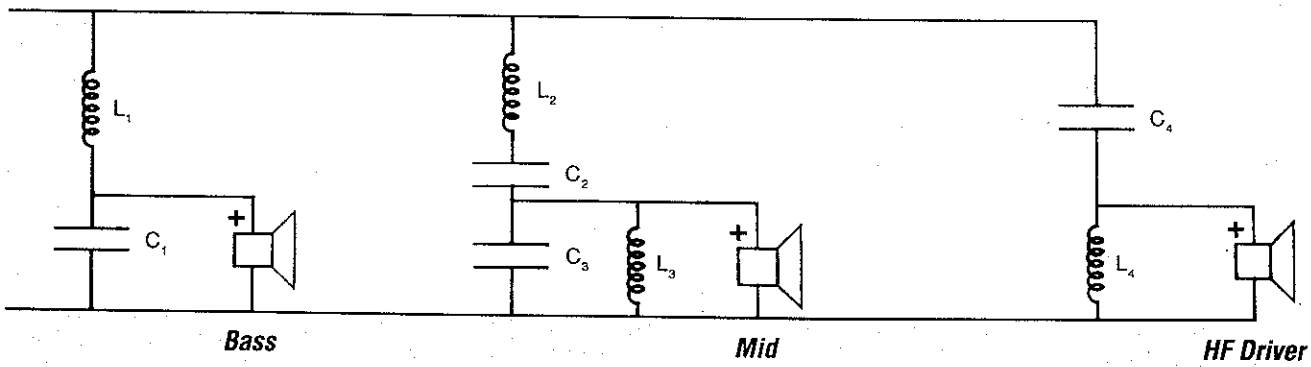
2 Way 3kHz



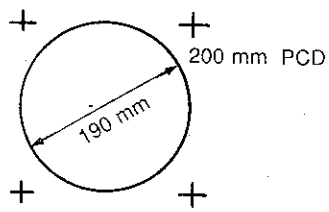
3 Way 600Hz & 4kHz



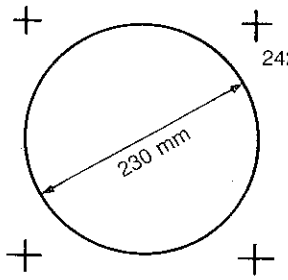
3 Way 1kHz & 7kHz



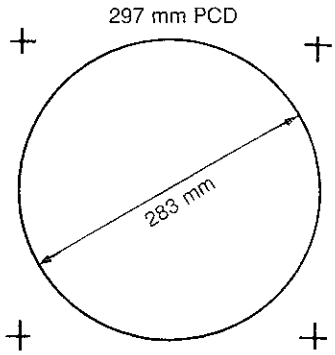
DRIVE UNIT CUT-OUT AND FIXING BOLT DETAILS



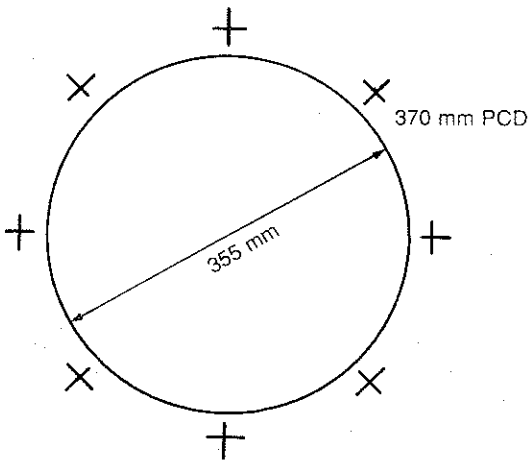
8"



