APPLICATION NOTE 4320

Reference Design for a Class-D, 2.1 Channel, Audio Amplifier for an MP3 Player Docking Station

Abstract: This reference design demonstrates the use of the MAX9736 Class D audio amplifier in a stereo audio, docking station application. The MAX9736 2.1 demo box is a complete powered speaker dock that uses two MAX9736 ICs to drive a 3-channel speaker system consisting of two 2in satellite speakers and one 5in subwoofer. The reference design is intended to be used with a portable audio player as its main music source. The overall solution size is very compact and features active equalization, power-supply monitoring, and dynamic equalization for the subwoofer.

Important Design Features

- Compact all-in-one design
- Operates from a single 12V to 20V DC power supply
- High SPL output from a small box
- High-efficiency Class-D design
- Active EQ, including dynamic bass equalization
- Excellent sound quality from cost-effective drivers

Bill of Materials

Designator	Qty	Description
C1	1	470µF ±20% 25V aluminum electrolytic capacitor Panasonic® EEU-FM1E471
C2, C12, C310	3	0.1µF ±10% 50V X7R ceramic capacitor (0603) Murata® GRM188R71H104K TDK C1608X7R1H104K
C321	1	1µF (0603)
C16	1	10µF (1206)
C106, C109–111, C114, C206, C209–211, C214	10	NS (0603)
C3–5	3	0.1µF ±10% 16V X7R ceramic capacitor (0603) Murata GRM188R71C104K TDK C1608X7R1C104K
C13	1	0.1µF (0603)
C316–317	2	0.1µF (0805)
C303	1	0.33µF (0603)
C302	1	0.47µF (0603)
C305, C307	2	100nF (0603)
C103–104, C203–204, C301	5	100pF (0603)
C121, C220–221, C120, C314–315	6	100pF (0603)
C117–119, C217–219	6	10nF (0603)
C107, C207	2	150pF (0603)
C306, C308	2	15nF (0603)
C6–10, C15, C313, C318–320	10	1µF ±10% 16V X7R ceramic capacitor (0603) Murata GRM188R71C105K TDK C1608X7R1C105K
C312, C14, C311	3	1µF (0603)
C216, C116	2	1µF (0805)

C100–101, C200–201	4	2.2µF (0805)
C304	1	2.2µF (0805)
C102, C108, C112, C115, C202, C215, C300	7	33pF (0603)
C208, C212	2	33pF (0603)
C322	1	33pF (0603)
C113, C213	2	4.7nF (0603)
C105, C205	2	68nF (0603)
C11, C309	2	220µF ±20% 35V aluminum electrolytic capacitor (10mm x 12.5mm) Panasonic EEUFM1V221
J30	1	4-pin header HIROSE DF3A-4P
L100–101, L200–201, L300–301	6	Ferrite bead (1206)
FB1	1	Ferrite bead (1206)
J3	1	6-pin header
J10, J20	2	2-pin header HIROSE DF3A-2P
J2	1	RCA® dual jack PCB mount
D1	1	LED red (0603)
D5	1	LED blue (0603)
Q2	1	Transistor NPN (SOT23) Fairchild MMBT3904
X1–2	2	Connector, screw mount
R7	1	Potentiometer 100K SMT
R303	1	Potentiometer 20K SMT
J1	1	Power jack, right angle Switchcraft® 722RA
R1	1	10kΩ ±5% resistor (0805)
R110, R210	2	NS resistor (0603)
R111, R211	2	10.5kΩ ±5% resistor (0603)
R100, R200	2	100Ω ±5% resistor (0603)
R10	1	100kΩ ±1% resistor (0603)
R106, R108, R206, R208	4	10kΩ ±5% resistor (0603)
R300–301	2	10kΩ ±5% resistor (0603)
R2–3	2	10kΩ ±1% resistor (0603)
R113, R213	2	11kΩ ±5% resistor (0603)
R309, R311–312, R314	4	11kΩ ±5% resistor (0603)
R306	1	12kΩ ±5% resistor (0603)
R114, R214	2	137kΩ ±5% resistor (0603)
R305	1	14.7kΩ ±5% resistor (0603)
R112, R212	2	150Ω ±5% resistor (0603)
R317	1	1kΩ ±5% resistor (0603)
R107, R109, R207, R209	4	1MΩ ±5% resistor (0603)
R8–9, R315–316	4	2.2kΩ ±5% resistor (0603)
R101–102, R201–202	4	20kΩ ±5% resistor (0603)
R5	1	220Ω ±5% resistor (0603)
R310, R313	2	24.3kΩ ±5% resistor (0603)
R302	1	2kΩ ±5% resistor (0603)
R308	1	3.24kΩ ±5% resistor (0603)
R307	1	3.3kΩ ±5% resistor (0603)

R115, R215	2	30.1kΩ ±5% resistor (0603)
R4	1	4.22kΩ ±1% resistor (0603)
R103–104, R203–204	4	40kΩ ±5% resistor (0603)
R304	1	7.15kΩ ±5% resistor (0603)
R105, R205	2	0Ω resistor (0603)
D6	1	Diode, dual, common-cathode (SOT-23-3) Fairchild MMBD4148CC
D2–3	2	Zener diode 4.3V, 20mA (SOT-23) Central CMPZ5229B
SPK1, SPK2	2	2in full-range loudspeaker Tymphany® 830970
SPK3	1	5.25in subwoofer loudspeaker Tymphany 830945
U1	**1**	**Maxim® MAX9736BETJ+ (7mm x 7mm, 32-pin TQFN)**
U2	**1**	**Maxim MAX9736AETJ+ (7mm x 7mm, 32-pin TQFN)**
U3–5	**3**	**Maxim MAX4234 (TSSOP-14)**
U6	**1**	**Maxim MAX809_EUR-T (SOT-23)**
U7	**1**	**Opto-FET (DIP6-SMT) Fairchild™ H11F1SM**

Detailed Design Description

The reference design consists of a single, carefully tuned box enclosure containing all of the electronics and speaker hardware. Only an external power supply and a signal source are required to complete the system.

The design features two 2in loudspeaker drivers for the left and right channels, and a 5in loudspeaker for the subwoofer. A single MAX9736B is used in stereo mode for the left/right channels and a MAX9736A is used in mono mode for the subwoofer channel. The detailed description here is divided into two sections: electronic circuit description and speakers/physical enclosure description.

Electronic Circuit Description

The electronics of the reference design comprise two sections: the left/right and subwoofer. Each section has three stages: input, EQ, and power. See **Figure 1**.
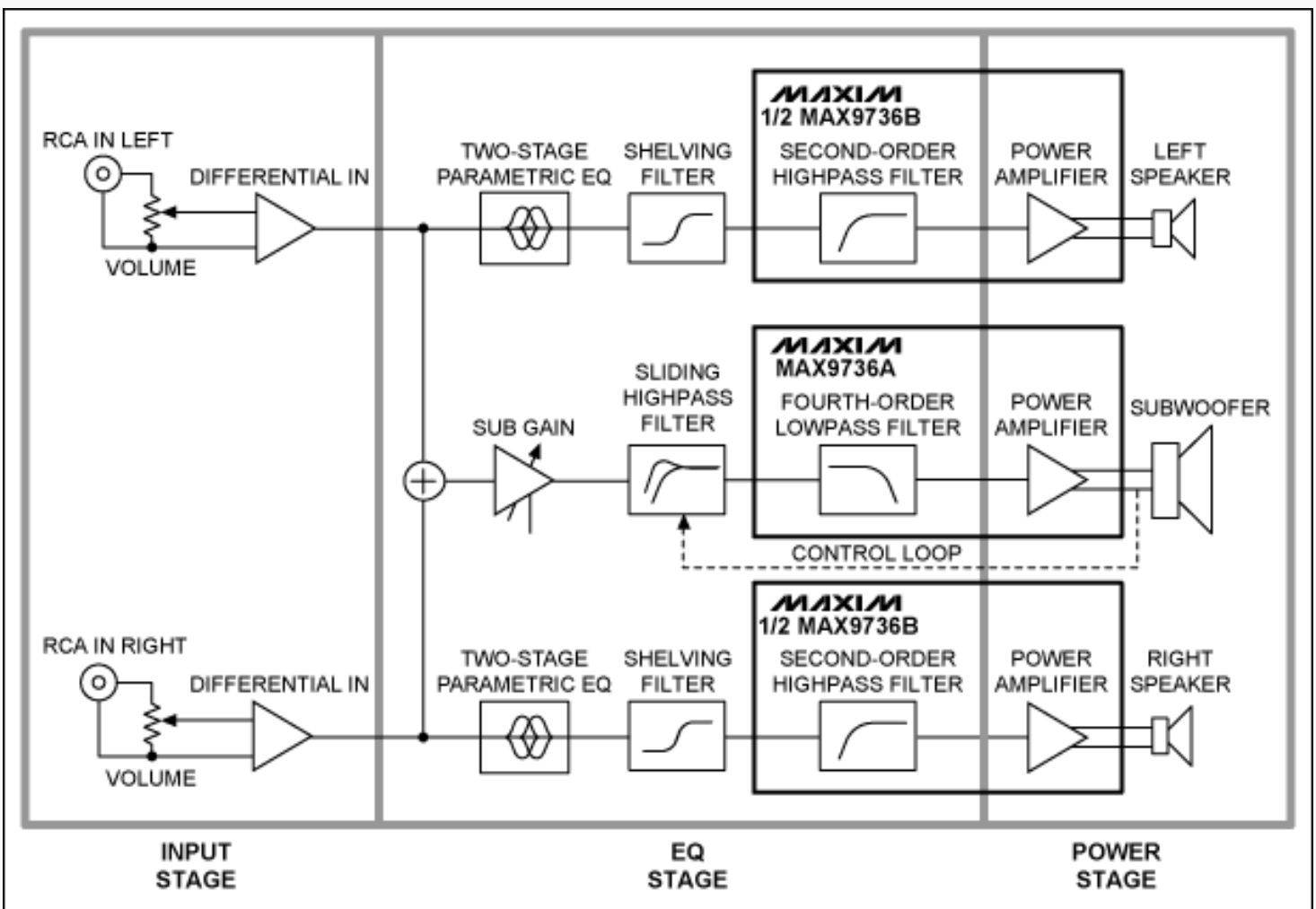
Figure 1. Electrical circuit block diagram features the MAX9736 Class D audio amplifier. The design has an input, EQ, and power stage.

