2. Piezo ceramic speakers (SPS & SCS)

2.1. INTRODUCTION

Based on the development and production of our SCS series Sonitron improved the frequency characteristics of the piezo speaker system to more flatness in the frequency response curve.

The SPS series are based on a sandwich construction of a specially shaped piezo ceramic disk and a composite polymer membrane. The complex polymer membrane is reducing resonance peaks and converts vibrations energy into a highly damped frequency response curve with low distortions.
The speakers are very flat in design. They can be delivered with open front and mountable against the panel inside a closed front in which the sound holes are provided. The sound output pressure is created through air holes in the front on which the speakers are mounted.

The piezo speaker has 60% more net sound output per membrane surface than the electro-dynamic speaker in function of the average current drain and average sound pressure level. High sound quality and low distortion guarantee perfect reproduction of music and speech. The loudspeakers are extremely reliable and can be used in difficult environmental conditions and applications because of resistance of the front to water, humidity, vibrations and dust.
The described models are released for industrial applications in the field of mobile communication equipment such as: GSM, WAP, GPRS, flat LCD computer screens and computer monitors, car radio sound systems, instrumentation, portable sound reproduction devices, public address systems, paging systems etc.
The speakers are available in pin and SMD versions.

Family range speakers

2.2. ADVANTAGES & APPLICATIONS

ADVANTAGES:

- very flat and solid construction
- shock, water and dust-proof front panel
- resistant to temperature variations
- broad frequency range in small size
- combined use as speaker/micro
- no electro-magnetic field (EMC)
- little energy required at low frequencies
- less current consumption needed in the leads to the speaker
- 60% higher acoustic output in smaller speakers compared to electro-dynamic speakers
- low weight
- low distortion
- high impedance
- can be driven directly by IC

APPLICATIONS:

- home equipment & domotics
- communication equipment
- talking buzzer & door bell
- computer equipment
- cars, busses and trains
- vending machines
- multi-media equipment
- industrial equipment
- portable voice recorders
- paging systems
- public address systems
- instrumentation
- GSM, WAP, GPRS
- car radio sound system

2.3. PRODUCT CODIFICATION

The speaker series are available in 2 pin versions: through hole (P) or SMD (S).

SPS	-	4640 8770 10080 30090	-	01	P S
SCS	-	17 24 32			P S
↓	↓	↓		↓	
	Square diameter (mm)				

SPS Sonitron Polymer Speaker
SCS Sonitron Ceramic Speaker

ID code
(identification code)
P: Pin distance (mm)
S: SMD-connection

The SMD models can not be soldered in reflow process, the terminals must be soldered by hand.
Miniature screws with nut are delivered with the speaker on request: add N to the product code. The frame can also be glued to the front. The kind of glue depends on the nature of the material used for the front.

2.4. LIST OF AVAILABLE PRODUCT TYPES

SPS-4640-01 P10 SPS-4640-01 S	SPS-8770-01 P10 SPS-8770-01 S	SPS-10080-01 P10 SPS-10080-01 S	SPS-30090-01 P10
SCS-17 P10 SCS-17 S	SCS-24 P10 SCS-24 S	SCS-32 P10 SCS-32 S	

2.5. SPECIFICATIONS

Model	Frequency range	Peak frequency SPL ±20%	voltage	Capacitance at 1 KHz ±20%	OperatingImpedance	Weight	
SPS-4640-01	350 Hz - 10 kHz	-		300 nF	5 to 30 Vpp	574 ohm	5 g
SPS-8770-01	250 Hz - 20 kHz	-		660 nF	5 to 30 Vpp	240 ohm	25 g
SPS-10080-01	200 Hz - 20 kHz	-		600 nF	5 to 60 Vpp	265 ohm	35 g
SPS-30090-01	200 Hz - 20 kHz	-		1550 nF	5 to 60 Vpp	100 ohm	170 g
SCS-17	700 - 8000 Hz	2100 Hz - 88 dB(A) 5500 Hz - 88 dB(A)		20 nF	5 to 30 Vpp	7957 ohm	1.7 g
SCS-24	500 - 8000 Hz	700 Hz - 60 dB(A) 1500 Hz - 90 dB(A) 4200 Hz - 94 dB(A)		37 nF	5 to 30 Vpp	4300 ohm	4 g
SCS-32	300 -8000 Hz 2500 Hz - 96 dB(A) 3100 Hz - 94 dB(A) 4700 Hz - 81 dB(A)	700 Hz - 86 dB(A)		66 nF	5 to 30 Vpp	2400 ohm	5.9 g

Sound pressure level: see frequency response curves
Serial resistance of the SPS-4640-01 is 220 ohm

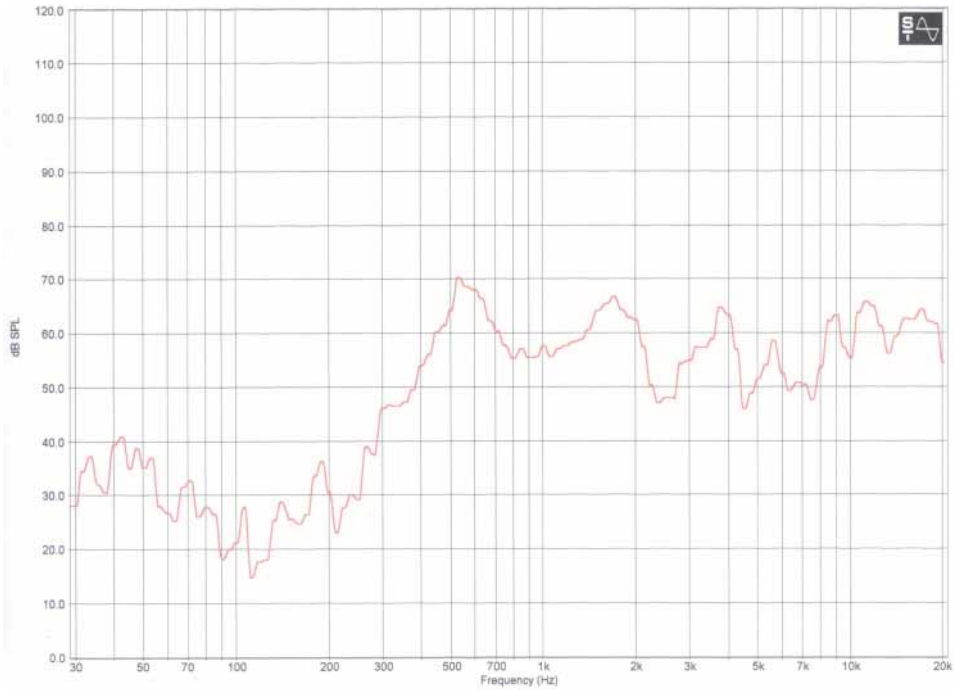
Measurements	Distance	Voltage
SPS-4640-01	10 cm	60 Vpp peak raise
SPS-8770-01	30 cm	60 Vpp peak raise
SPS-10080-01	30 cm	60 Vpp peak raise
SPS-30090-01	30 cm	60 Vpp peak raise
SCS-17	30 cm	30 Vpp sine wave
SCS-21	30 cm	30 Vpp sine wave
SCS-32	30 cm	30 Vpp sine wave
All measurements are made in free air. Speakers mounted in a closed box with dimensions 40 x 15 x 5 cm		

Operating temperature	-20°C to +60°C
Storage temperature	-40°C to +60°C
Life time (at 21°C)	See expected life time curve in addendum
Case material SPS series	ABS
Case material SCS series	ABS (UL rating: 94 HB) for pin-versions, PPS (UL rating: 94 V0/5V) for SMD-versions
Standard colour of case for SPS series	Grey
Standard colour of case for SCS series	Black

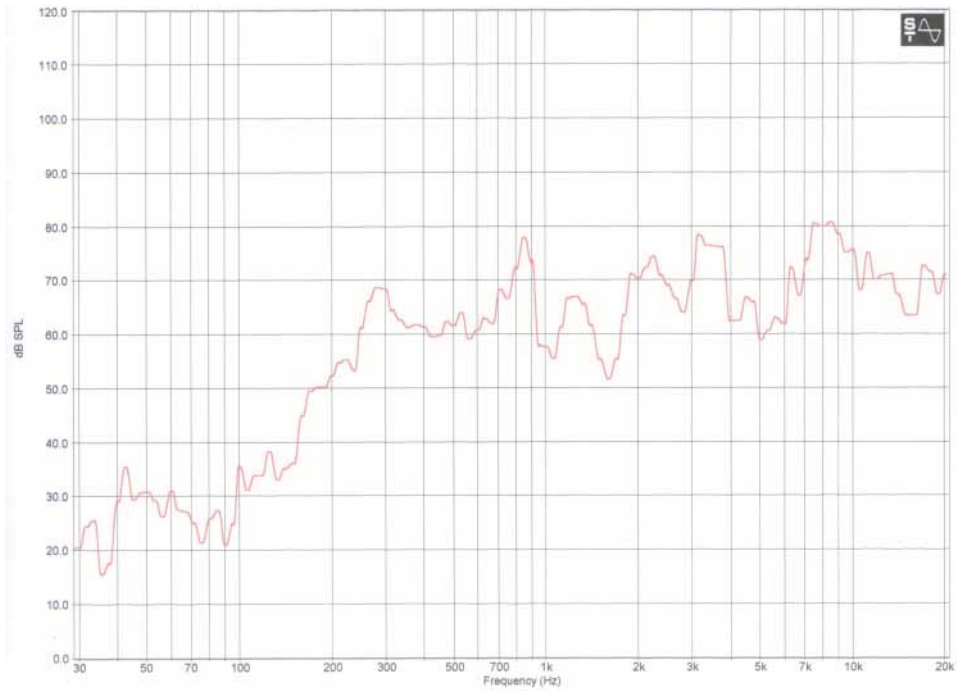
2.6. FREQUENCY RESPONSE CURVE

The frequency response curve of the SPS-4640-01 is measured on an axis at distance 10 cm; the SPS-8770-01, SPS-10080-01 and SPS-30090-01 at 30 cm.
The input voltage is 60 Vpp (pink noise) at room temperature (21°C) and in free air.
During measurement, the speaker was mounted in a closed box of
40 cm H x 15 cm W x 5 cm D, deduct 18 dB(A) in average for use at 10 Vpp.