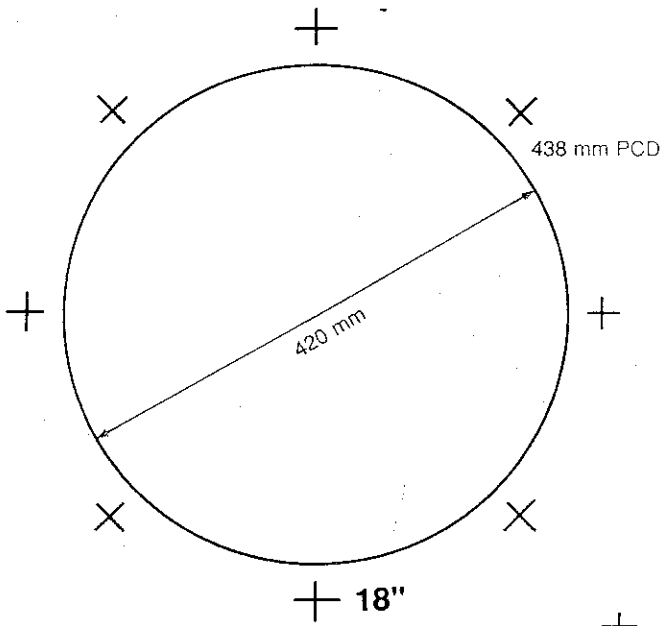
10"



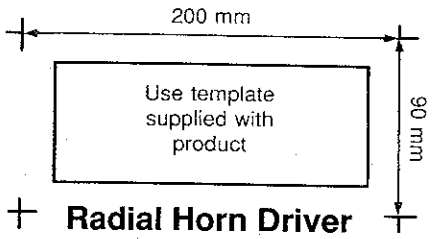
12"



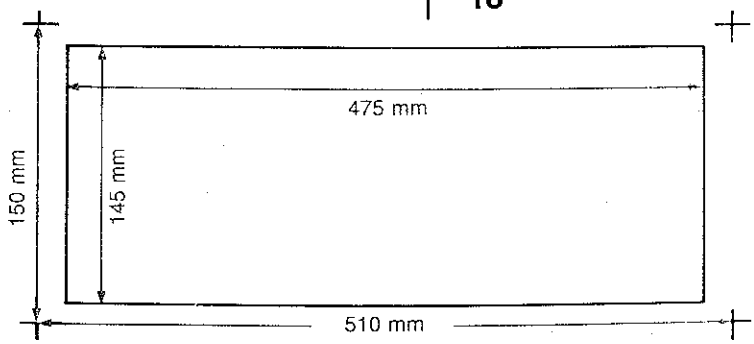
15"



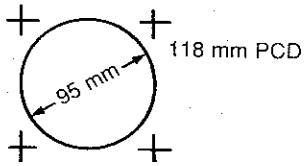
18"



Radial Horn Driver



Radial Horn



Bullet Driver

APPENDIX

The cabinet enclosure designs presented in this Handbook are tested and proven designs. The following section includes theory which is included for the reader's interest and is the basic simplified theory for designing a sealed or bass reflex enclosure.

Since not all drivers are suitable for a given alignment (design) predicted by this theory, the less experienced reader is cautioned not to build his own design solely on the basis of calculations taken from this theoretical approach.

SEALED CABINET

The calculation for the sealed box design is fairly simple, and uses only three of the Thiele-Small parameters; V_{as}, Q_{ts} and f_s.

First, the system's compliance ratio (α) can be approximated, using the formula:

$$\alpha = \left(\frac{Q_{tc}}{Q_{ts}}\right)^2 - 1$$

Where Q_{tc} = the Q of the total system.

For a 2nd order Butterworth aligned box $Q_{tc} = 0.7$, the box volume V_b and -3dB point f_3, can then be calculated using :-

$$V_b = \frac{V_{as}}{\alpha}$$

$$f_3 = f_s \frac{Q_{tc}}{Q_{ts}}$$

PORTED CABINET

It is only since the early 1970s that the mathematics for this type of box became fully documented by Neville Thiele and Richard Small. The calculations can be highly complex, but if restricted to designing a maximally 'flat' response (4th order Butterworth), then they can be simplified enough to be worked out on a scientific calculator or home computer.

Using the Thiele-Small parameters: Q_{ts} f_s V_{as} V_D *the ported cabinet volume* V_b *and the -3dB point* f_3 *can be calculated by:*

$$V_b = 20\, V_{as}\, Q_{ts}^{\,3.3}$$

$$f_3 = \frac{0.28\, f_s}{Q_{ts}^{\,1.4}}$$

Porting

The calculation of the port is of equal importance to the calculation of the cabinet size. What is important about the port is its overall area, S_v *and length,* L_v.

The port can be made any shape as long as the overall area and length are maintained. Square, oblong or round, or even divided into two ports, it can be arranged in whatever way is most convenient for building into the box.