Input Stage

The input stage is common to both the left/right and subwoofer sections. A stereo, log-taper potentiometer is used as a volume control to adjust the signal level to the preamplifier. To avoid ground loops, the input is sensed differentially and the RCA input connectors are not directly connected to the system ground. A 100Ω resistor is used to reduce the common-mode voltage; U3-A and U3-D (see schematics below) perform differential-to-single-ended conversion with a gain of 2. The outputs of the input stage are referred to as V_{REF}, the reference voltage of power amplifier U2 which is buffered using U5-D.

EQ Stage

After the input stage, the left and right signals are passed to a two-stage parametric EQ built around U3-B (for left) and U3-C (for right). Each parametric EQ uses an op-amp gyrator to simulate an inductor in an LC-series resonant circuit. The series circuit has two access points for either attenuation or boost, and the access points are realized by two different capacitors. C105 and C106, for example, are the boost and attenuation points for the first parametric EQ band for the left channel. If only C106 is used (and C105 is not stuffed), the resonant circuit forms a voltage-divider in combination with the series resistor R105 (10kΩ), and the resonant frequency is attenuated. Conversely, if only C105 is used, the feedback is reduced, resulting in a boost at the resonant frequency. If neither of the capacitors is used, then the band is disabled.

The resonant frequency, f_0, can be calculated using the equation:

$$f_0 = 1/(2 \times \pi \times \sqrt{(L_0 \times C_0)})$$

Where:

$$L_0 = R108 \times C107 \times R107$$
$$C_0 = C105$$

And the Q is:

$$Q_0 = \sqrt{L_0/(C_0 \times R_0^2)}$$

A third EQ band is added that realizes a shelving filter and only needs an RC: one capacitor (C113 for boost; C114 for attenuation) and one resistor (R111).

As a stereo Class D IC, the MAX9736 also features two integrated op amps at the input. Available to use for general filtering, in this reference design those op amps are used to build a second-order highpass filter for the left/right channels. The op amps have their negative inputs and outputs accessible, so a multiple-feedback inverting filter configuration is used. C116/C216 are for blocking the DC-input voltage to reduce output offset.

Power Stage

The design features three channels of speaker power amplification. A MAX9736B is configured in stereo mode to drive the left and right speakers, and can provide 2 × 11W into 4Ω. For the third channel, a MAX9736A is configured as a mono subwoofer amplifier.

In mono mode, the two Class D outputs of the MAX9736A are connected in parallel to allow for higher output power. In mono mode the subwoofer channel can deliver 30W into 4Ω (V_{DD} = 19V). The input stage for the subwoofer channel is the same as that used for the left and right channels. After the input stage, the left and right signals are then summed using U5-B to create the mono subwoofer channel. R303 is used to set the subwoofer channel gain at the summing amp.

To enable a maximally flat response down to very low frequencies, the system is configured with a sixth-order filtered alignment for the subwoofer. This approach means that the fourth-order highpass response of the vented speaker is supplemented with a second-order electrical highpass in the active circuitry. U5-C is used to realize the noninverting Sallen-Key, second-order highpass filter for the subwoofer.

This system requires a high Q, which leads to 13dB of boost at 40Hz. To avoid overloading the speaker and amplifier, the Sallen-Key filter is set up to act as a sliding highpass; the filter acts dynamically as the amplifier output reaches its limit. The value of input resistor R305 is designed to reduce automatically (using the opto-coupled FET, U7) to a value so that the filter Q is lowered to 0.5, resulting in no boost at all.

The peak output voltage of the subwoofer amplifier, U2, controls the signal to the opto-FET. D6 and C16 form a peak detector, which senses the output peak level with a fast attack time. The operating threshold for the peak detector can be adjustable or fixed, depending on whether R7 is stuffed or R8/R9 are stuffed. The LED D5 turns on when this control circuit is active.
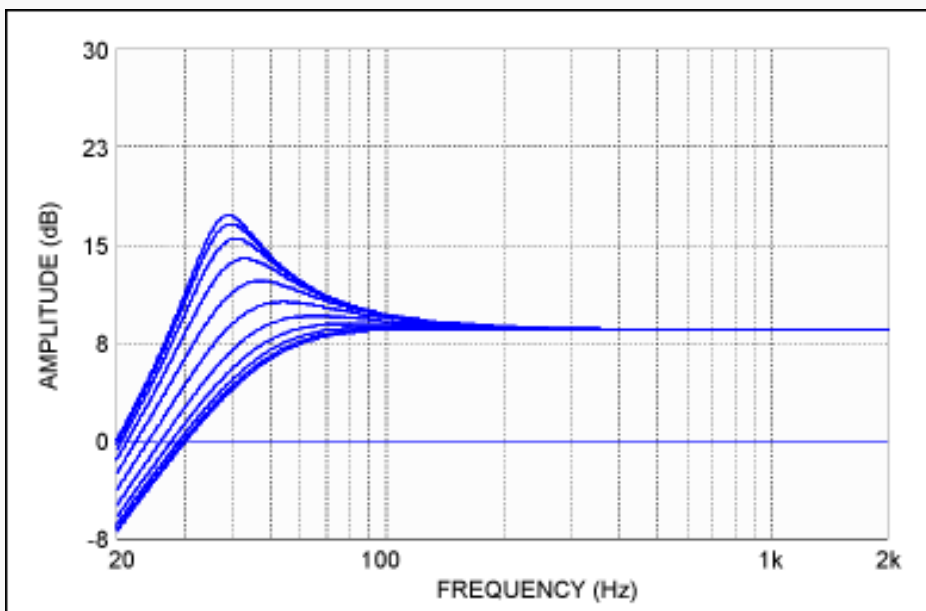
Figure 2. Simulation results of the dynamic bass boost from the subwoofer channel. The Q of the highpass filter is reduced while the cutoff frequency is also increased, as the subwoofer level approaches its limit.

The two op amps built into the MAX9736A are configured into a fourth-order lowpass subwoofer filter that complements the highpass filter used for the left/right channels.

J1 is the power-supply input connector chosen to be a standard laptop-type coaxial socket. A typical laptop power supply has an average output voltage of around 19V and serves as a good power source for the docking system. After some filtering through C1 and C2, the voltage is labeled PV_{DD} and D1 is set to light blue when power is attached.

A simple reset circuit (through U6) is used to create a mute signal on power-up and power-down for both amplifier chips. This step avoids output transient noises due to input circuitry settling. The mute control threshold is programmed to approximately 10V with the R3 and R4 resistor-divider.

The MAX9736 features a filter-less modulation method which eliminates the need for bulky inductor-based filters. Only simple ferrite beads (L100 to L301) are required at the output.

Speakers and Physical Enclosure

The loudspeaker used for the subwoofer is a 5in-diameter model from Tymphany, part 830945, with a 4Ω nominal impedance and a resonance frequency of 47.4Hz. The 2in loudspeakers used for the left and right channels are model 830970, also from Tymphany. These loudspeakers have 4Ω nominal impedance and a resonance frequency of 147.5Hz.

A low f_3 of 35Hz is targeted for the acoustic system, so a sixth-order alignment is used. That alignment includes a second-order highpass filter within the active crossover. The overall system is housed in a single box enclosure with the three loudspeakers, tuned port, and circuit PCB. The subwoofer is mounted as down-firing to minimize the box size and to help increase efficiency by compression loading. The resulting box volume is approximately 3.79l and the vented port is tuned to 54Hz. The outside overall box dimensions are approximately 355mm x 180mm x 120mm. The speaker crossover equalization is designed as a fourth-order Linkwitz-Riley at 250Hz; the speaker equalization for the satellites consists of a parametric EQ with f = 500Hz, gain = +6dB, Q = 0.5, and a shelving filter with f_3 = 3.8kHz and a gain of +5.8dB. **Figure 3** shows the system's response.
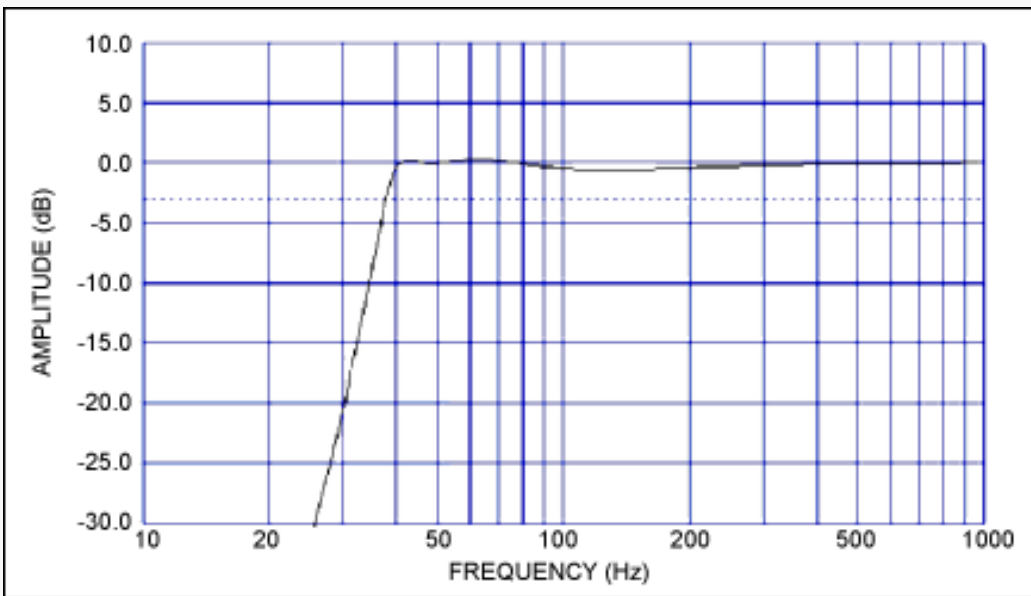
Figure 3. Total system simulated response shows maximally flat down to 40Hz.