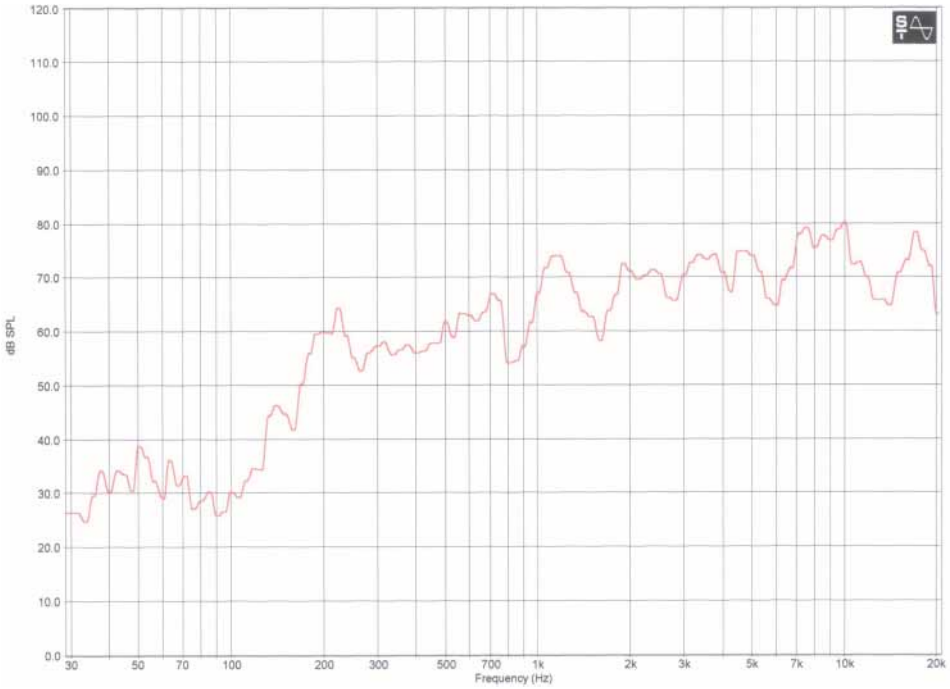
SPS-4640-01



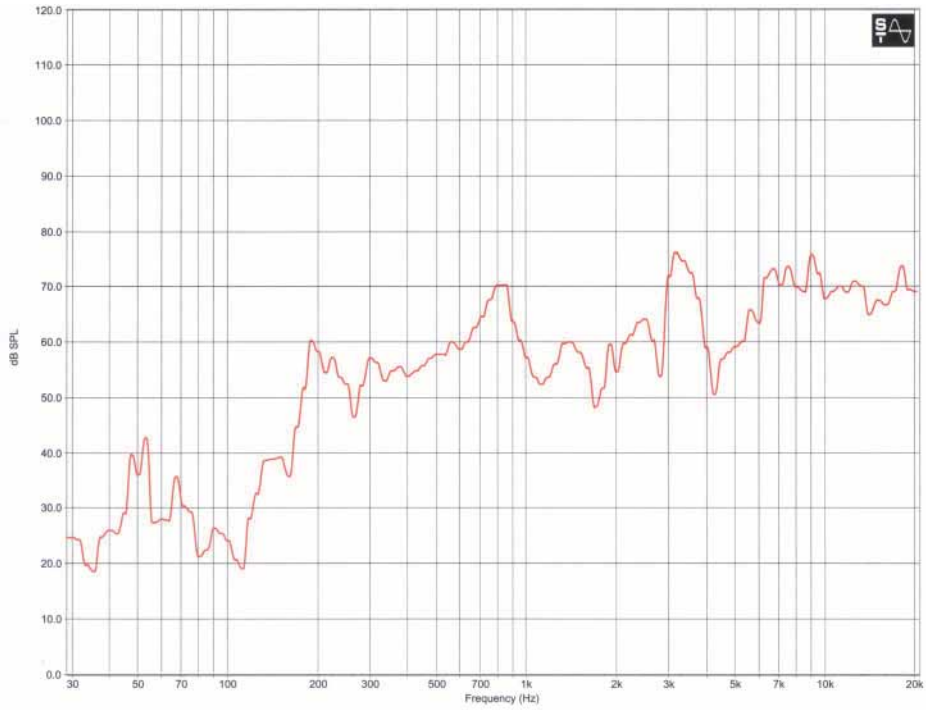
SPS-8770-01



SPS-10080-01

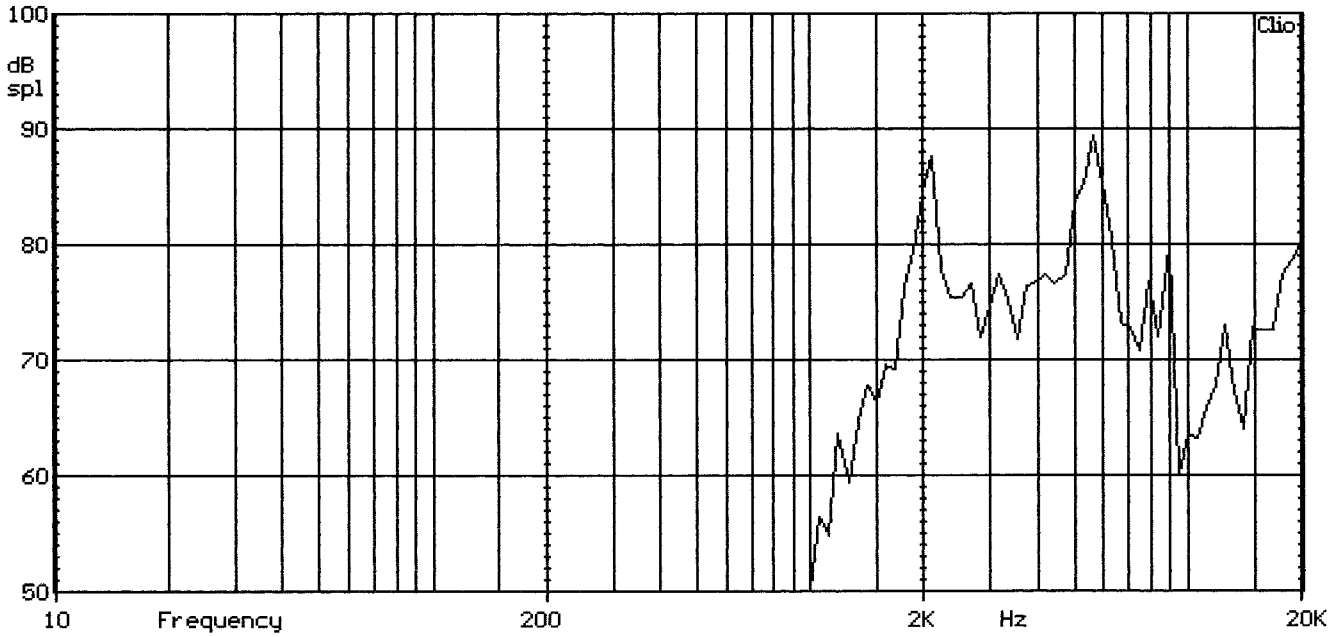


SPS30090-01

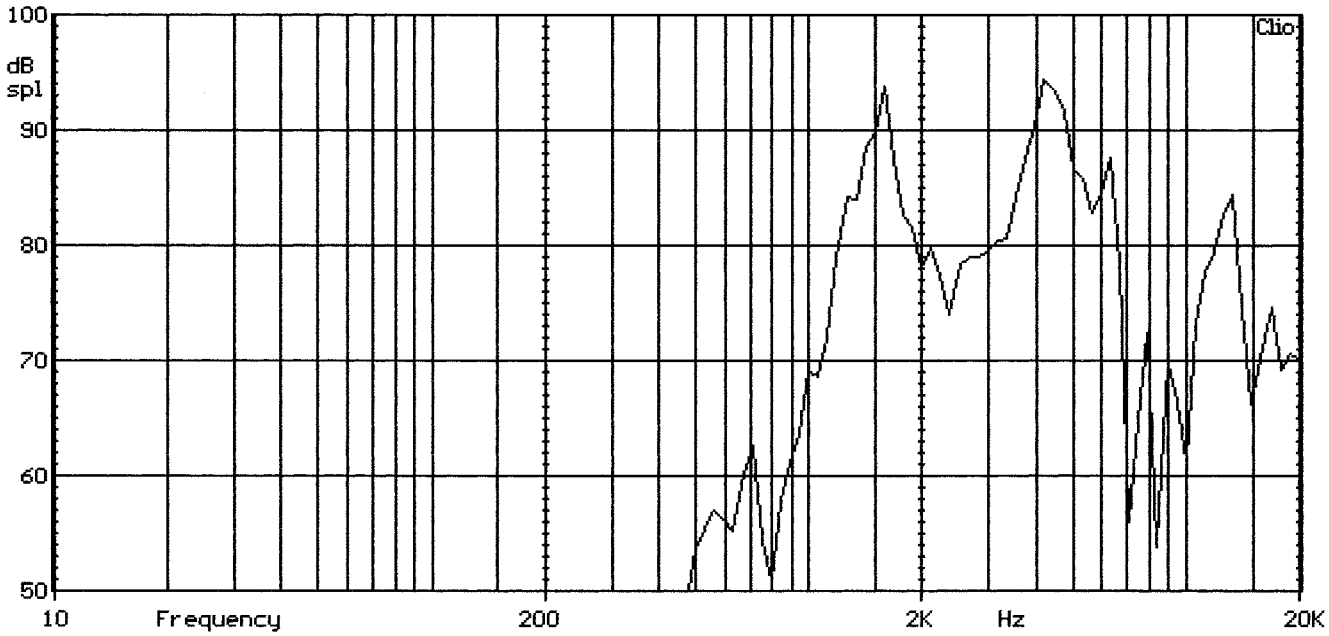


The frequency response curves of the SCS series are measured on an axis at a distance of 30 cm at 30 Vpp input voltage (sine wave) at 21°C in free air. During measurement, the speaker is mounted in a closed box of 40 cm H x 15 cm W x 5 cm. Deduct 6 dB(A) in average for use at 10 Vpp.