The calculations define a minimum vent area $d_{v\,(min)}$. *If the vent is made substantially smaller than this then the vent will not work correctly. It will also produce 'wind noise' as the air rushes through the port.*

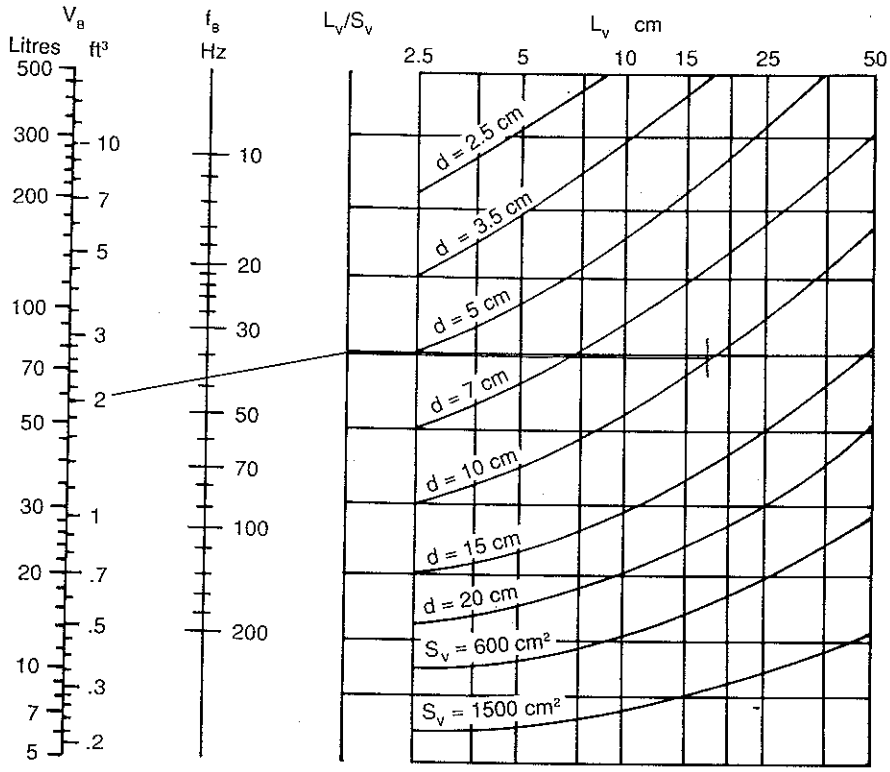
The minimum port diameter $d_{v\,(min)}$ *in cm can be calculated from:-*

$$d_{v\,(min)} = \frac{20\sqrt{V_D}}{\sqrt[4]{f_B}}$$

Where f_B *(the enclosure resonant frequency) =*

$$f_3 \left(\frac{V_b}{V_{as}}\right)^{.13}$$

Using the nomogram below, the correct port length can be determined.

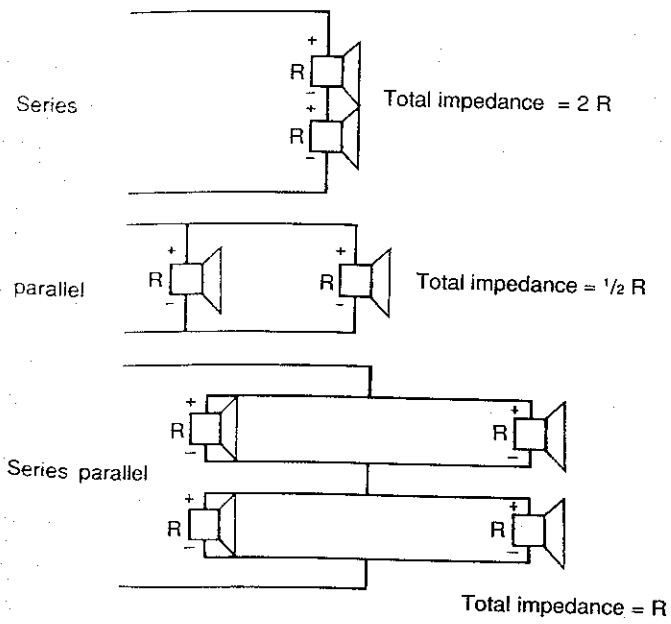


Using a ruler, join required V_B and f_B to the L_V/S_V Line. From that intersection go horizontally to the first curve where d *is greater than the minimum vent diameter. Read off vent length in centimetres.*