The mechanical drawings included in this document are copies of those used to construct the prototype model. The prototype was built using 1/4in clear acrylic plastic and assembled with drilled/tapped screws and acrylic adhesive. A consumer product version might be constructed using a more cost-effective material such as wood, MDF, ABS, etc.
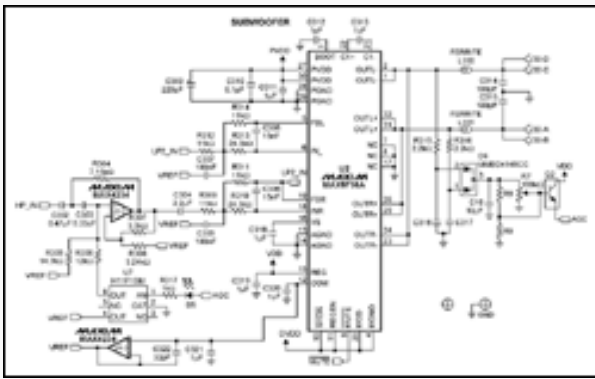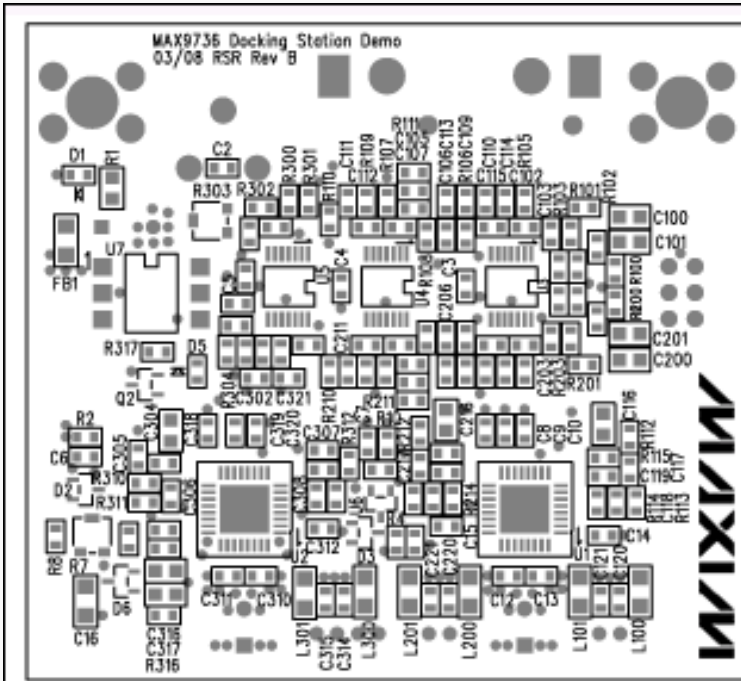
Circuit Schematics
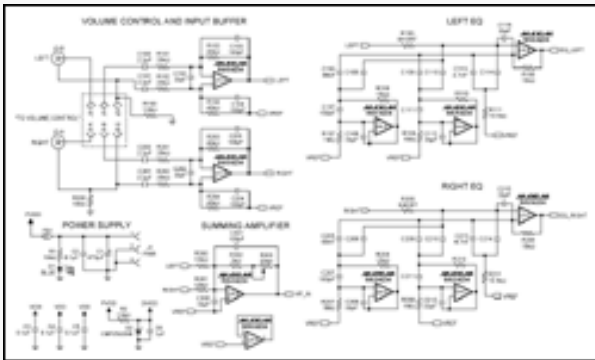
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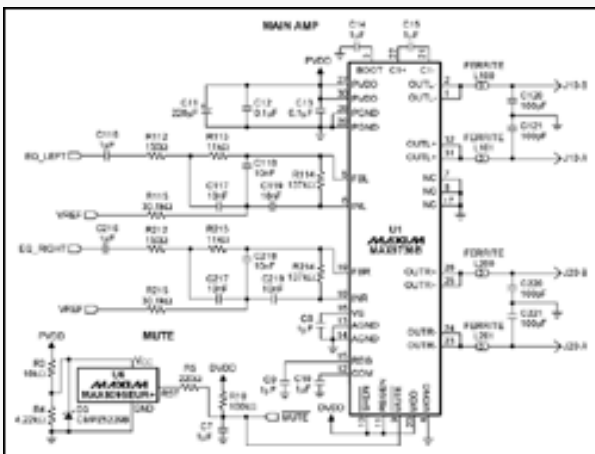
More detailed image (PDF, 84.4kB)

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PCB Layout

PCB: TOP SILKSCREEN
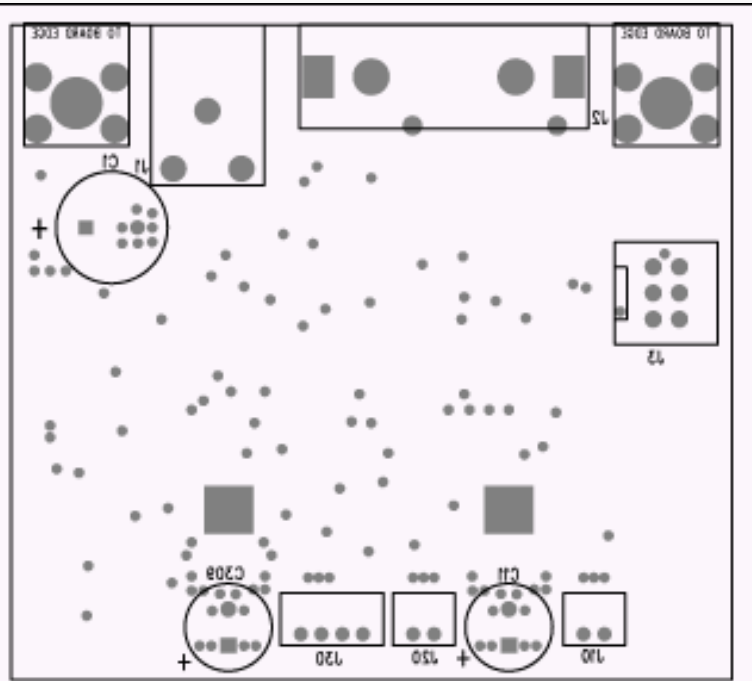
PCB: BOTTOM SILKSCREEN