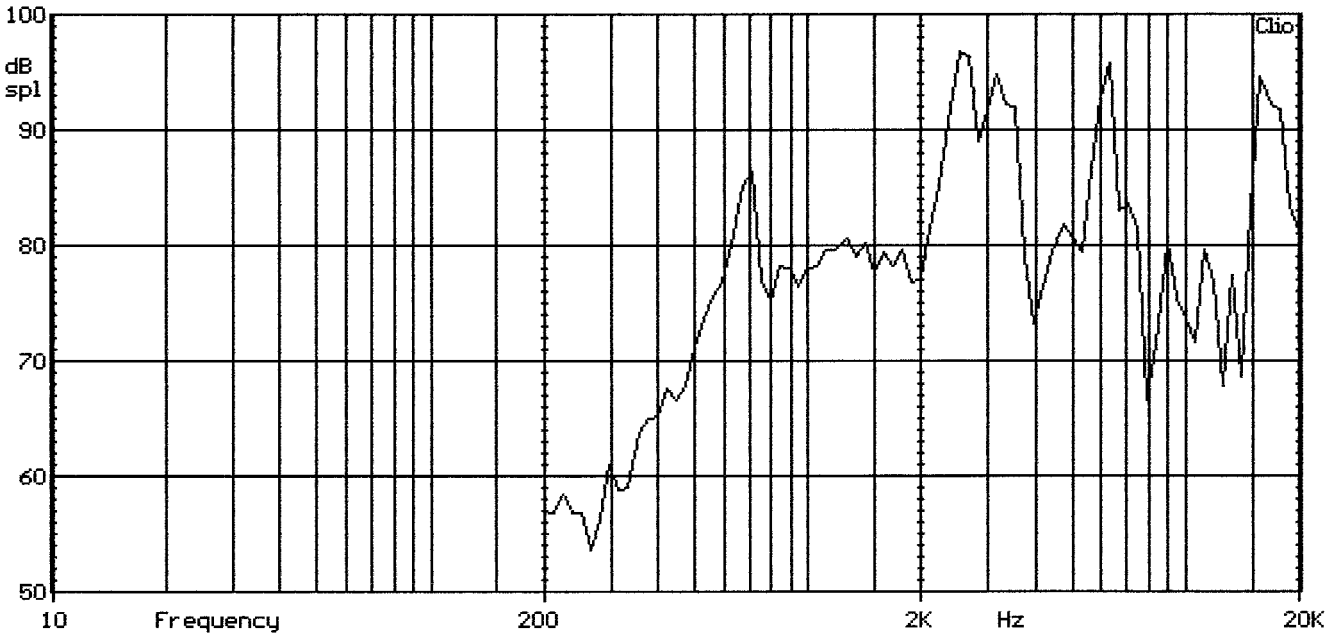
SCS-17



SCS-24



SCS-32

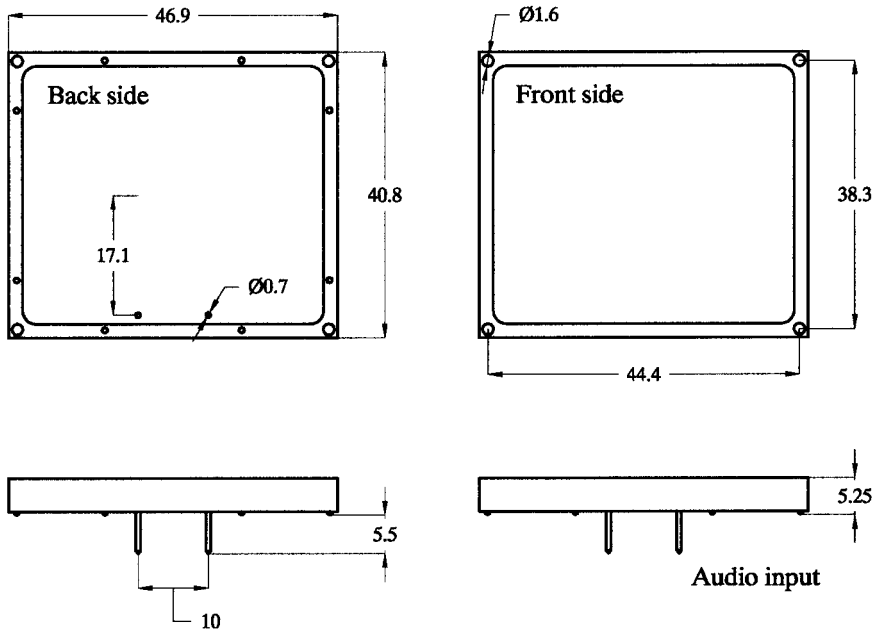


The frequency response curves of the SCS series are measured on an axis at a distance of 30 cm at 30 Vpp input voltage (sine wave) at 21°C in free air. During measurement, the speaker is mounted in a closed box of 40 cm H x 15 cm W x 5 cm. Deduct 6 dB(A) in average for use at 10 Vpp.

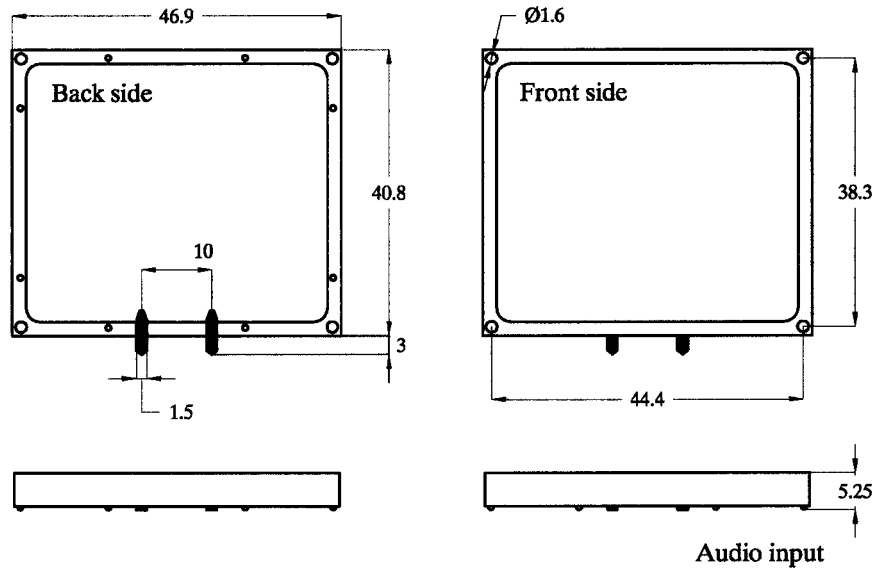
2.7. DIMENSIONS (All dimensions are in mm)

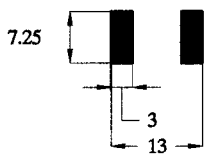
SPS-4640-01

Pin version (case in ABS)



SMD version (case in ABS)





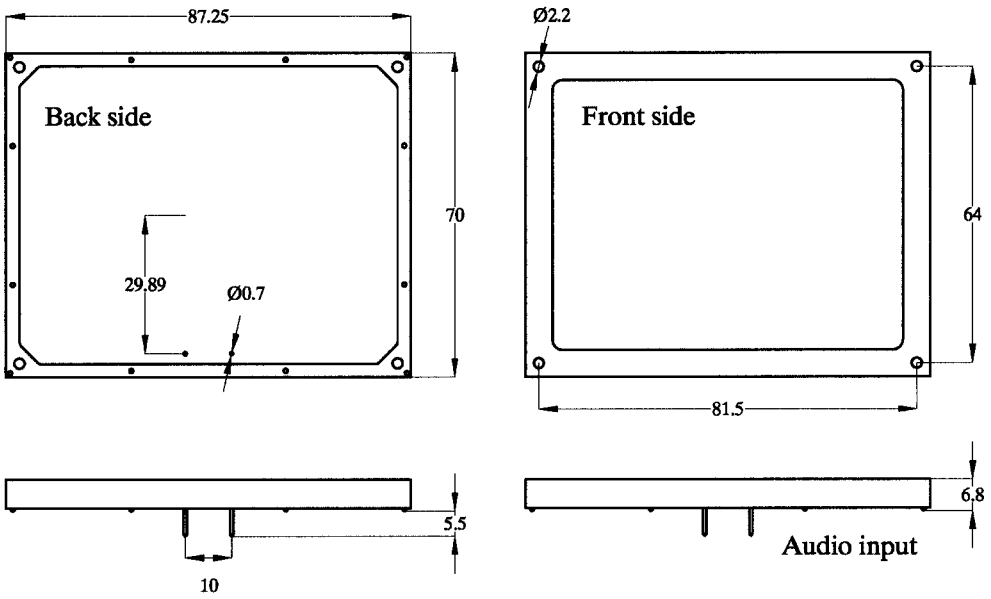
Recommended PCB lay-out

Tolerance : +/- 0.2 mm

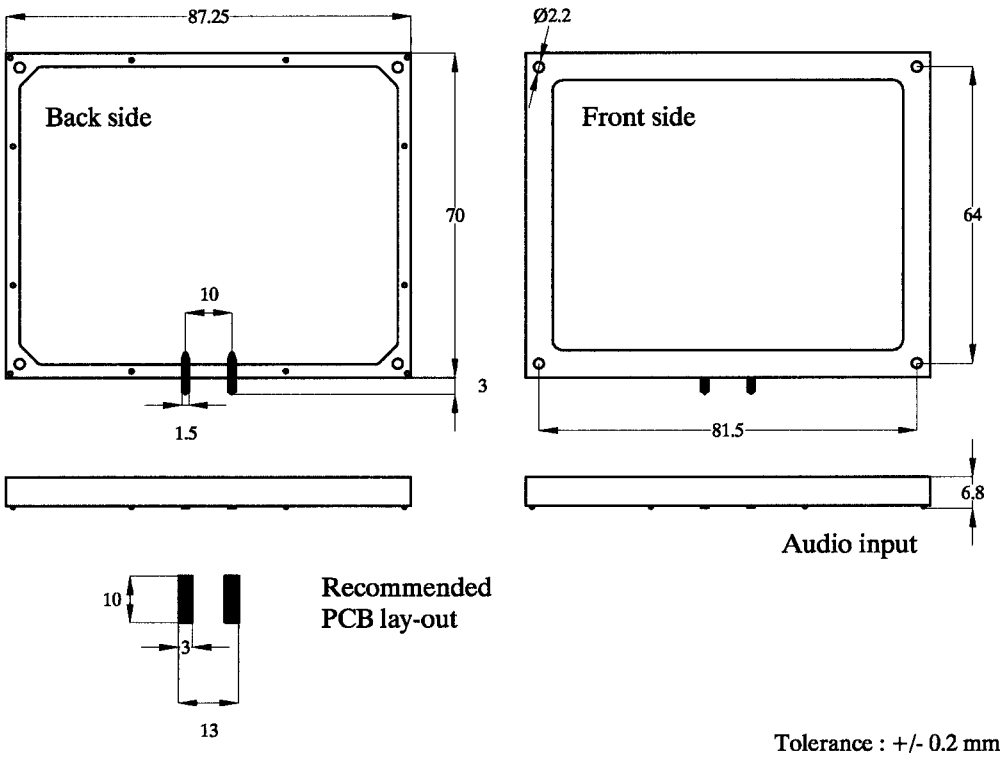
SPS & SCS SPEAKERS

SPS-8770-01

Pin version (case in ABS)



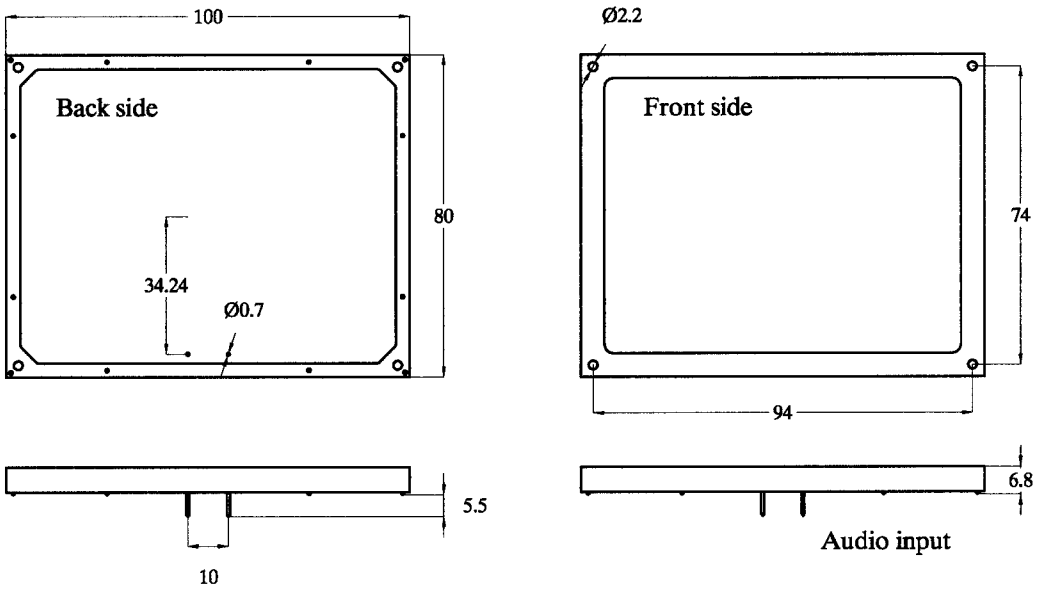
SMD version (case in ABS)