The port area can be calculated from the port diameter d_v *using the formula:-*

$$S_v = \frac{\pi d_v^{\,2}}{4}$$

IMPEDANCE MATCHING



In series, the total impedance increases as drivers are added:

$$R_{total} = R_1 + R_2 + R_3 + ...$$

In parallel, the total impedance decreases as drivers are added:

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$$

Series/parallel offers the opportunity to even out the total impedance, when four or more drivers are used:-

e.g. $$R_{total} = \frac{R_1\ R_2}{R_1 + R_2} + \frac{R_3\ R_4}{R_3 + R_4}$$

PASSIVE CROSSOVER DESIGN

Below is a list of formulae for calculating the component values required for crossovers with various rates of cut-off. These will be adequate in most cases. However, please bear in mind the following:-

i) A loudspeaker having a nominal impedance of, say, 8 ohms may only have this value in its piston range, i.e:

200 Hz - 500 Hz; cone driver
1 kHz - 3 kHz; compression driver
2 kHz - 4 kHz; HF driver

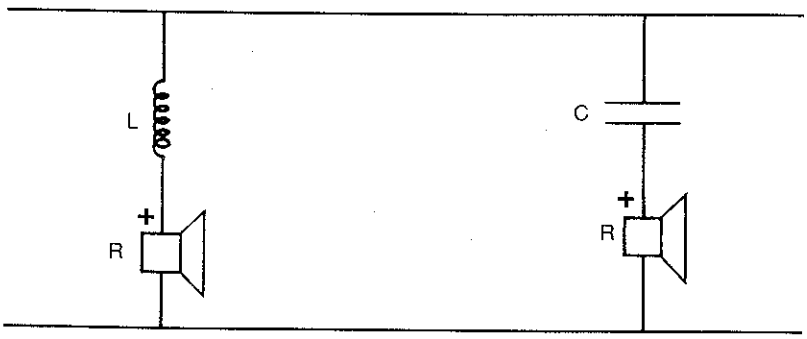
Outside of these ranges the true impedance will be affected by either the driver resonance or the contribution made by the coil inductance.

Very often the design of a passive crossover requires a degree of trial and error.

Key:

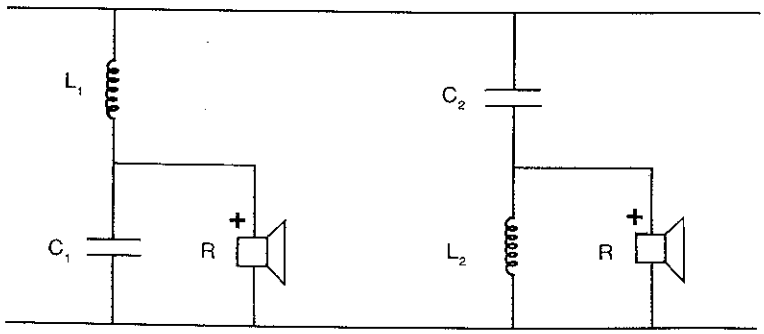
R = nominal impedance of drive unit
f_c = crossover frequency

First order (6 dB/octave)



$$L = \frac{0.866R}{\pi f_c} \qquad C = \frac{0.29}{\pi f_c R}$$

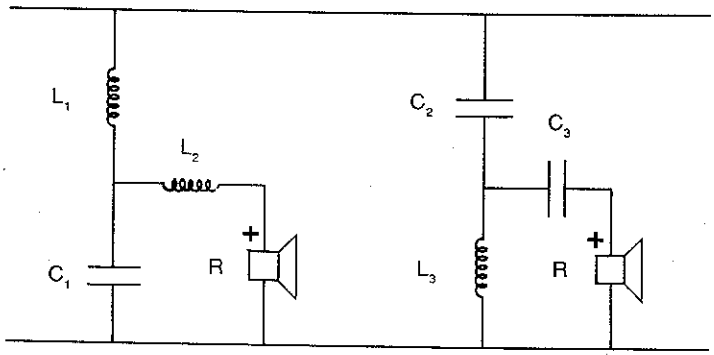
Second Order (12 dB/octave)



$$L_1 = \frac{0.93R}{\pi f_c} \qquad L_2 = \frac{0.54R}{\pi f_c}$$

$$C_1 = \frac{0.47}{\pi f_c R} \qquad C_2 = \frac{0.27}{\pi f_c R}$$

Third Order (18 dB/octave)