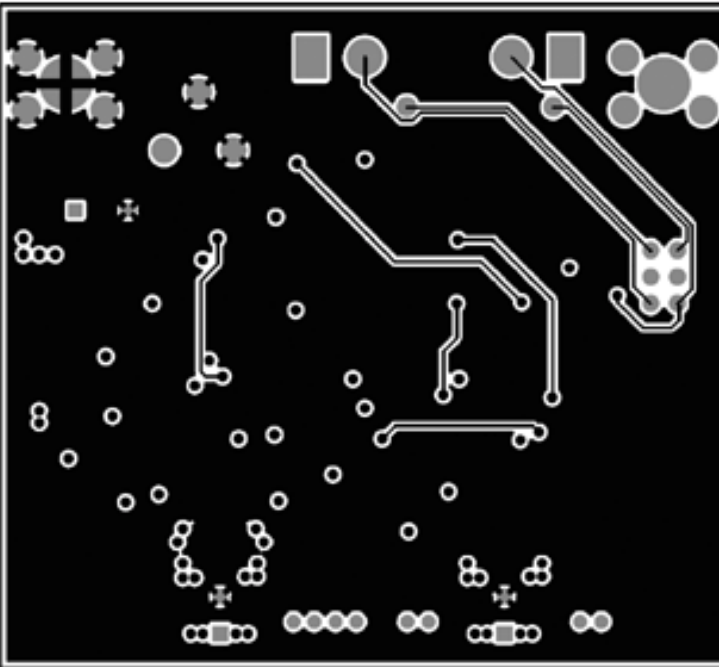[More detailed image of the Top Silkscreen](#) (PDF, 277kB)
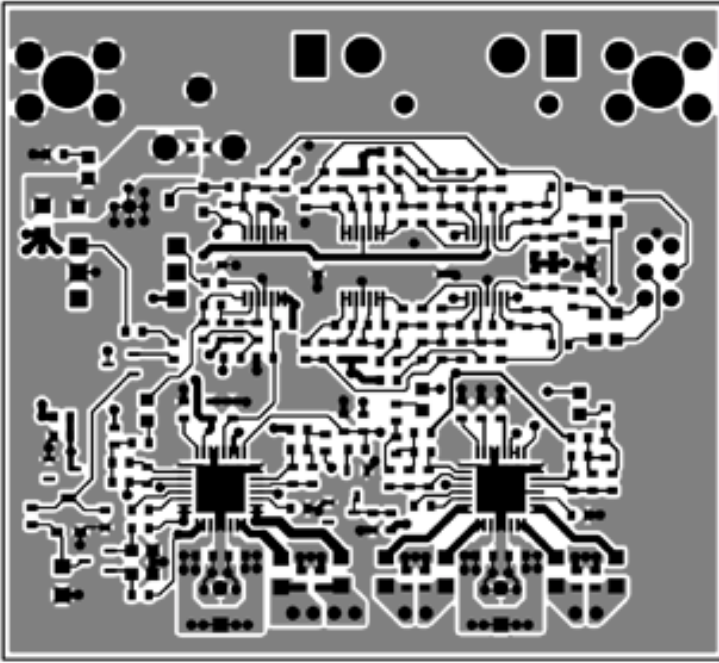
PCB: TOP SIDE
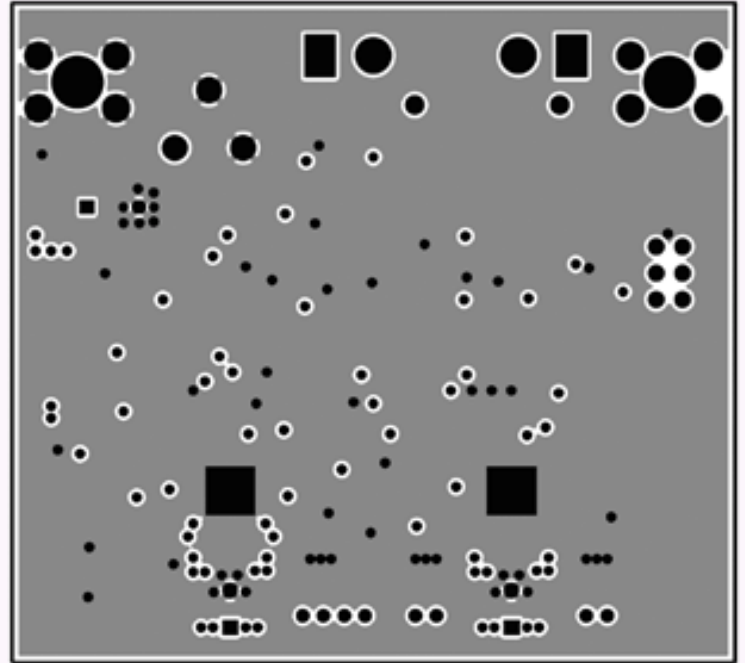
PCB: LAYER 2 - GND

PCB: BOTTOM LAYER

PCB: LAYER 3 - PWR

Mechanical Drawings

[More detailed image](#) (PDF, 72kB)

[More detailed image](#) (PDF, 56kB)
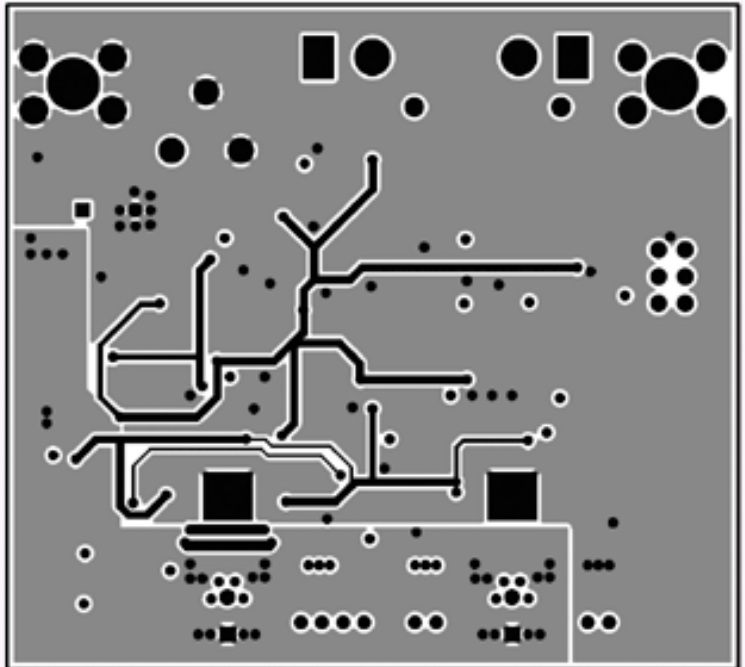
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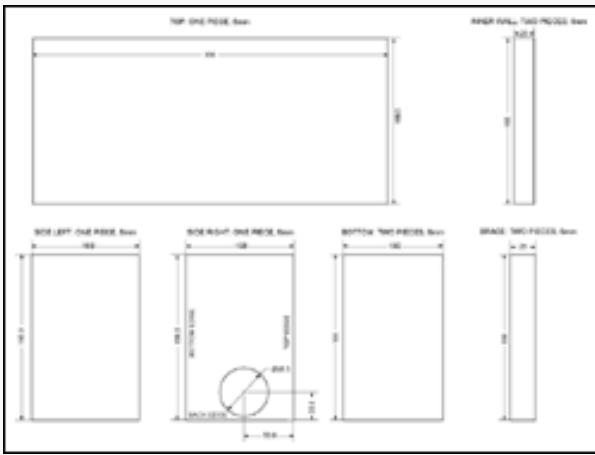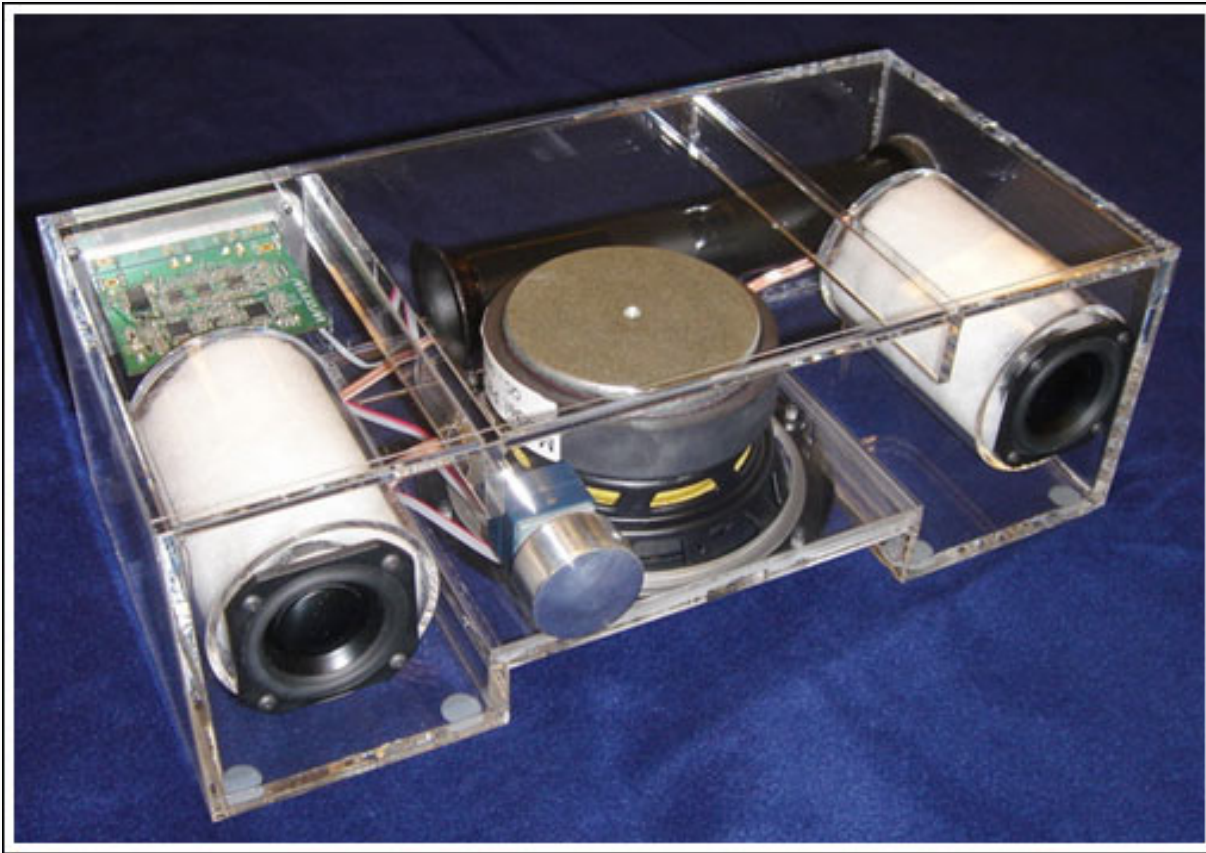
[More detailed image](#) (PDF, 48kB)