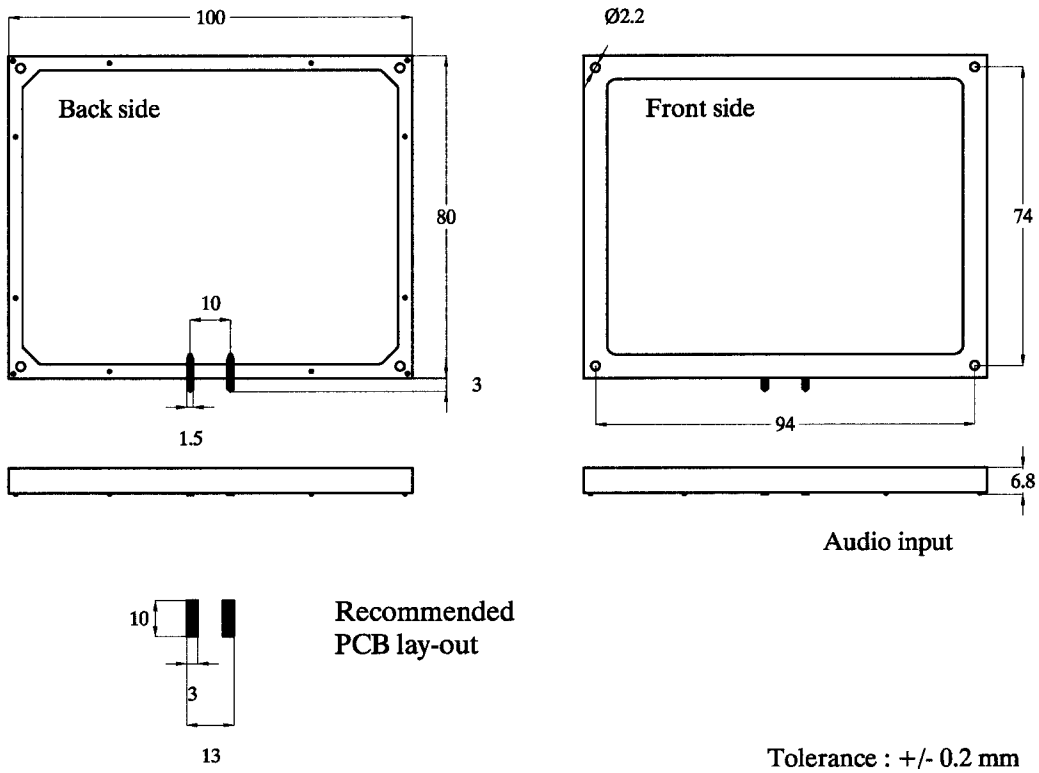
Tolerance : +/- 0.2 mm

SPS-10080-01

Pin version (case in ABS)

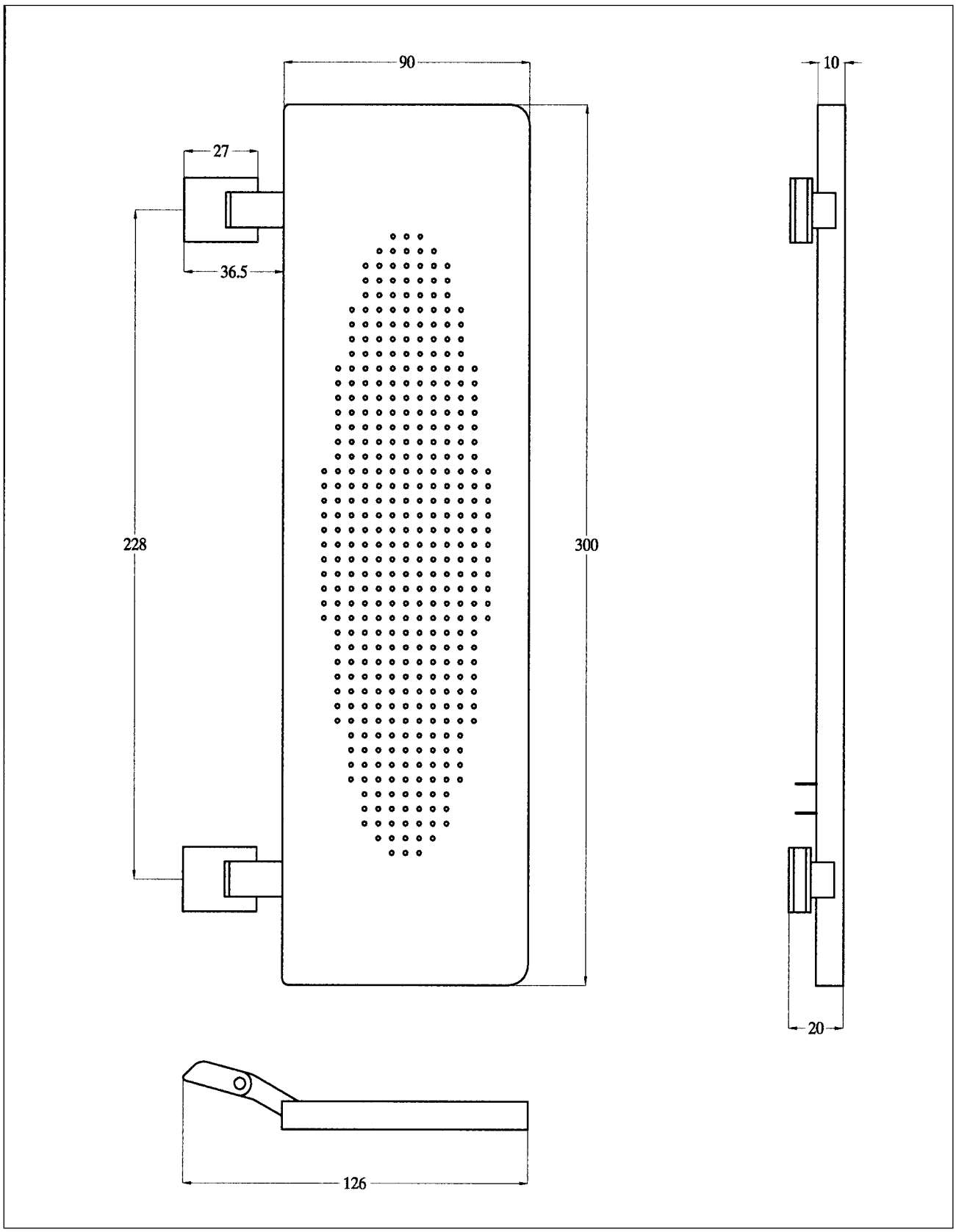


SMD version (case in ABS)

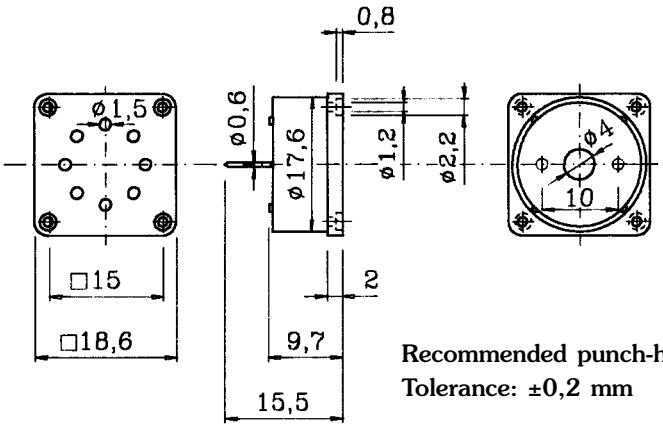
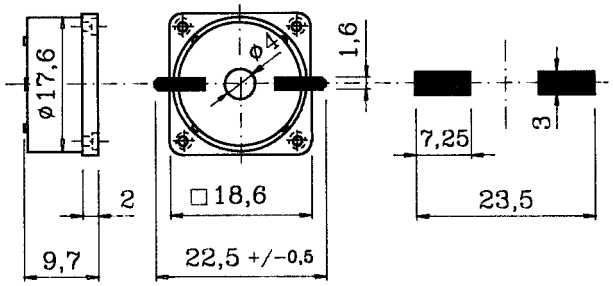


SPS-30090-01

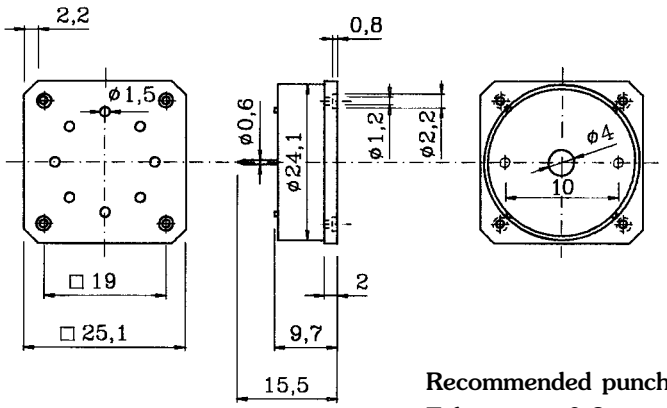
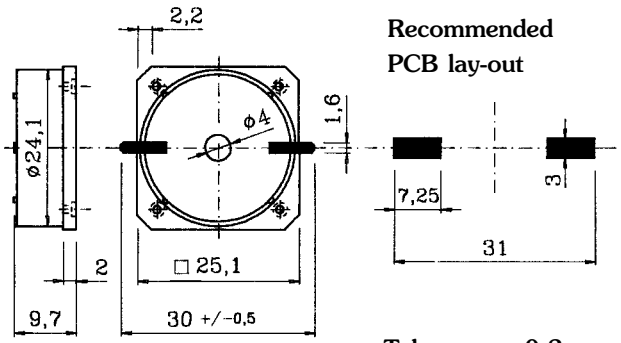
Pin version (case in ABS)



SCS-17

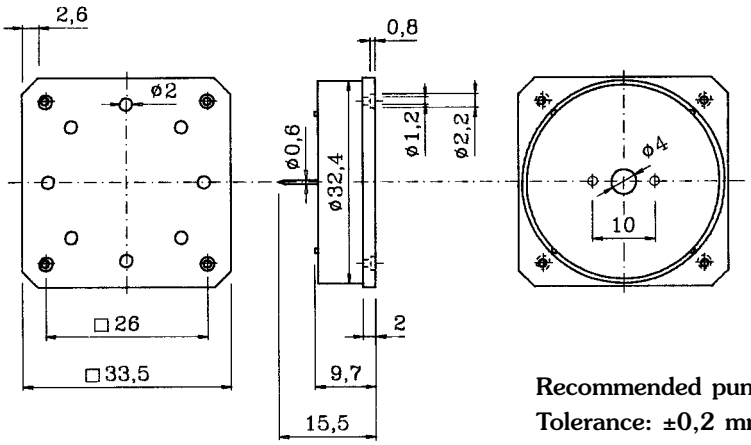
Pin-version (case in ABS)	 Recommended punch-hole: 18,1 Tolerance: ±0,2 mm
SMD-version (case in PPS)	Recommended PCB lay-out  Tolerance: ±0,2 mm

SCS-24

Pin-version (case in ABS)	 Recommended punch-hole: 24,8 Tolerance: ±0,2 mm
SMD-version (case in PPS)	 Recommended PCB lay-out Tolerance: ±0,2 mm