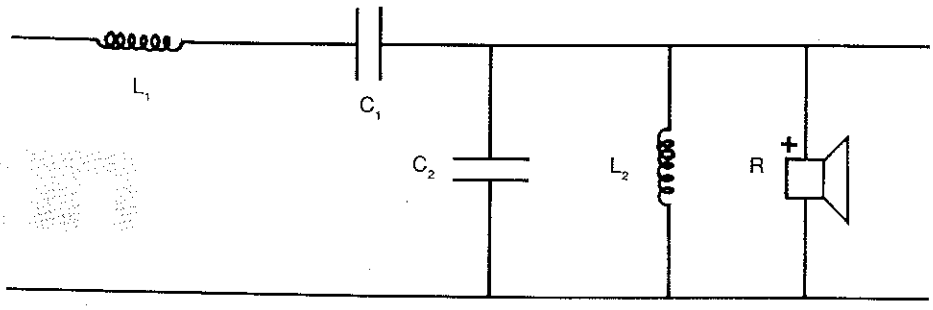
$$L_1 = \frac{0.9R}{\pi f_c} \qquad C_2 = \frac{0.28}{\pi f_c R}$$

$$L_2 = \frac{0.3R}{\pi f_c} \qquad C_3 = \frac{0.83}{\pi f_c R}$$

$$C_1 = \frac{0.8}{\pi f_c R} \qquad L_3 = \frac{0.31R}{\pi f_c}$$

Band Pass

We shall include second order only.



Bass ***Tweeter***

f_1 = *Lower crossover point* f_2 = *Upper crossover point*

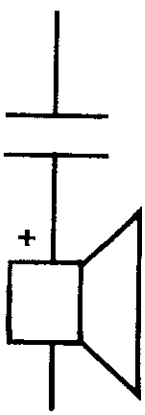
$$L_1 = \frac{1.41R}{\omega_c} \qquad L_2 = \frac{1}{C_2 \omega_0^2}$$

$$\omega_c = 2\pi\left(\frac{f_2}{1.32} - 1.32f_1\right)$$

$$C_2 = \frac{1}{1.41\,\omega_c R} \qquad C_1 = \frac{1}{L_1 \omega_0^2}$$

$$\omega_0 = \sqrt{4\,\pi^2\, f_1\, f_2}$$

PROTECTION CAPACITORS



With an actively driven system the HF driver is connected directly to the output of the amplifier. The low frequency elements of any accidental switch-on 'thumps' can burn out the HF unit. Adding a protection capacitor in series with the HF driver will filter out the worst of this energy. So that they will not affect the crossover point, protection capacitors start rolling off the signal at around an octave below the crossover frequency.

For a crossover frequency f_c, *and driver impedance* R, *the value of the filter capacitor* C *can be worked out from :-*

$$C = \frac{0.6}{f_c R}$$

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GLOSSARY OF TERMS

- α - *"alpha" compliance ratio*
- *Bl* - *Bl Product*
- *v* - *Velocity of sound in air (=345 ms $^{-1}$)*
- C_{ms} - *driver mechanical compliance (mN $^{-1}$)*
- d - *effective piston diameter (m)*
- *dB* - *'decibel' - logarithmic scale of sound pressure*
- f_3 - *3 dB down frequency*
- f_s - *driver free-air resonance (Hz)*
- *HF* - *High frequency*
- *LF* - *Low frequency*
- *MF* - *Mid frequency*
- M_{mt} - *Total moving mass of driver (gm)*
- *Q* - *Q (damping) factor*
- Q_{es} - *Electrical Q of driver*
- Q_{ms} - *Mechanical Q of driver*
- Q_{ts} - *Total Q of driver*
- Q_{tc} - *Total Q of system*
- R_e - *DC resistance of driver (ohms)*
- V_{as} - *Volume of air giving same compliance as the compliance of the driver suspension (litres)*
- V_d - *Peak displacement volume of driver cone (litres)*
- ω - $2\pi f$