Picture of System

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Related Parts

MAX9736A: QuickView -- Full (PDF) Data Sheet
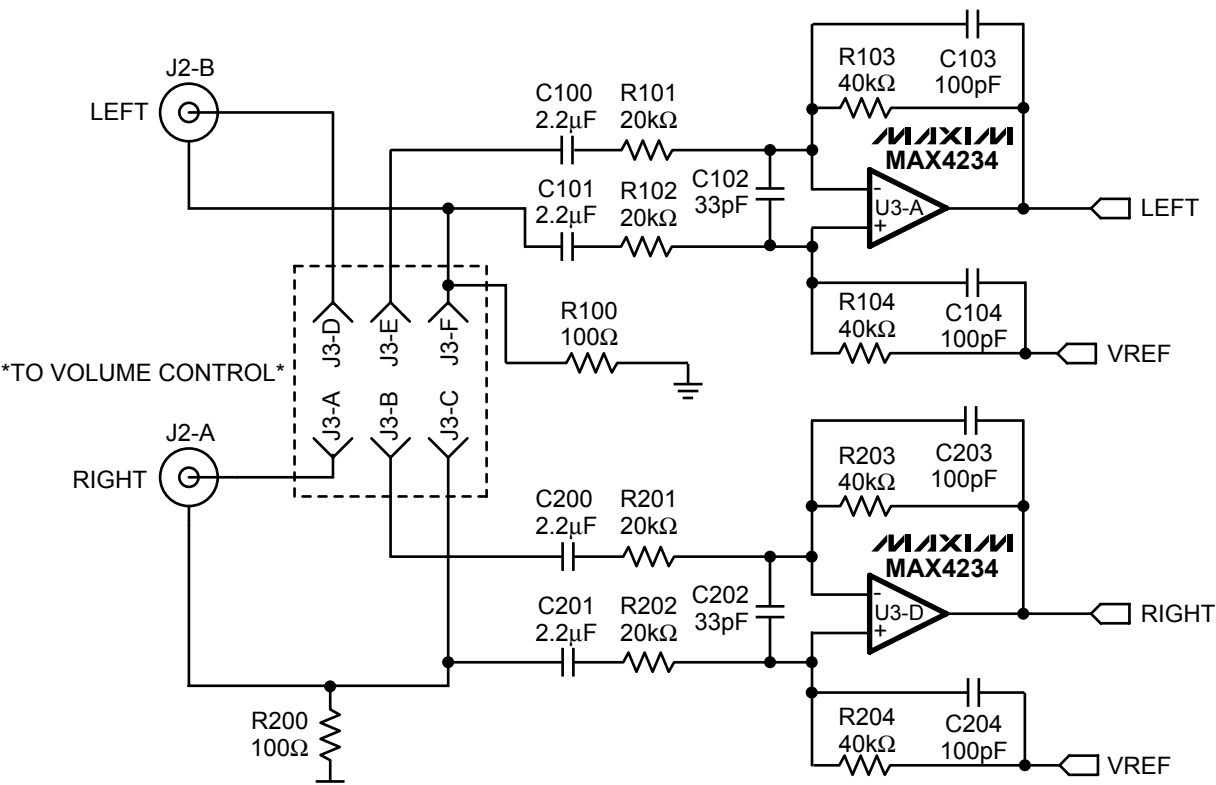
MAX9736B: QuickView -- Full (PDF) Data Sheet