SCS-32

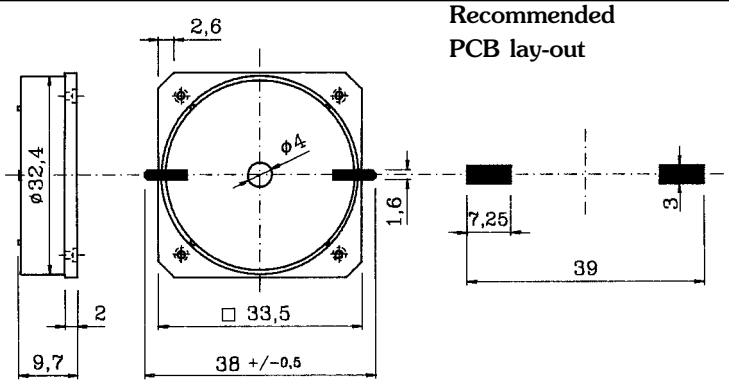
Pin-version (case in ABS)



Recommended punch-hole: 32,95
Tolerance: ±0,2 mm

SMD-version (case in PPS)

Recommended PCB lay-out

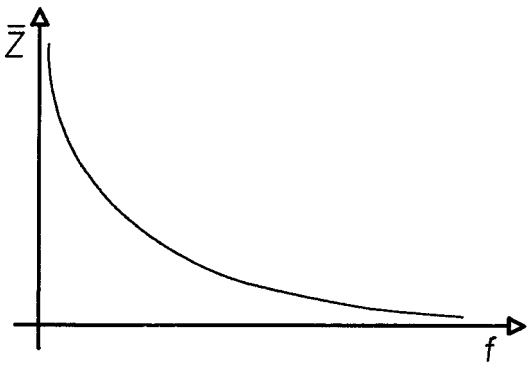


Tolerance: ±0,2 mm

2.8. IMPEDANCE

The impedance of the piezo speakers is a capacitive reactance and follows an asymptotic function.

$$Z_c = -j.X_c$$
$$X_c = \frac{1}{\omega.c}$$



The typical impedance values (±20%) for frequencies of 100 Hz up to 20 kHz of our speakers are as follows:

Model	SCS-17	SCS-24	SCS-32
Capacitance *	20 nF	37 nF	66 nF
Z (0.1 kHz)	79577 ohm	43000 ohm	24114 ohm
Z (1 kHz)	7957 ohm	4300 ohm	2411 ohm
Z (2 kHz)	3978 ohm	2150 ohm	1205 ohm
Z (5 kHz)	1591 ohm	860 ohm	482 ohm
Z (10 kHz)	795 ohm	430 ohm	241 ohm
Z (15 kHz)	530 ohm	286 ohm	161 ohm
Z (20 kHz)	397 ohm	215 ohm	121 ohm

Model	SPS-4640-01	SPS-8780-01	SPS-10080-01	SPS-30090-01
Capacitance *	300 nF	660 nF	600 nF	1550 nF
Z (0.1 kHz)	5310 ohm	2410 ohm	2653 ohm	1027 ohm
Z (1 kHz)	574 ohm	240 ohm	265 ohm	103 ohm
Z (2 kHz)	345 ohm	120 ohm	133 ohm	51 ohm
Z (5 kHz)	244 ohm	48 ohm	53 ohm	21 ohm
Z (10 kHz)	226 ohm	24 ohm	27 ohm	10 ohm
Z (15 kHz)	223 ohm	16 ohm	18 ohm	7 ohm
Z (20 kHz)	222 ohm	12 ohm	13 ohm	5 ohm

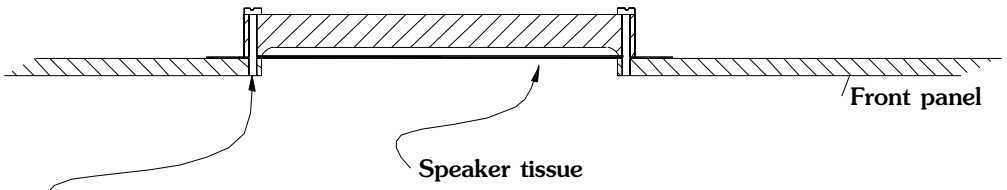
* Capacitance (±20%)

2.9. APPLICATION NOTES

- Recommended mounting methods for the SPS series
- Recommended mounting methods for the SCS series
- Blind power dissipation in a piezo ceramic capacitive load (for a sine wave)
- The importance of the isolation resistor (Riso)
- Example of a typical amplifier design
- Low voltage piezo audio amplifier

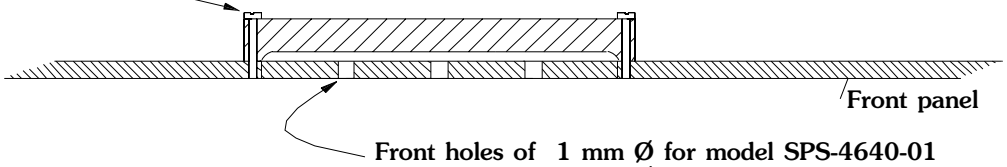
2.9.1. RECOMMENDED MOUNTING METHODS FOR THE SPS SERIES

Speaker tissue



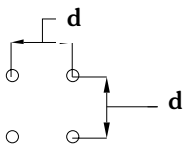
M1,5 for model SPS-4640-01
M2 for model SPS-8770-01
M2 for model SPS-10080-01

Front holes

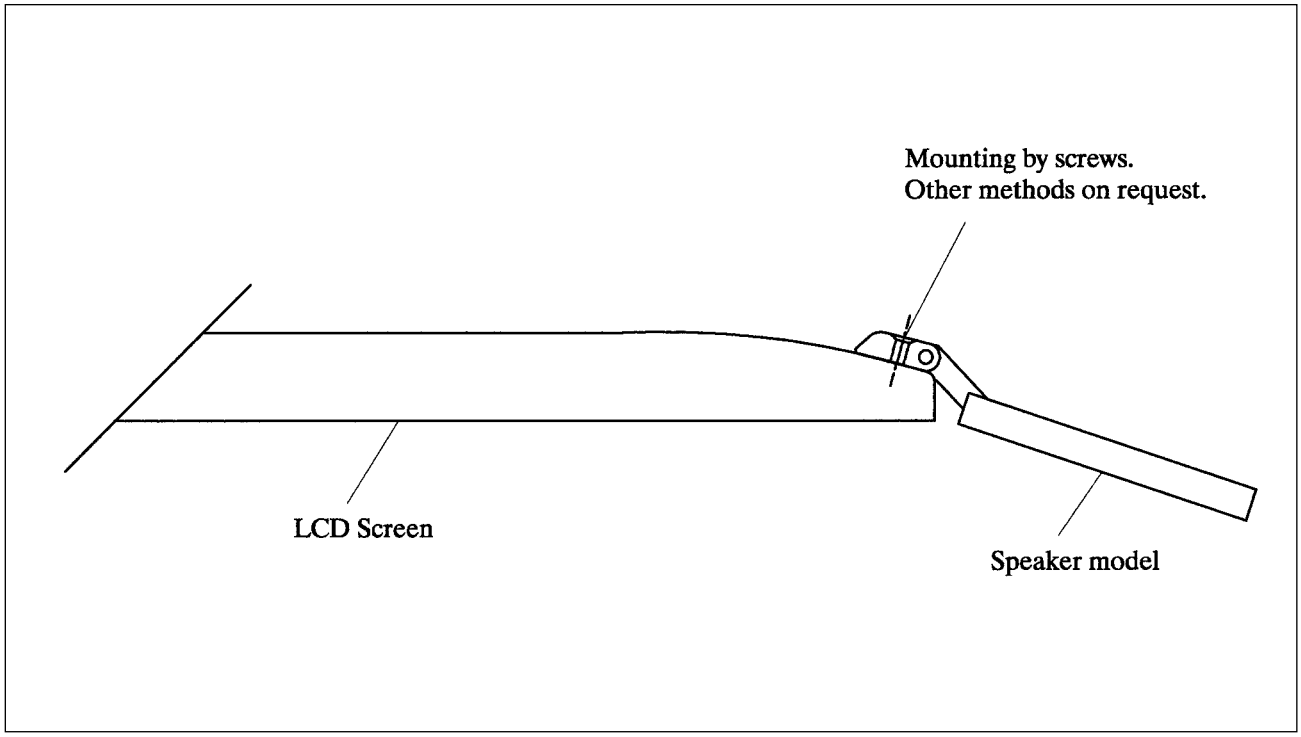


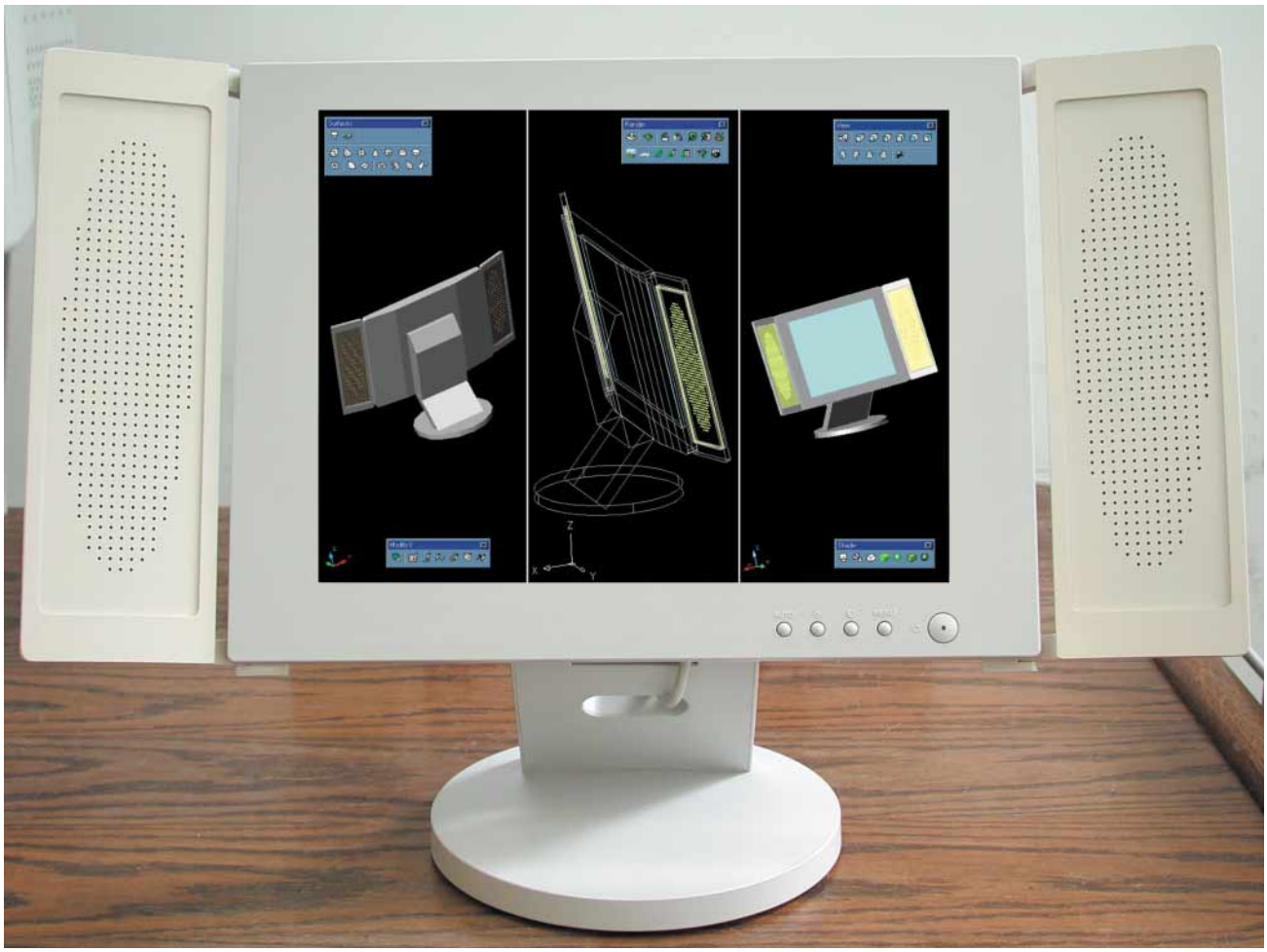
Front holes of 1 mm Ø for model SPS-4640-01
2 mm Ø for model SPS-8770-01
2 mm Ø for model SPS-10080-01