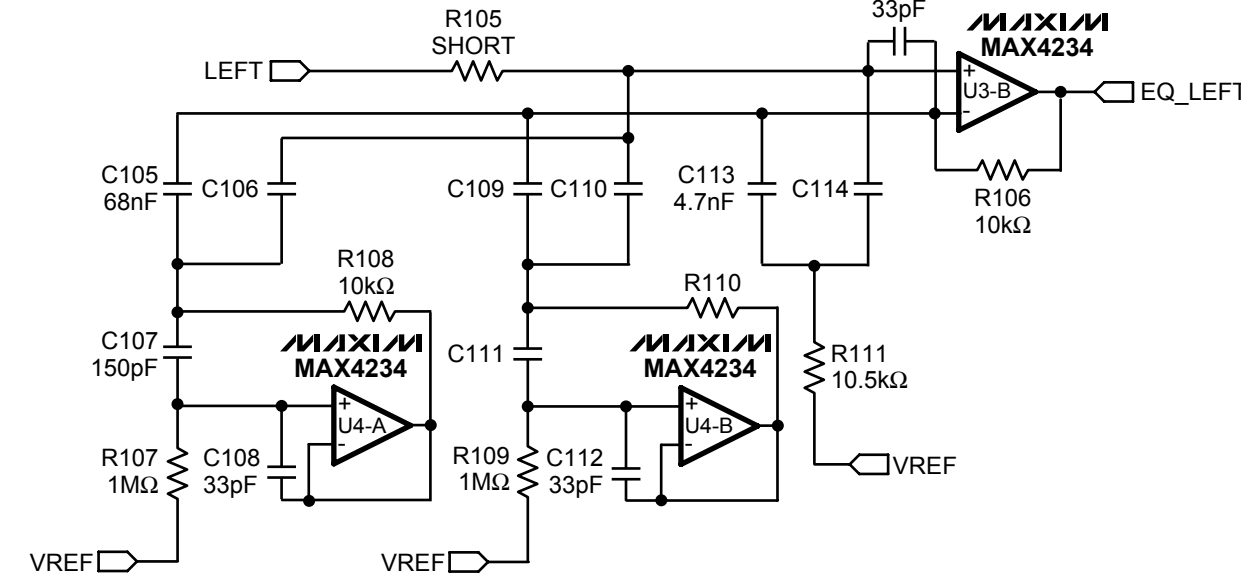AN4320, AN 4320, APP4320, Appnote4320, Appnote 4320
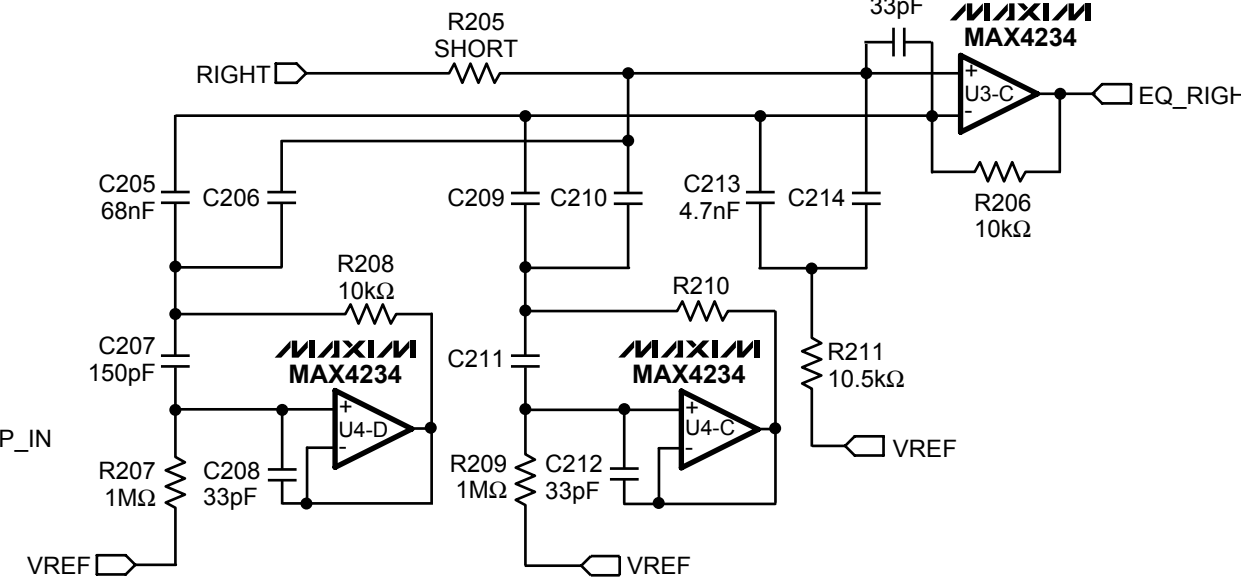Copyright © by Maxim Integrated Products
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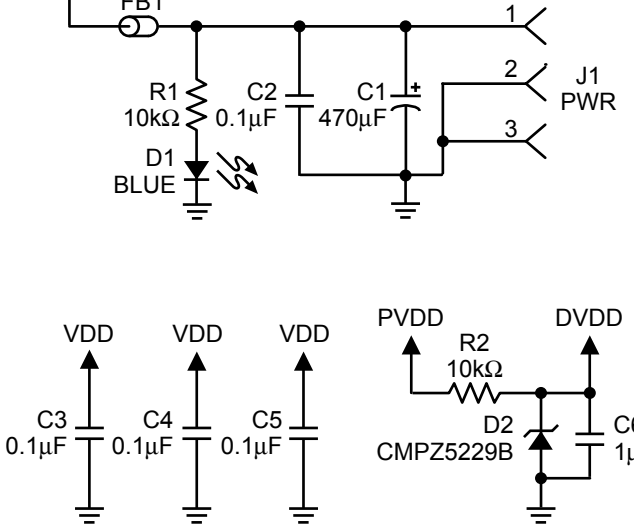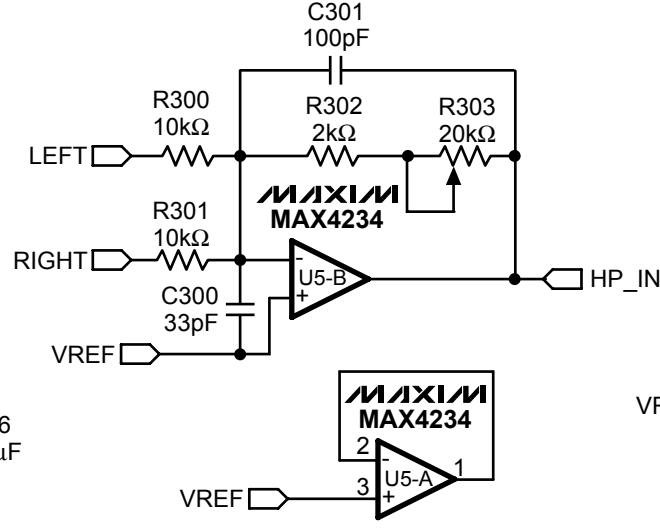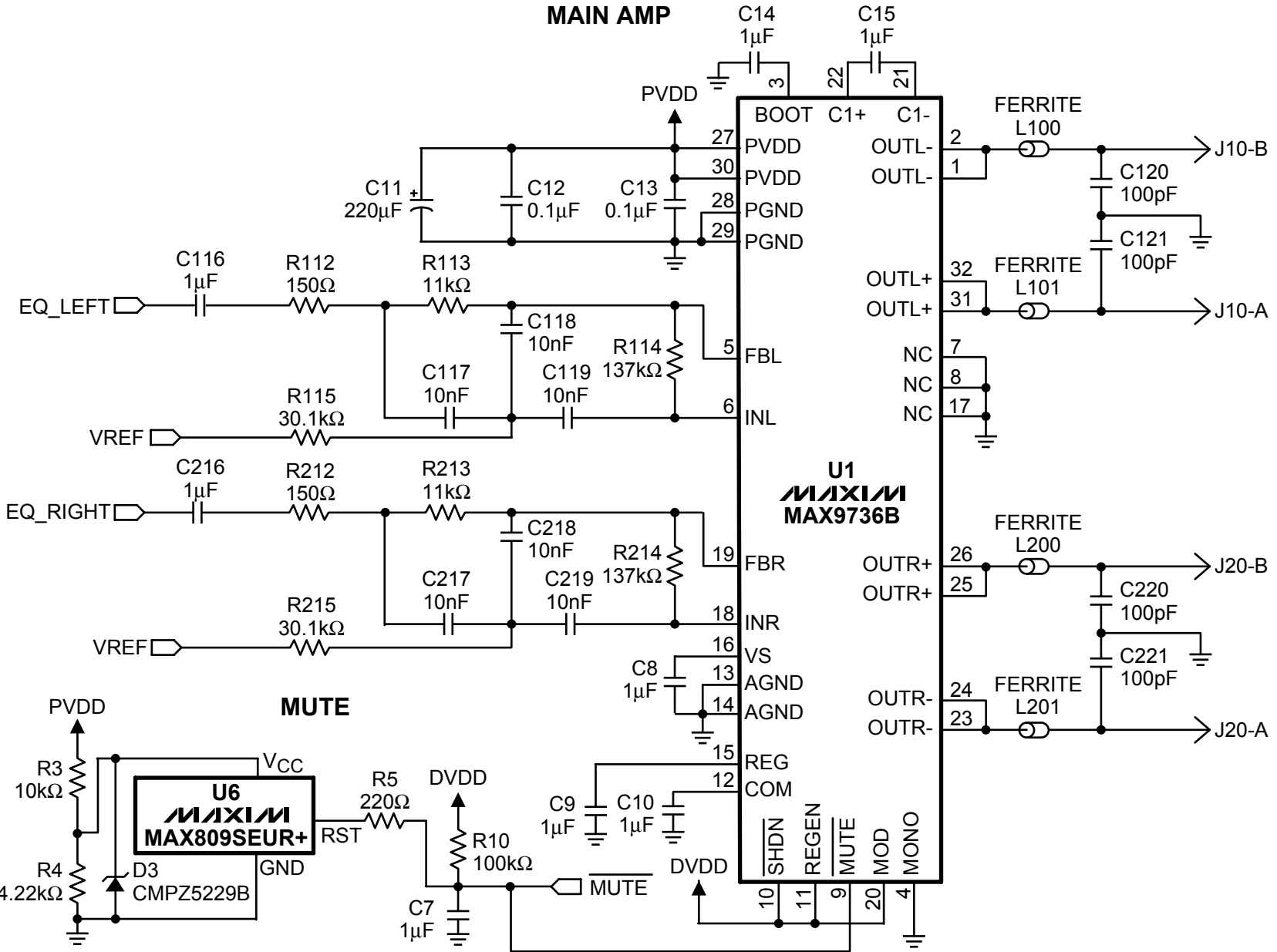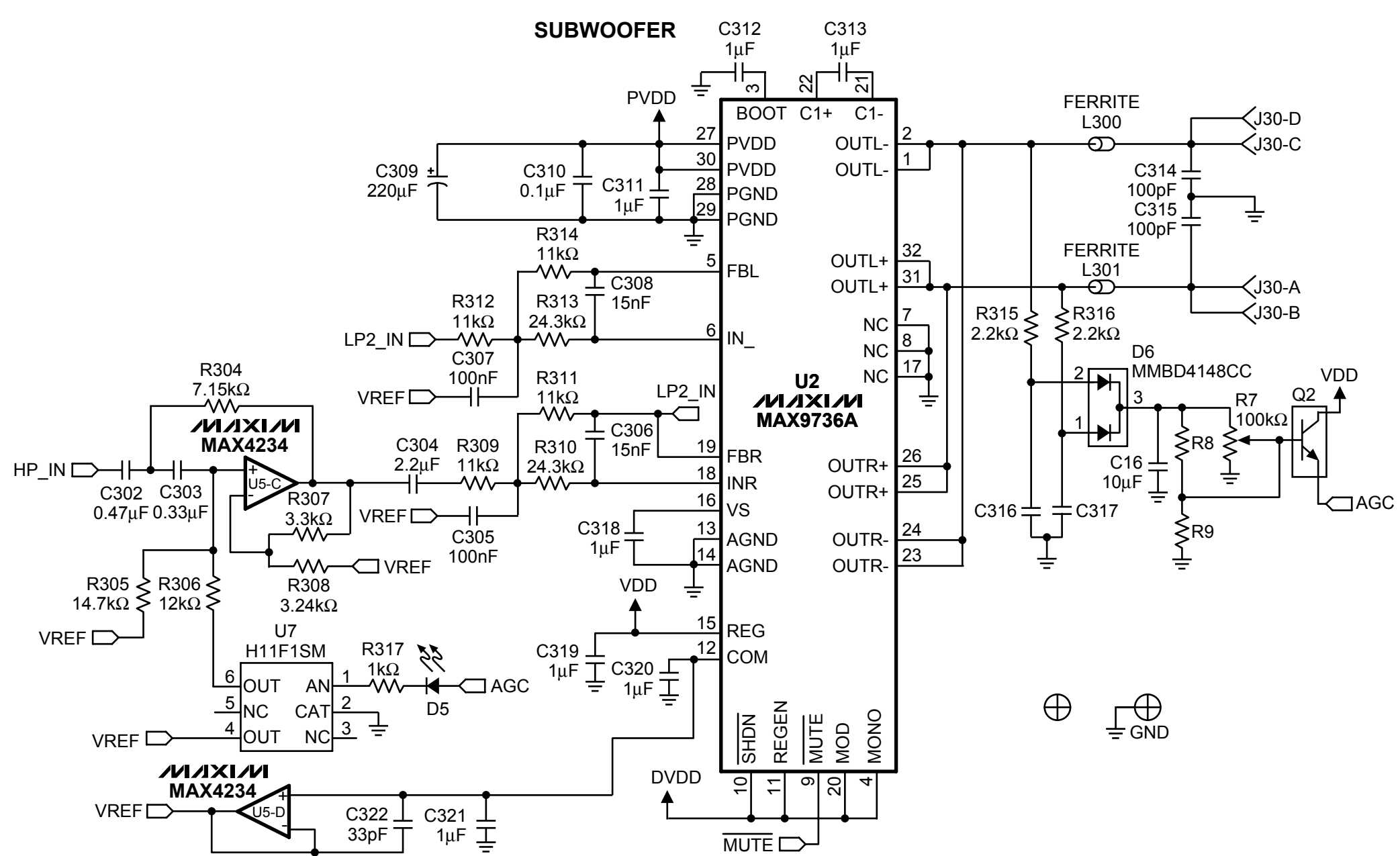
VOLUME CONTROL AND INPUT BUFFER

LEFT EQ

RIGHT EQ

POWER SUPPLY

SUMMING AMPLIFIER

MAIN AMP

C14 1µF
C15 1µF

3 BOOT
C1+
C1-

27 PVDD
30 PVDD
28 PGND
29 PGND

PVDD

C11 220µF
C12 0.1µF
C13 0.1µF

2 OUTL-
1 OUTL-
FERRITE L100
C120 100pF

32 OUTL+
31 OUTL+
FERRITE L101
C121 100pF

J10-B
J10-A

C116 1µF
R112 150Ω
R113 11kΩ

EQ_LEFT

C118 10nF
R114 137kΩ

5 FBL

C117 10nF
C119 10nF

R115 30.1kΩ
VREF

6 INL

7 NC
8 NC
17 NC

U1
MAXIM
MAX9736B

C216 1µF
R212 150Ω
R213 11kΩ

EQ_RIGHT

C218 10nF
R214 137kΩ

19 FBR

C217 10nF
C219 10nF

R215 30.1kΩ
VREF

18 INR

26 OUTR+
25 OUTR+
FERRITE L200
C220 100pF

24 OUTR-
23 OUTR-
FERRITE L201
C221 100pF

J20-B
J20-A

16 VS
13 AGND
14 AGND

C8 1µF

MUTE

PVDD

R3 10kΩ

U6
MAXIM
MAX809SEUR+
V_CC
RST
GND

R5 220Ω
DVDD

R10 100kΩ

15 REG
12 COM

C9 1µF
C10 1µF

R4 4.22kΩ
D3 CMPZ5229B

C7 1µF

MUTE

DVDD

10 SHDN
11 REGEN
9 MUTE
20 MOD
4 MONO

SUBWOOFER

C312 1µF
C313 1µF

U2 **MAXIM** MAX9736A

BOOT C1+ C1-

3 — BOOT
22 — C1+
21 — C1-

PVDD

C309 ± 220µF
C310 0.1µF
C311 1µF

27 PVDD
30 PVDD
28 PGND
29 PGND

R314 11kΩ
C308 15nF
5 FBL

R312 11kΩ
R313 24.3kΩ
6 IN_

LP2_IN
C307 100nF
VREF

R311 11kΩ
C306 15nF
LP2_IN
19 FBR

R304 7.15kΩ

MAXIM MAX4234
U5-C

HP_IN
C302 0.47µF
C303 0.33µF
R307 3.3kΩ
R308 3.24kΩ
VREF

C304 2.2µF
R309 11kΩ
R310 24.3kΩ
18 INR

VREF
C305 100nF

16 VS

C318 1µF
13 AGND
14 AGND

VDD

R305 14.7kΩ
R306 12kΩ
VREF

U7 H11F1SM

6 OUT   AN 1
5 NC   CAT 2
4 OUT   NC 3

R317 1kΩ
D5
AGC

VREF

15 REG
12 COM

C319 1µF
C320 1µF

MAXIM MAX4234
U5-D
VREF
C322 33pF
C321 1µF

DVDD

SHDN REGEN MUTE MOD MONO
10   11   9   20 4

MUTE

OUTL- 2
OUTL- 1

FERRITE L300
J30-D
J30-C
C314 100pF
C315 100pF

OUTL+ 32
OUTL+ 31

NC 7
NC 8
NC 17

FERRITE L301
J30-A
J30-B

R315 2.2kΩ
R316 2.2kΩ

D6 MMBD4148CC
2
1
3

VDD

R7 100kΩ
Q2

OUTR+ 26
OUTR+ 25

C316
C317

R8
R9

AGC

OUTR- 24
OUTR- 23

C16 10µF

GND

MAXIM

D1 R1

FB1

U7

R317 D5

Q1 Q2

R2

C6 R305 R310

D2 R311

R8 R7

D6

C16

C316
C317
R316

C2

R303 R302

C311 C310

C301
C315
C314

R300 R301

R111
R110 C111 R109
C112 R107
C107

R304 C302 C321

R304 C307

L301

L300
L30

R210 C307
R211
R10

R212

L6

L2
L3

C224
C220
C227

L201

L200
L20

R102

R300 R100

C100
C101

C201
C200

C12 C13

L101

L100
L10

MAXIM

MAXIM

FRONT VIEW

TOP

BRACE

PLATFORM

INNER WALL

BOTTOM

LEFT SIDE

RIGHT SIDE

RIGHT VIEW

TOP

PLATFORM

FRONT

REAR

BOTTOM

TOP VIEW

BRACE

TOP 70mm Ø

PIPE 70mm Ø

LEFT SIDE

RIGHT SIDE

FRONT

M3 TAPPED HOLES

	THICKNESS	QTY	WIDTH	LENGTH	HEIGHT
	mm		mm	mm	mm
TOTAL DIMENSIONS	x	x	356	178	120
FRONT	6	1	356	6	120
BACK	6	1	356	6	120
TOP	6	1	356	166	6
SIDE	6	2	6	166	108
BOTTOM	6	2	100	166	6
BRACE	6	2	6	166	25
INNER WALL	6	2	6	166	20
BRACKET	8	1	168	166	8

FRONT: ONE PIECE, 6mm

356

117.4

42

42

TOP

50mm Ø

50mm Ø

50

50

Ø8

Ø4

QTY 4 50mm HOLES WITH M3
TAP, SPACING DIAMETER 57mm,
45º OFFSET

120

Ø14

FROM INSIDE, 2mm
RECESSED CYLINDER

10

LEFT

26

156

BACK: ONE PIECE, 6mm

22

19.1

BACK

58.9

72

120.0

13

34

10.1

87.9

4 x M3 TAPPED HOLES

LEFT

356

BRACKET: ONE PIECE, 8mm

168

BACK EDGE

Ø120

61.5°   61.5°

61.5°   61.5°

166

FRONT EDGE

68

84
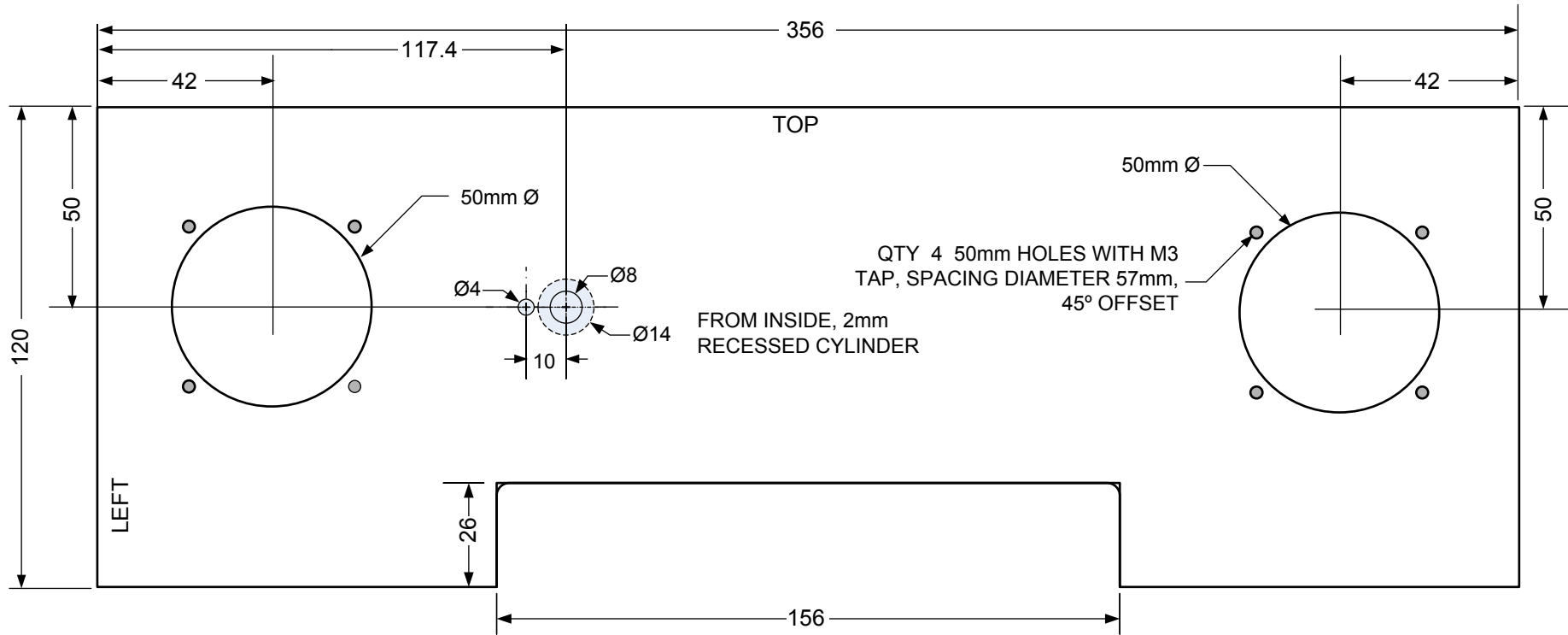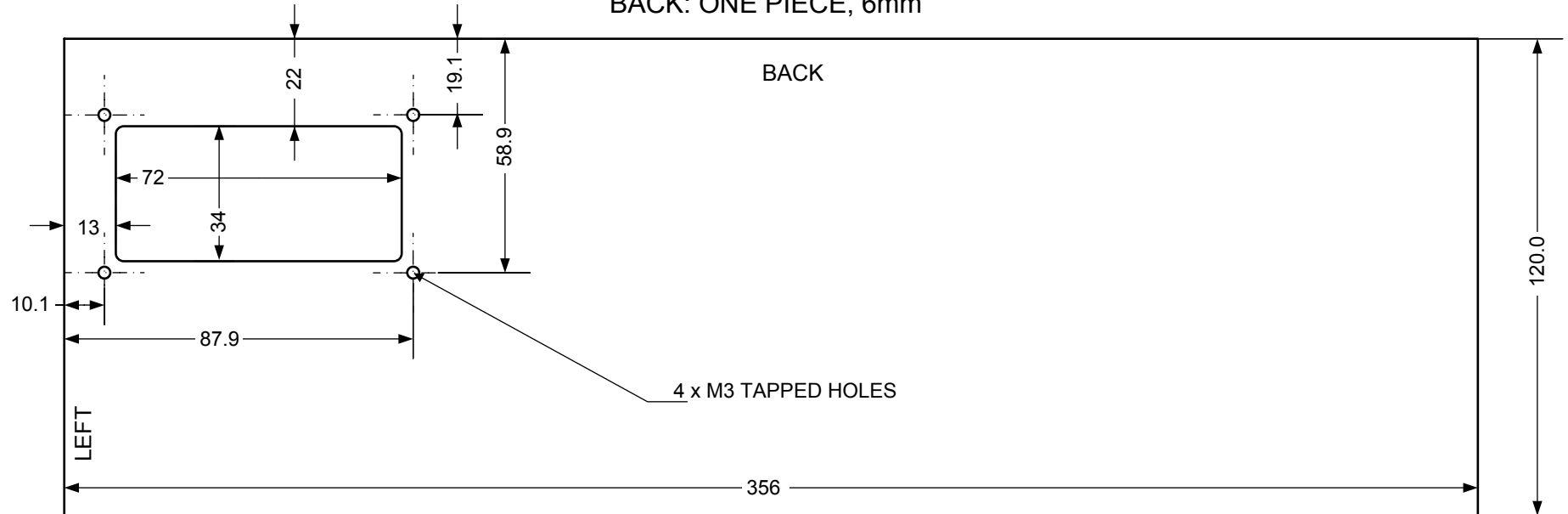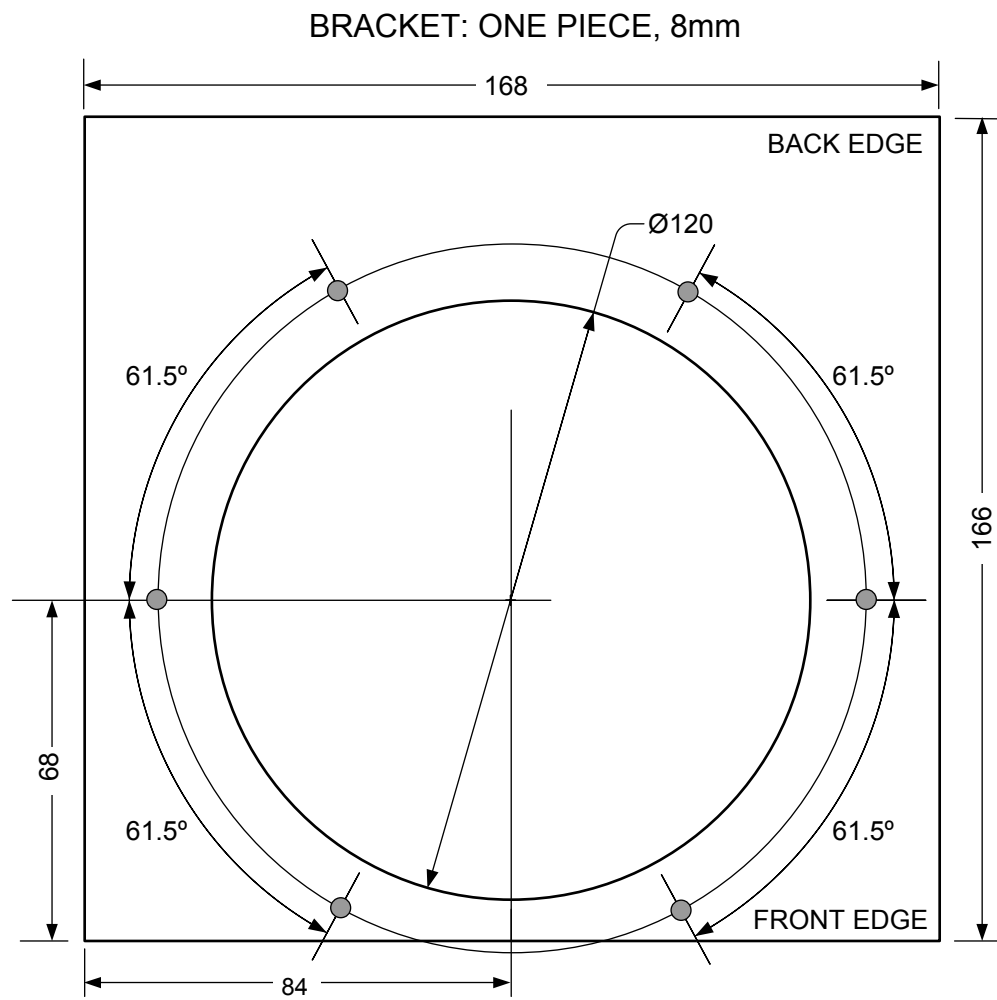
TAPPED HOLES:
QTY 6 x M4 TAPPING,
SPACING DIAMETER 142mm,
61.5°, 57°, 61.5°