Distance front holes d = 5 mm for model SPS-4640-01
d = 10 mm for model SPS-8770-01
d = 10 mm for model SPS-10080-01



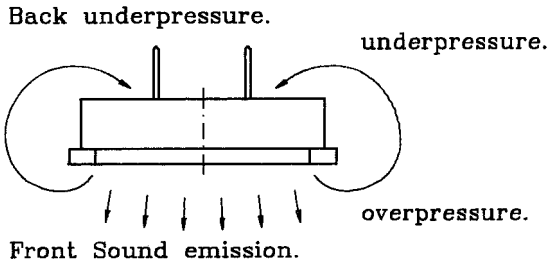
SPS-30090-01 (LCD screen)



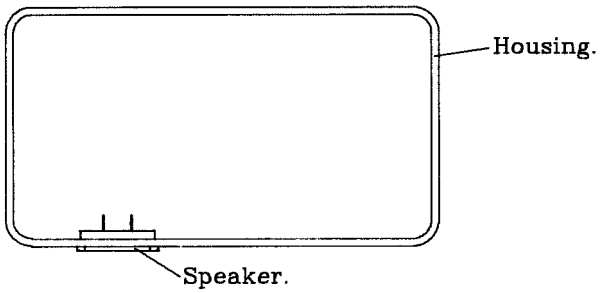


2.9.2. RECOMMENDED MOUNTING METHODS FOR THE SCS SERIES

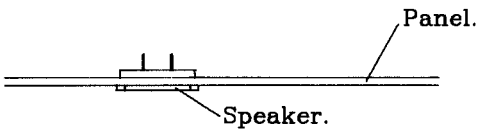
In order to avoid air pressure cancellation due to back pressure eliminating the frontal air pressure, which is radiated by the speaker, the mounting method must be optimised in function of the space with mounting aids available for your application.



If the front of the loudspeaker is not isolated from the back, the emitting sound pressure will be strongly eliminated because of the back underpressure, which will reduce the front overpressure sound emission.
A speaker can be mounted on the front of your equipment or instrument.



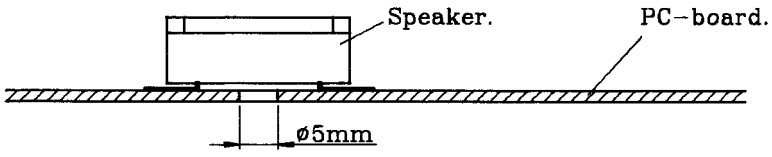
The front is then isolated from the back.



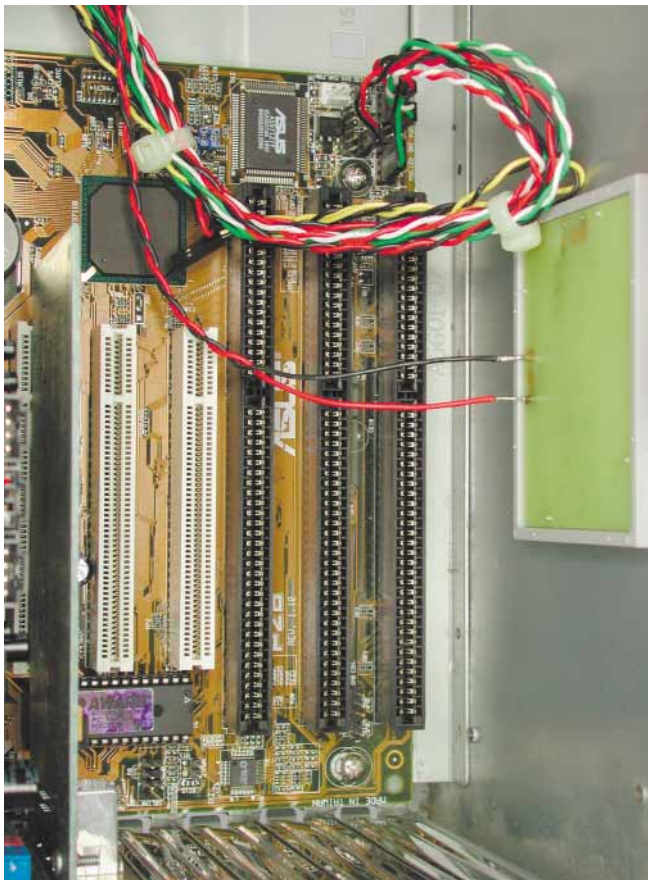
A flat panel isolates the front from the back. The size of the panel depends on the frequency response curve from the speaker. The recommended minimum panel size for each SCS-loudspeaker is:

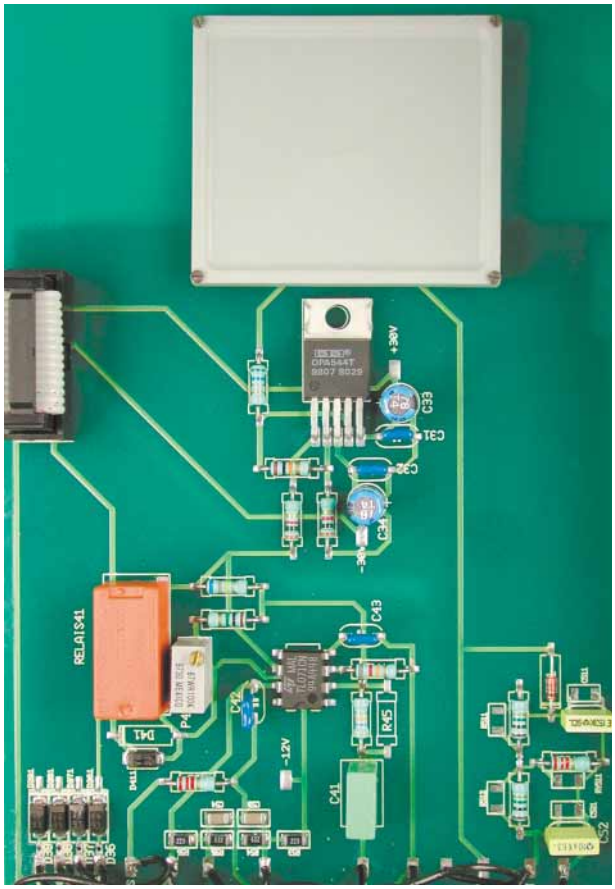
* SCS-32 0,5 m x 0,5 m
* SCS-24 0,3 m x 0,3 m
* SCS-17 0,3 m x 0,3 m

When mounted on a PC-board, a central hole in the PC-board of minimum 5 mm diameter is recommended.



Application examples for the SPS and SCS series





2.9.3. BLIND POWER DISSIPATION IN A PIEZO-CERAMIC LOAD (FOR A SINE WAVE)

The power dissipation in an electro-dynamic speaker depends on the resistance value of the drive coil. In our comparison, the power dissipated in an electro-dynamic speaker with Ø 68 mm and 16 Ω impedance at 2V is

$$\frac{V^2}{R} = \frac{4}{16} = 0{,}25\ W$$

The power dissipation in a piezo capacitive load, not in resonance, is

$$P = \underbrace{\frac{c.V^2.\omega.\cos\varphi}{2}}_{\text{capacitive power}} + \underbrace{\frac{c.V^2.\omega.D_F}{2}}_{\text{power dissipated in ceramic}} = \frac{c.V^2.\omega}{2} \cdot (\cos\varphi + D_F)$$

D_F: dissipation factor of the ceramic material
c: capacitance of speaker
ω: $2\pi f$
V: drive voltage
cos φ: the phase angle between current consumption and voltage (in a capacitor is this angle 90° before in phase, thus cos φ = 0)

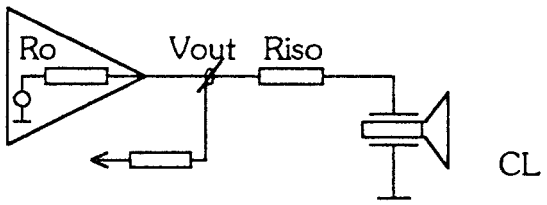
In theory, the capacitive power is zero. The power dissipated in the ceramic disc of the speaker strongly depends on the dissipation factor of D_F of the used ceramic.
The D_F is a measure of the di-electric losses in the material, defined as the tangent of the loss angle or the ratio of parallel resistance to parallel reactance, expressed in percent and measured at 1 kHz. This dissipation factor can vary from 0,4 up to 2% for the most typical ceramics available.
Our speakers are not used at resonance. Consequently the power dissipated mainly depends on the D_F and is very low or near to zero.

The power dissipation of the piezo speaker can be considered as a blind power drain. The amplifier must deliver the total power needed to drive the circuit. Thus the total power drain of the piezo speaker is the drain of the amplifier, needed to deliver the blind power for the speaker, the power dissipated in the ceramics (due to the dissipation factor) and the power dissipated in the isolation resistor R_{ISO}.

2.9.4. THE IMPORTANCE OF THE ISOLATION RESISTOR (R_{ISO})

Amplifiers feeding capacitive loads can be stabilised in order to avoid oscillation at 180° degrees phase shift at certain feedback conditions.
There are many ways to stabilise an amplifier in combination with a capacitive load, but a small resistor R_{ISO} is very effective and easy to design-in. By adding an isolation resistor R_{ISO} in series with the amplifier output and the capacitive load of the speaker CL, we improve the gain and phase margin over the entire frequency range.
By adding a R_{ISO}, we create:

1. an extra F_{zero} (Fz) in the transfer function
2. We reduce the frequency of the pole with an output load in the transfer function



Fp: At this frequency, the poles are represented by -45 degrees phase shift with -45 degrees per decade slope, extending this line with 0 degree and -90 degrees horizontal lines.

$$Fp = \frac{1}{2\pi CL\,(Ro + R_{ISO})}.$$

Fz: At this frequency, the phase for zero is represented by a +45 degrees phase shift at the frequency of zero with +45 degrees per decade slope, extending this line with 0 degree and +90 degree horizontal lines.

$$Fz = \frac{1}{2\pi CL\,R_{ISO}}.$$

The Fz in the transfer function is the product of RISO and CL. The phase improvement is:

$$\Delta\theta: \tan^{-1}(2\pi.UGBW.R_{ISO}.CL)$$

$\Delta\theta$ = improvement in phase margin
UGBW = unity gain bandwidth frequency
R_{ISO} = isolation resistor
CL = capacitive load of the speaker

2.9.5. EXAMPLE OF A TYPICAL AMPLIFIER DESIGN

As an illustration we take the SPS-4640-01 with a capacitive load of 300nF and a R_{ISO} of 6,5 Ω in combination with a Burr-Brown OPA547T amplifier.