END COVER: TWO PIECES, 4mm

70mm Ø

5mm Ø
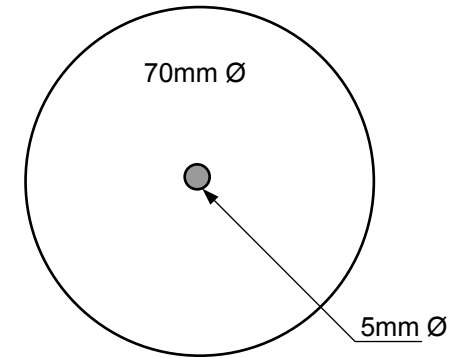
**CYLINDER: TWO PIECES,
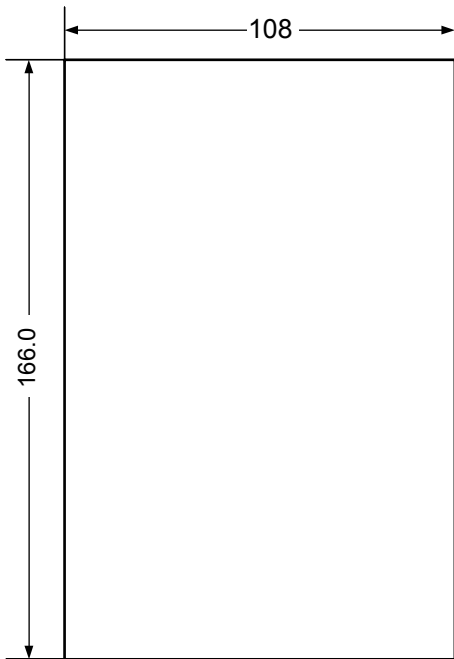70mm OUTER DIAMETER,
3mm WALL THICKNESS**

92

3mm

70.00

TOP: ONE PIECE, 6mm

356

166.0
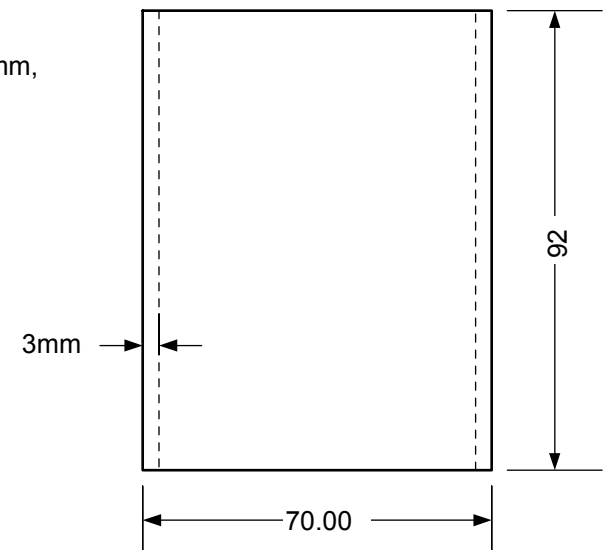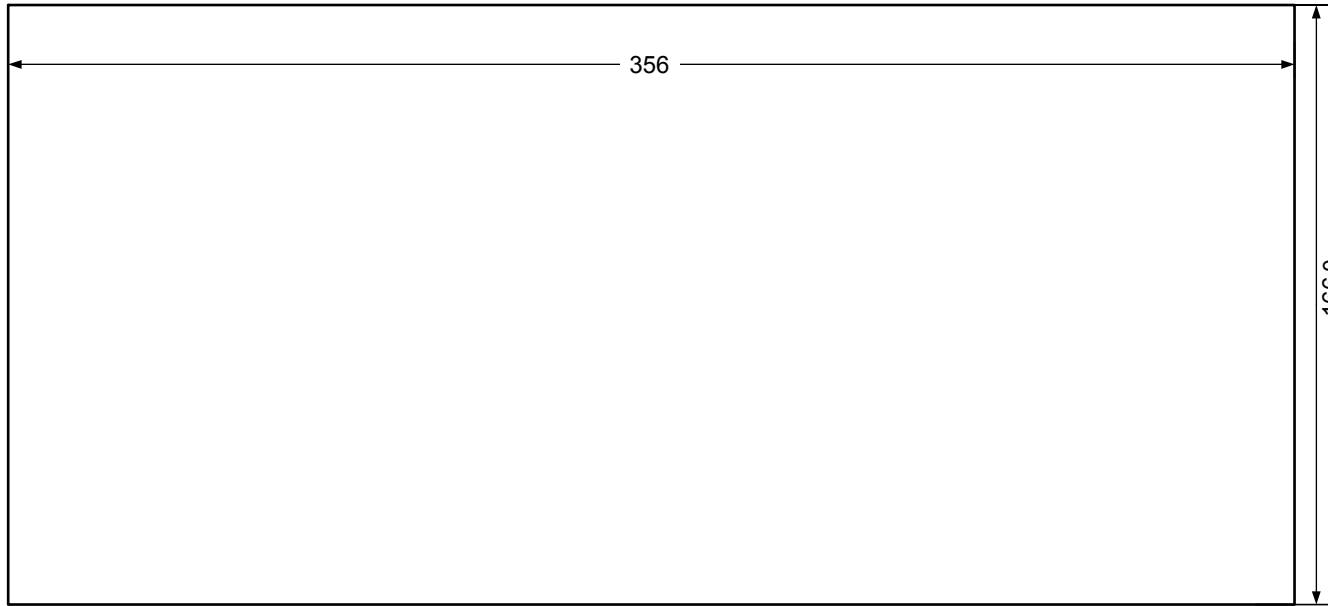
INNER WALL: TWO PIECES, 6mm

20

166
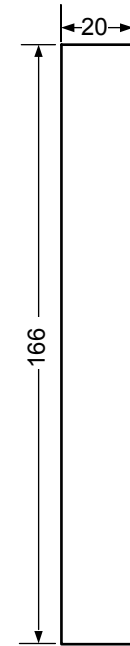
SIDE LEFT: ONE PIECE, 6mm

108

166.0

SIDE RIGHT: ONE PIECE, 6mm

108

166.0

BOTTOM EDGE

TOP EDGE

BACK EDGE

Ø48.5

28.0

50.0

BOTTOM: TWO PIECES, 6mm

100

166

BRACE: TWO PIECES, 6mm

25

166