The Fz is then:

$$Fz = \frac{1}{2\ \pi.CL.R_{ISO}} \cdot = \frac{1}{2\ \pi\ .\ 300nF\ .\ 6{,}5\ \Omega} \cdot = 74\ kHz$$

For the pole Fp we need the dynamic output impedance Ro of the amplifier. The Ro is always a low value of 1 to 50 ohm; for the theoretical calculation we take a value of Ro ≈ 40 Ω.

The Fp is then

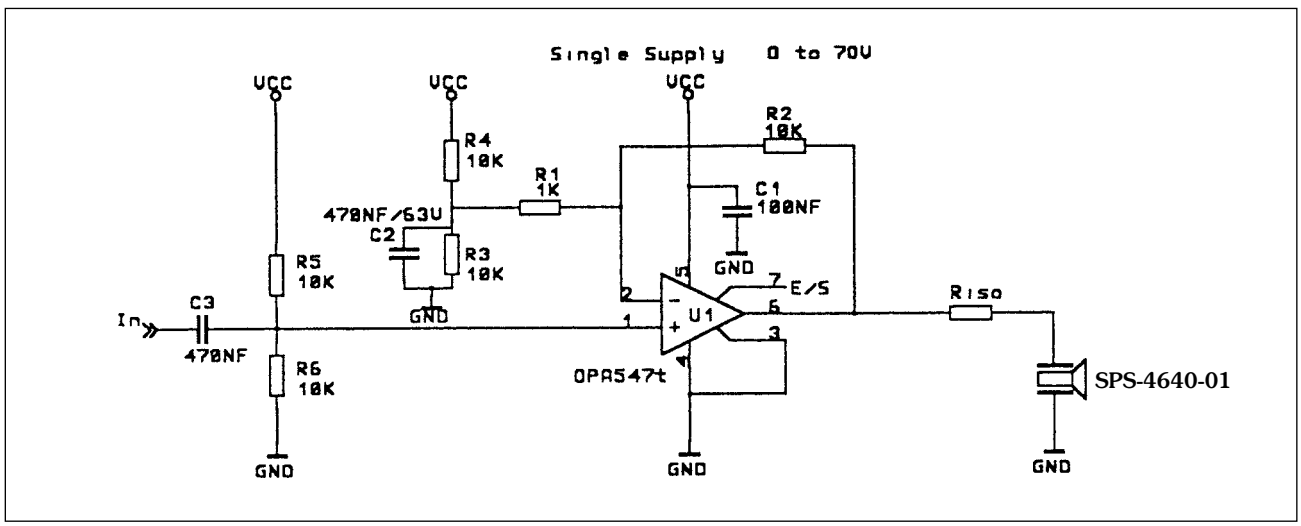
$$Fp = \frac{1}{2\ \pi\ .\ CL\ .\ (\ Ro + R_{ISO})} \cdot = \frac{1}{2\ \pi\ .\ 300nF\ .\ (40\ \Omega + 6{,}5\ \Omega)} \cdot = 11\ kHz$$

The phase improvement is:

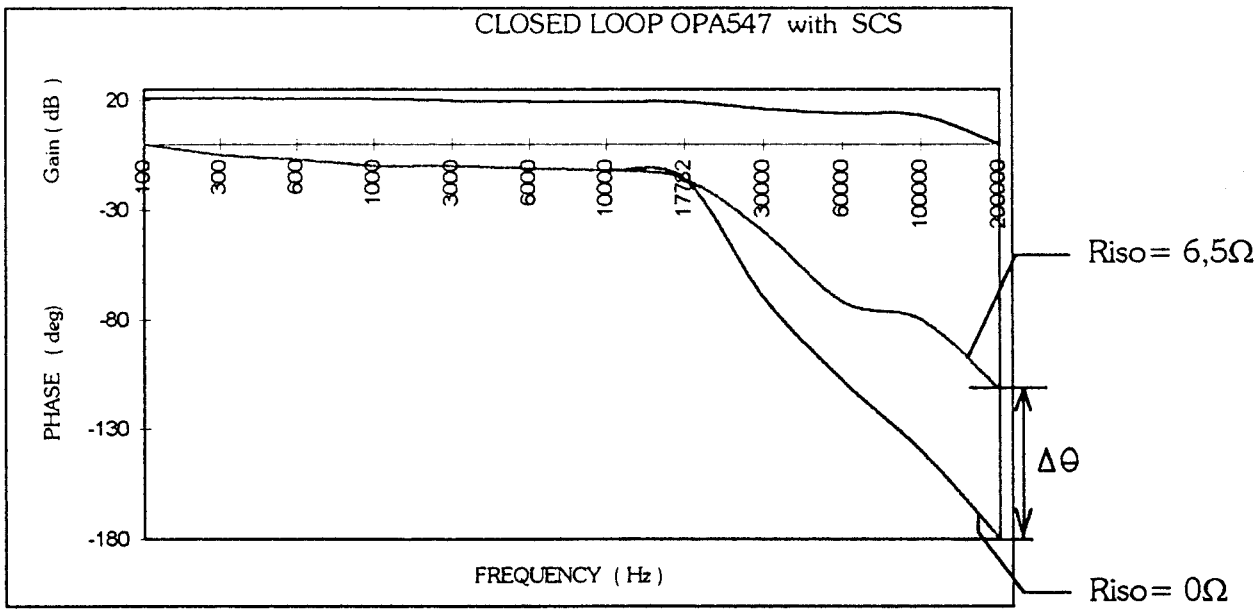
$$\Delta Y = \tan^{-1}(\ 2\ \pi\ .\ UGBW\ .\ R_{ISO}\ .\ CL\ )$$

$$\Delta Y = \tan^{-1}(\ 2\ \pi\ .\ 1MHz\ .\ 6{,}5\ .\ 300nF\ ) = 86\ degrees.$$

The SPS-4640-01 with a R_{ISO} of 0 Ω and 6,5 Ω was driven as illustrated here below:



In practice the closed loop for a OPA547t with and without a RISO is shown below:



The closed loop gain of 20log11= 21dB is nearly equal with or without R_{ISO}. The Fp at 11 KHz is shown. Because of the low value of R_{ISO} this roll-off point is almost the same with and without R_{ISO}, but the Fz we create with R_{ISO} at about 74 kHz is an improvement for the stability: the improvement of the phase margin ΔY is ≈ 68 deg.

The dissipation in the isolation resistor R_{ISO} is very small because of the low value of the R_{ISO} and the low current drain of the piezo speakers.

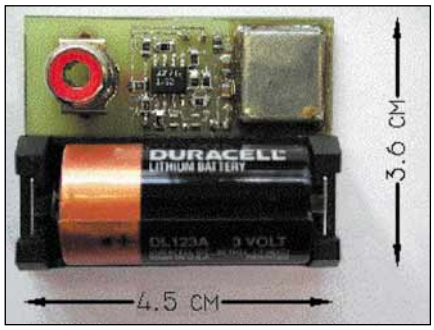
2.9.6. LOW VOLTAGE PIEZO AUDIO AMPLIFIER (ref. PAA110-60-4435)

2.9.6.1. Description

The following design is especially developed to drive piezo speakers. It consists of a DC-DC upconverter that generates the high voltage, and a full bridge audio amplifier. The DC-DC upconverter can operate from 3V to 10V power supply. The audio amplifier has a standard 1Vrms audio input. By using a full bridge audio amplifier, the drive signal for the piezo speaker can go up to 60Vptp.

2.9.6.2. Specifications

DC-DC upconverter
- 1.4MHz switching frequency that is why tiny capacitors and an inductor can be used
- wide supply voltage range: 3V to 10V
- high output voltage: up to 34V
- low shutdown current: <1µA
- very small dimensions: 13.2mm x 18.2mm (L x W)

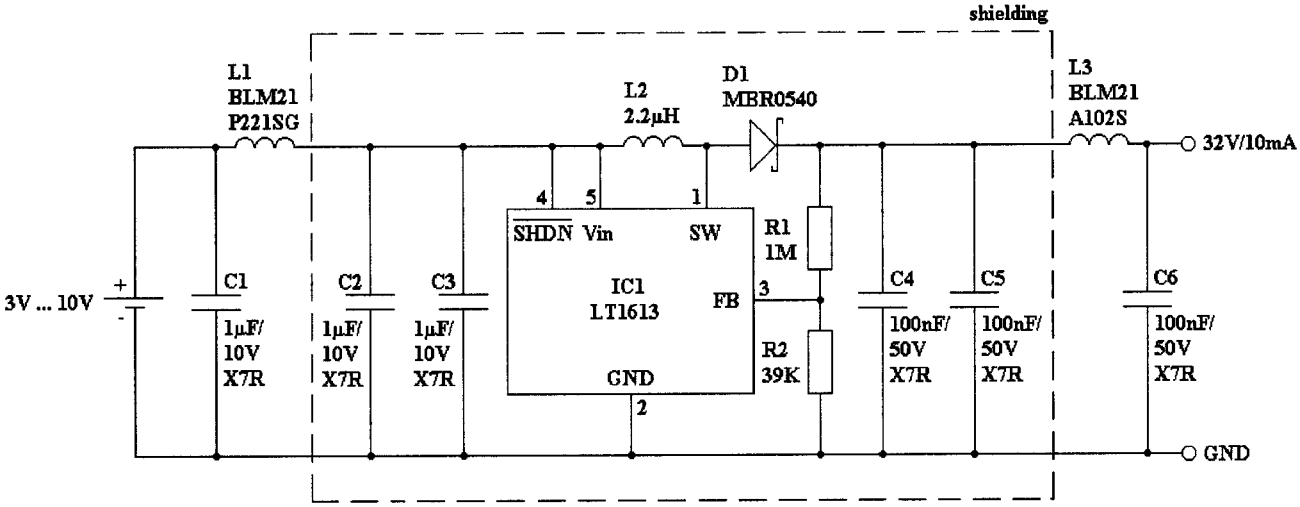


Audio amplifier
- max. output voltage: 60Vptp
- low quiescent current: 1.25mA
- large output drive current: 20mA
- wide supply voltage range: 2.5V to 36V
- single ended supply voltage range
- excellent slew rate vs. power: 3V/µs

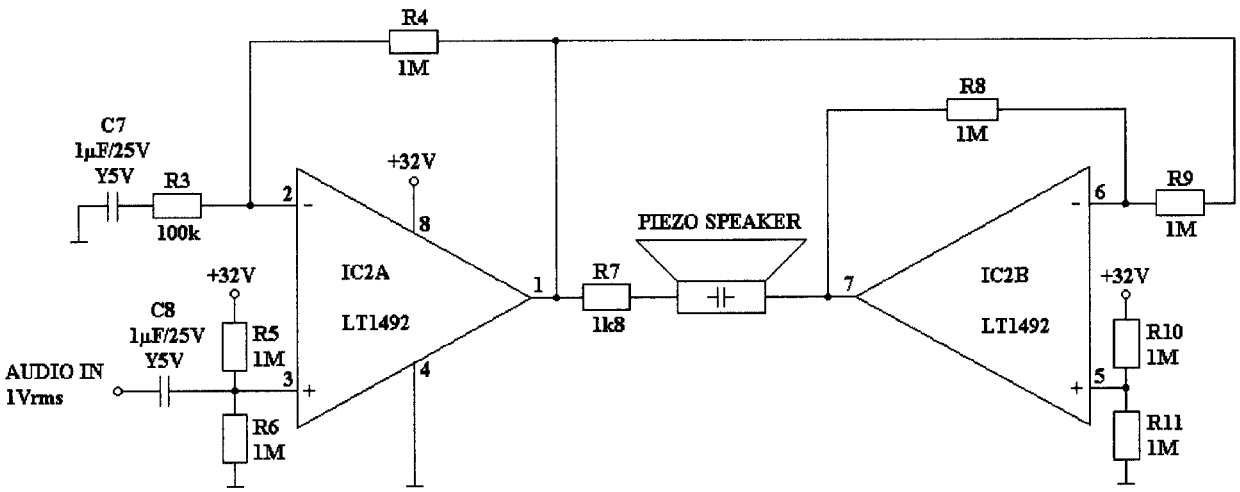
2.9.6.3. Electronic parts

Ref. Des.	Type	Description
R1,R4,R5,R6,R8,R9, R10,R11	1MΩ, 0805, 1%	chip resistor
R2	39k, 0805, 1%	chip resistor
R3	100k, 0805, 5%	chip resistor
R7	1k8, 0805, 5%	chip resistor
C1,C2,C3	1µF/10V, X7R, 0805, ±10%	chip capacitor
C4,C5,C6	100nF/50V, X7R, 0805, ±10%	chip capacitor
C7,C8	1µF/25V, Y5V, 0805, ±10%	chip capacitor
L1	BLM21P221SG	Murata EMI filter
L2	1008LS-222XKBC or C2520F-2R2K	Coilcraft inductor or Sagami inductor
L3	BLM21A102S	Murata EMI filter
D1	MBR0540T1	Motorola diode
IC1	LT1613CS5	Linear Technology IC
IC2	LT1492CS8	Linear Technology IC

2.9.6.4. Scheme

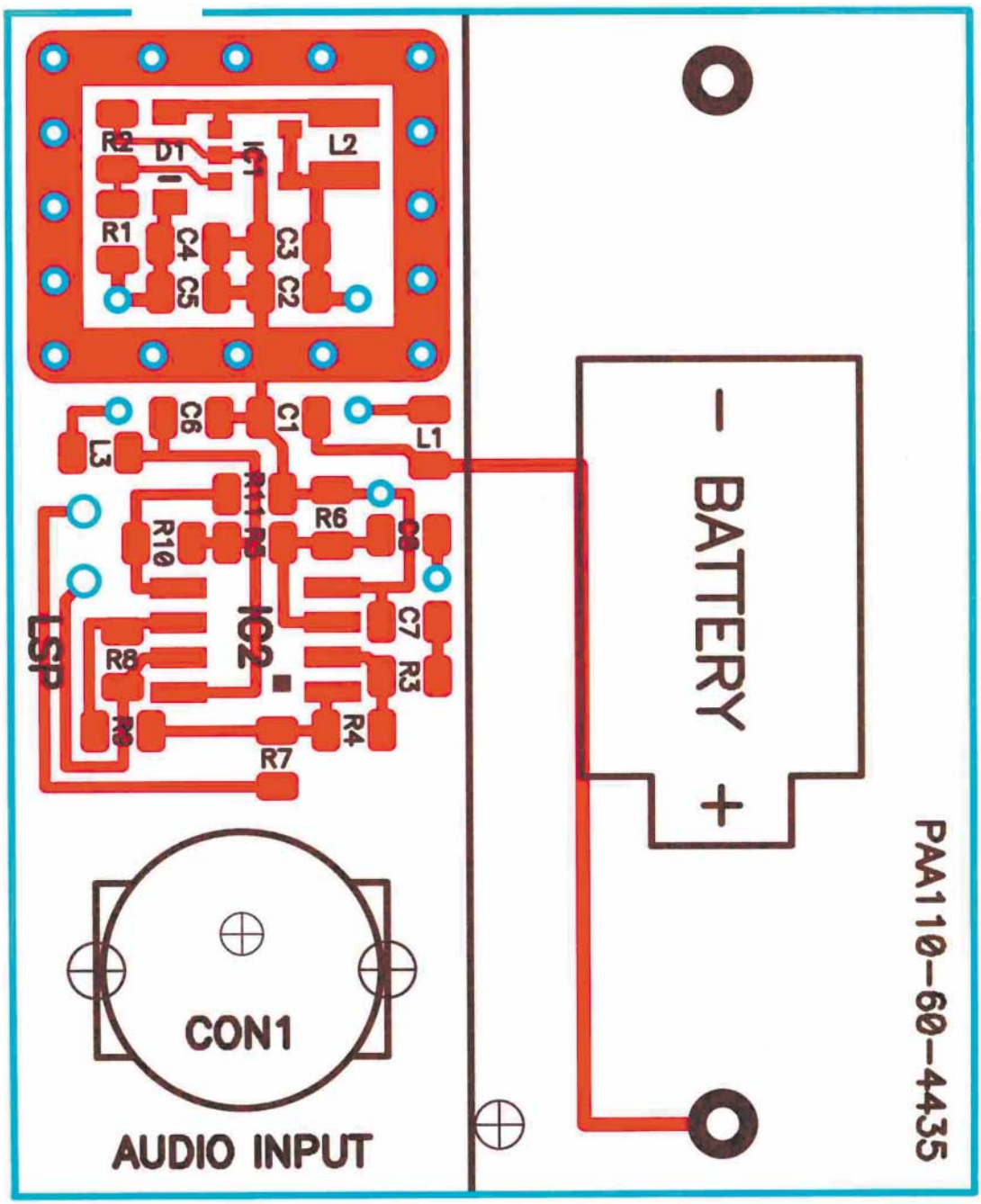


DC-DC UPCONVERTER



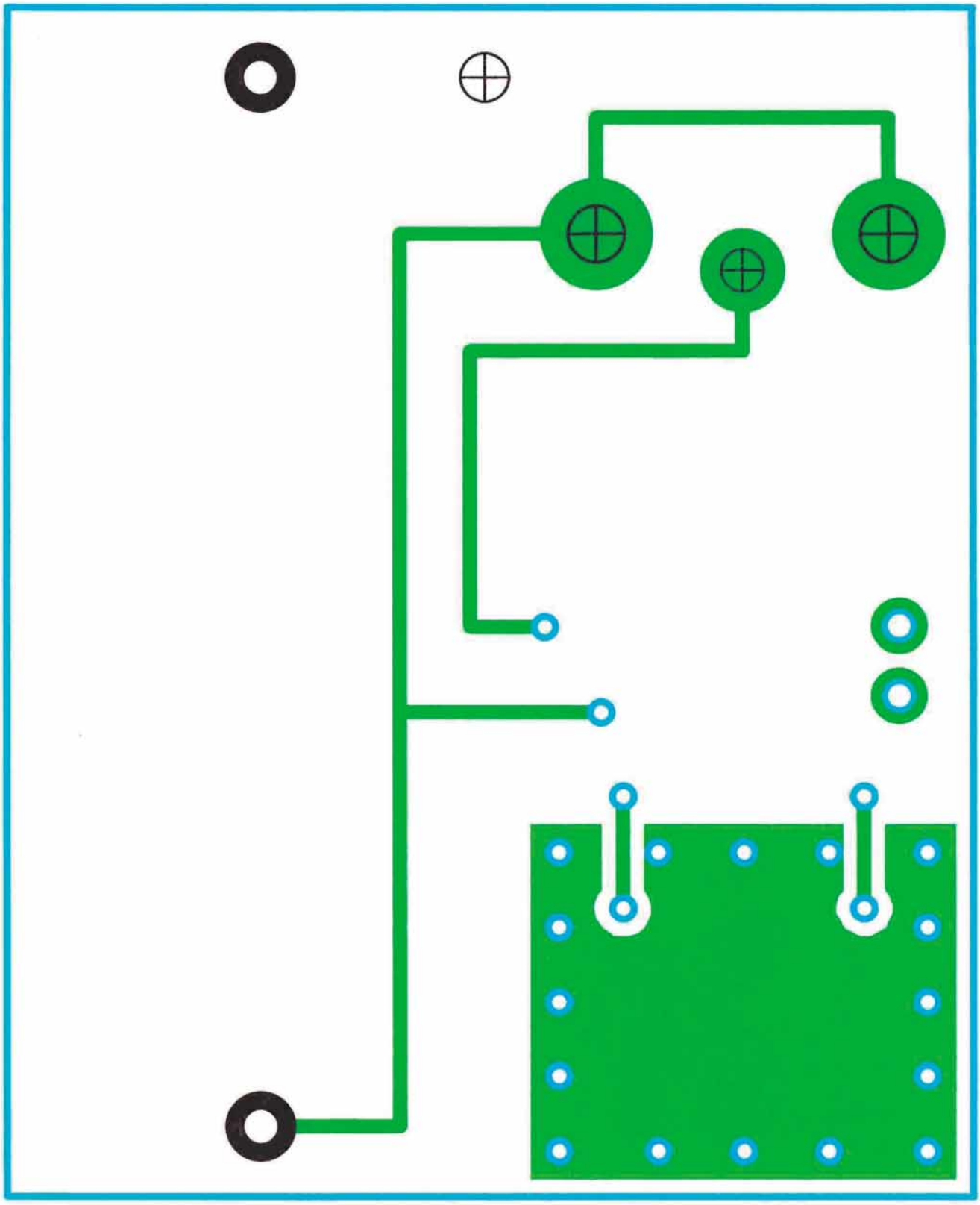
AUDIO AMPLIFIER

2.9.6.5. PCB layout of top layer



LOW VOLTAGE PIEZO AUDIO AMPLIFIER

2.9.6.5. PCB layout of bottom layer



LOW VOLTAGE PIEZO AUDIO AMPLIFIER

2.10. PACKAGING

All speakers with through hole pins are put on a board of polystyrene (245 L x 245 W) and sold in boxes with dimensions 250 L x 250 W x 125 H.

Number	SCS-17 P10	SCS-24 P10	SCS-32 P10
per board	100	81	49
per box	(5 x 100) 500	(5 x 81) 405	(5 x 49) 245

Number	SPS-4640-01 P10	SPS-8770-01 P10	SPS-10080-01 P10	SPS-30090-01
per board				
per box	On request	On request	On request	On request

All SMD models are packed in trays (245 L x 245 W) and sold in boxes with dimensions 250 L x 250 W x 125 H.

Number	SCS-17 S	SCS-24 S	SCS-32 S
per tray	81	42	25
per box	(8 x 81) 648	(5 x 42) 210	(6 x 25) 150

Number	SPS-4640-01 S	SPS-8770-01 S	SPS-10080-01 S
per tray			
per box	On request	On request	On request

The dimensions of the tray and position of the SMD components of the model SCS-17- S are illustrated below: