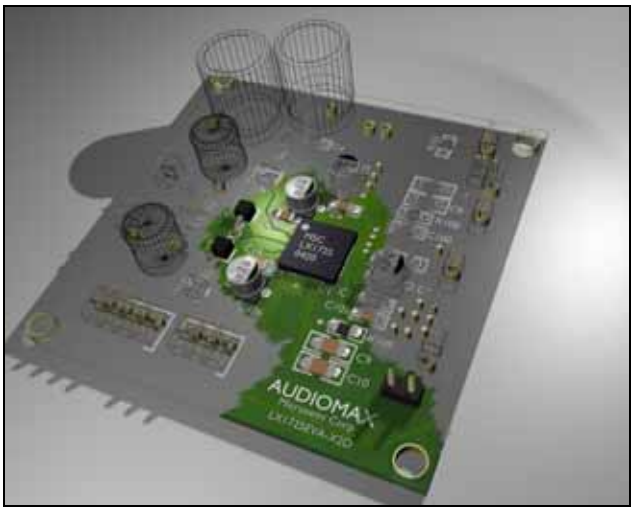
LX1725 15W X 2 30W BTL CLASS-D AUDIO AMPLIFIER

AN-35



User Information

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KEY FEATURES

- 11Wx2 @ 8Ω THD+N<1% | 15Wx2 @ 8Ω THD+N<10%
- 25W BTL @ 8Ω THD+N<1% 32W BTL @ 8Ω THD+N<10%
- High Efficiency: >90% @8Ω
- Full Audio Band: 20Hz~20KHz
- Low Distortion:<0.1% @1KHz, 8Ω | <0.4% @20~20KHz, 8Ω
- High Signal-to-Noise Ratio: >85dB non A-Weighted
- Split/Single Power Supply
- Wide Supply Voltage Range: ±6V ~ ±15V or 12V ~ 30V
- Low quiescent current <20mA
- Turn ON/OFF POP Free
- STANDBY/MUTE Feature
- Programmable gain 14/20/26dB
- Built-in over current Protection
- Built-in Under Voltage Lockout
- Thermal shut down
- Power Limiting Based on Die Temperature (gain fold back)
- Synchronization

APPLICATIONS

- LCD TV, PDP Sets
- CD/DVD Combo Player
- Combo DVD 5.1 Amplifier
- Home theater system
- Computer Speaker System
- Game Machine

PART SPECIFIC INFORMATION

Part Number	Product	Description
LX1725ILQ	-40 to +85 T_J(°C) 32-Pin MLPQ Package	15W + 15W Stereo Class-D Amplifier (Filter less 30W Mono BTL)

TABLE 1 – PART INFORMATION

IC	EVALUATION BOARDS		
LX1725ILQ	LX1725D EVAL	Dual Supply Stereo Evaluation Board	
LX1725ILQ	LX1725S EVAL	Single Supply Stereo Evaluation Board	

TABLE 2 – EVALUATION BOARD INFORMATION

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IC BLOCK DIAGRAM

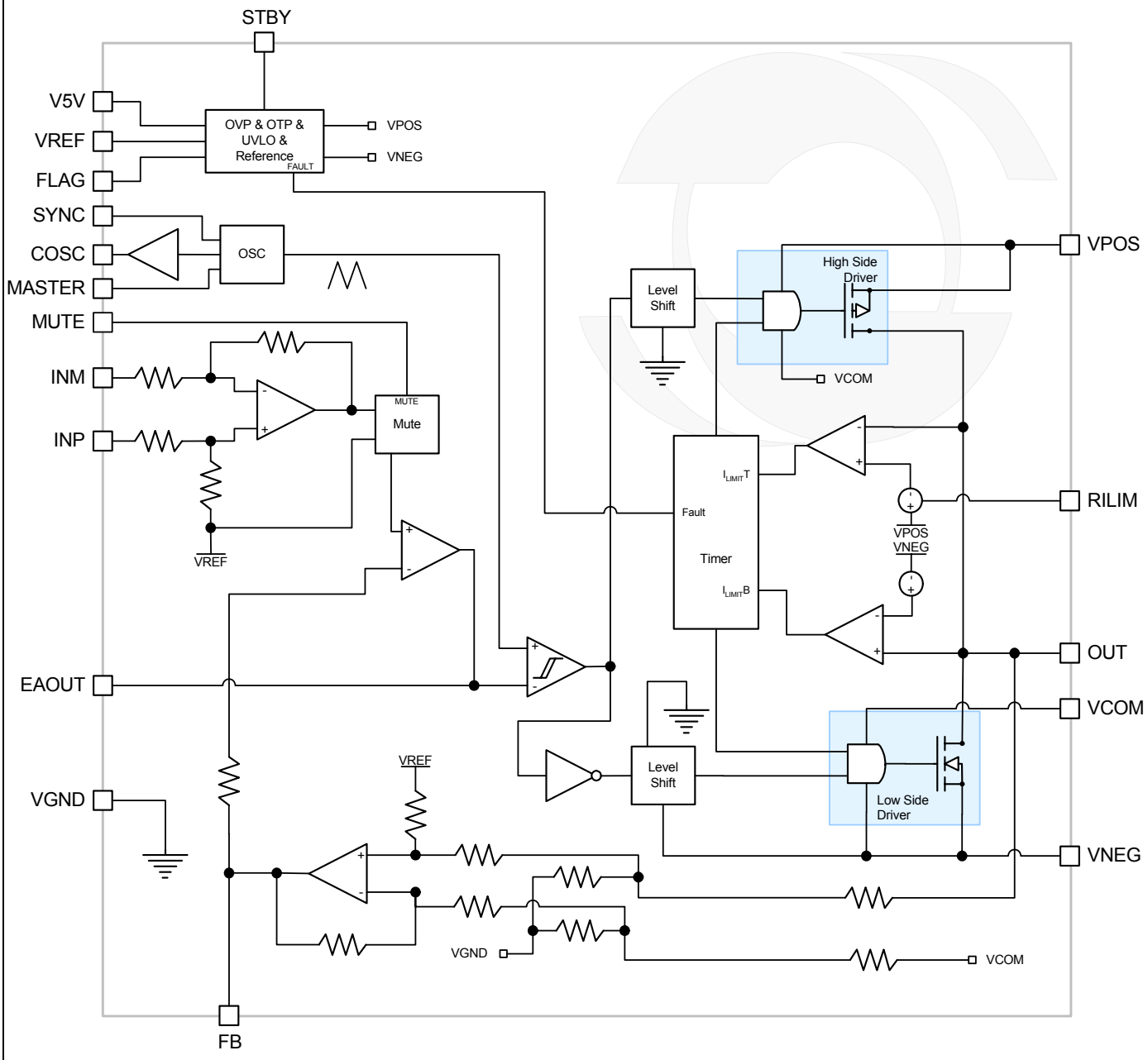

Figure 1 – Simplified Block Diagram

APPLICATION INFORMATION

OUTPUT LC FILTER DESIGN

Class-D audio amplifiers basically are Pulse width modulation (PWM) amplifiers; these types of amplifier require low pass filtering of the output to demodulate the PWM carrier. Some applications also utilize the filter as a way to achieve an impedance transformation that draws less power supply current than is delivered to the load. These filters can be as simple as a single inductor; to multiple LC nodes depending on the application. In some applications the load will have enough inductance to act as its own filter called filter less configuration which uses the speaker's own inductance as a low pass filter. PWM filters are normally a low pass configuration, many different types of low pass filters exist. The Butterworth filter (flat response in the pass band and good roll off beyond the cutoff frequency) is the most common filter used in class-D amplifier applications.

Initial considerations of LC filter design basically includes cut-off corner frequency, usually 1/10 ~ 1/5 of the switching frequency FSW; the poles of filter, which are decided by the bridged supply voltage (supply voltage) and desired voltage ripple cross the load. Normally two pole LC filter is used in the design.

Consider deciding the L and C value, there are two types of LC low pass filter: Single-ended and Bridged (Figure 2, 3).

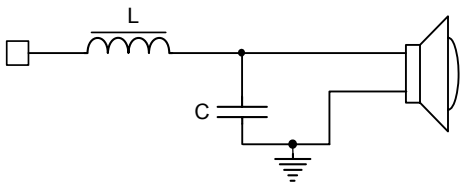

Figure 2 – Half bridged LC filter

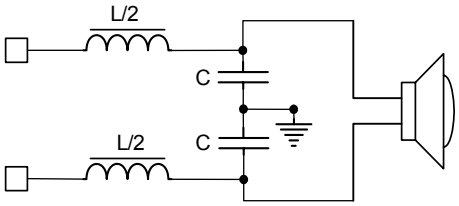

Figure 3 – Full bridged LC filter

For the half bridge LC filter configuration, if the cut-off frequency to remain unchanged (compaired to full bridge); the value of the inductor is doubled while the value of the capacitor across the load stays the same. Therefore, from system design the half bridge will save two inductors and capacitors which reduces the system cost and PCB area. Aside from the primary advantage of reduced system cost, the half filter also decreases the quiescent current. In the half bridge filter each output sees the full inductance value, which effectively reduces the rate of change in the inductor current, providing less power loss in the filter. Although this filter attenuates the differential signal, which reduces the magnetic field radiation.

Figure 4 is the frequency response based on the different load:

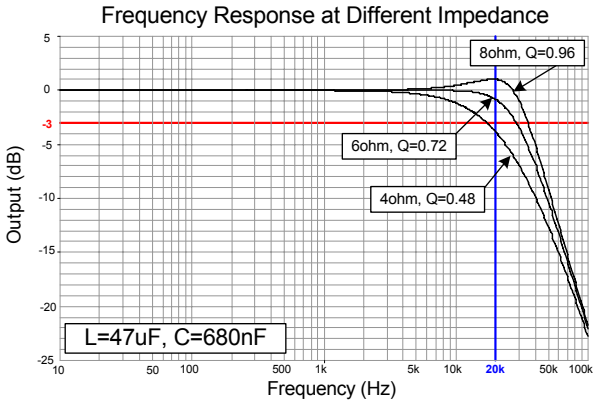

Figure 4 – Frequency Response at different load

Figure 5 shows the Frequency response of different LC values based on 4Ω / 8Ω.

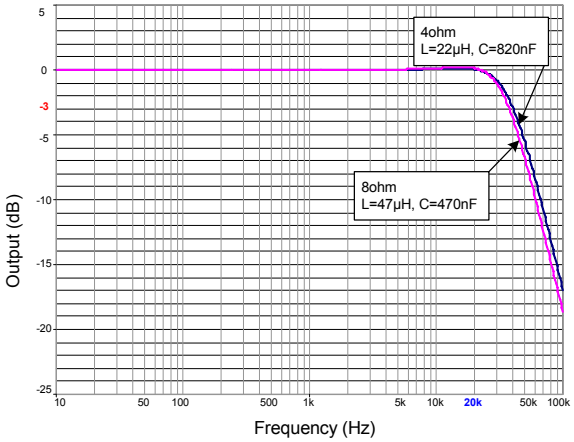

Figure 5 – Frequency at different LC value

Suggested LC value at different speaker impedance:

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Table 3 shows best LC value combination for 4Ω, 6Ω, and 8Ω load.

Suggested LC value table		
Speaker (Ω)	**Inductor (µH)**	**Capacitor (µF)**
4	22	0.82
6	47	0.68
8	47	0.47

Table 3

For Bridge-Tied-Load (BTL) configuration, keep the capacitor value same, and split the inductor L value to half, added on the output stage.

BTL OUTPUT WITH FILTER LESS

When using the power amplifier in a mono BTL application the inputs of both channels must be connected in parallel and the phase of one of the inputs must be inverted. In principle the loudspeaker can be connected between the outputs of the two single-ended demodulation filters.

Also the LX1725 output stage is configured as a filter less push-pull driver. With zero input voltage, the duty cycle at each output is around 50% and the signals are in-phase with each other. In this case, there is basically no differential voltage across the speaker. When the input signal goes positive, the duty cycle at OUT1 increases above 50% and the duty cycle at OUT2 decreases below 50%. This causes a net positive current to flow into the speaker. A negative input voltage causes the OUT2 duty cycle to increase and the OUT1 duty cycle to decrease, which causes a net negative current to flow into the speaker. The differential voltage across the speaker has a fundamental frequency of twice the switching frequency. The speaker itself serves as the low pass filter, which then recreates the audio signal. This type of modulation can be described as driving VPOS-VNEG, VNEG and VNEG-VPOS across the speaker, which is why it is referred to as 3-Level modulation.

The filter can be completely eliminated if the speaker is inductive at the switching frequency. The main trade off to eliminating the filter is that the power from the switching waveform is dissipated in the speaker, which leads to a higher quiescent current, I_{QQ}. The speaker is both resistive and reactive, whereas an LC filter is almost purely reactive. The switching waveform, driven directly into the speaker, may damage the speaker, however this is not as significant because the speaker cone movement is proportional to 1/f2 for frequencies beyond the audio band. Therefore, the amount of cone movement at the switching frequency is insignificant. But damage could occur to the speaker if the voice coil is not designed to handle the additional power. Eliminating the filter also causes the amplifier to radiate EMI from the wires connecting the amplifier to the speaker. Therefore, the filter less application is not recommended for EMI sensitive applications, or long speaker wire application.

LX1725 SYSTEM CONFIGURATIONS

The power supply of LX1725 can be dual or single supply with supply voltage range: ±6V ~ ±15V dual or 12V ~ 30V single. So there are 4 different system configurations: Split Supply / Stereo, Split Supply / BTL, Single Supply / Stereo and Single Supply / BTL.

The dual supplies condition is very simple, just connect “VPOS” to positive supply, “VNEG” to negative supply and “VCOM” connected to GND.

For the single supply condition, the “VCOM” voltage must be half of VPOS for device internal reference and feedback, you can either use a zener diode to climb the VPOS down to the half if the “VPOS” voltage is fixed (Figure 6).

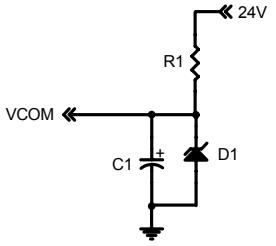

Figure 6 – VCOM voltage generation circuit (zener)

D1 is a 12V zener diode, R1 is for limiting the current through the zener diode, C1 is a bypassing capacitor to eliminate any ripple on the VCOM, it also can be useful for “de-pop” when the system used for stereo configuration or a pair of resistors also can be used for voltage divider to divide the POS into half to feed into VCOM.

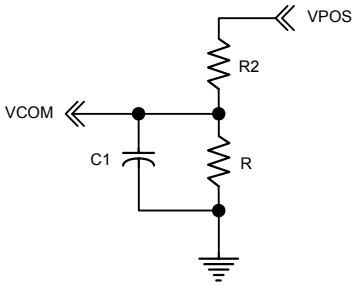

Figure 7 – VCOM Voltage Generate Circuit (Resistor)

When LX1725 is used as single supply stereo mode, a AC coupling capacitor must be added in series with speaker to cancel the DC offset caused by VCOM (Figure 8).

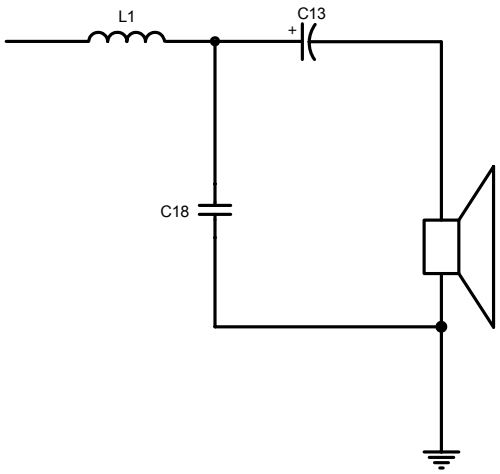

Figure 8 – Single-supply half-bridge output

In this configuration, the output will give a higher cut-off corner frequency in the lower frequency response than dual supply because that AC coupling capacitor, the corner frequency calculation as:

$F = 1/2\pi R_L C$

RL – Speaker load impedance;

C – The AC coupling capacitor value;

Because usually the AC coupling capacitor value is quite big (normally 220µF ~ 4700µF) for obtaining a lower frequency response, this will cause another problem – turn ON/OFF "POP" noise due to the slow discharge of the capacitor. Slow charge the capacitor is one of the approaches to cancel this "POP" noise, basically the VCOM start slowly up to half of VPOS to make the output duty cycle slowly start from zero to 50% (Figure 9). When the AC coupling capacitor charge time is slower than its discharge time, there will not be discharge at all, the "POP" noise will be gone.

C1 in Figure 7 is VCOM slow start-up control capacitor, its value should be calculated as:

$C1 > (R_L \times C) / R1$

R_L – Speaker load impedance;

C – The AC coupling capacitor value;

R1 – VCOM current limit resistor;

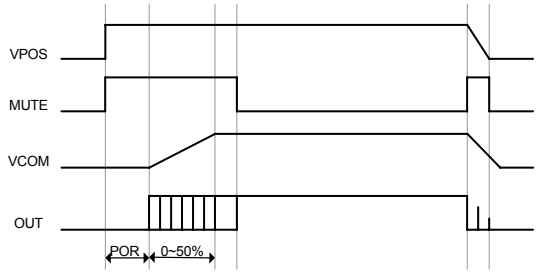

Figure 9 – VCOM start up time sequence

THERMAL DESIGN

Thermal Protection

LX1725 has thermal gain fold back (power limiting) and shuts down depended on the junction temperature as described in "Function Description" on Page 11.

Heatsink Requirement Calculation:

To calculate the heatsink thermal resistance requirement, the following equation maybe used:

$$R_{TH(J-A)} = \frac{T_{J(MAX)} - T_A}{P_{DISS}}$$

where: $T_{J(MAX)}$ = 150°C is the maximum junction temperature which can not be exceeded.

P_{diss} depends on the LX1725 efficiency (η),

for example:

P_{OUT} = 10W+10W into 8Ω speaker, η = 90%, T_A = 70°C

So, P_{diss} = 20W x (1/0.9-1) = 2.2W

$R_{TH(j-a)}$ = (150-70) / 2.2 = 36.4°C/W

From the thermal resistance of LX1725 on Page 2, Θja = 30.7°C/W < $R_{TH(j-a)}$

So, no extra heatsink required.

P_{OUT}=15W+15W into 4Ω speaker, η = 82%, T_A = 70°C

So, P_{diss} = 30W x (1/0.82-1) = 6.6W

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$R_{TH(j-a)}$ = (150-70) / 6.6 = 12.1°C/W

From the thermal resistance of LX1725 on Page 2, Θja = 30.7°C/W > $R_{TH(j-a)}$

So, extra heatsink with at least 12.1°C/W thermal resistance required.

Thermal Considerations

This calculation shows that the LX1725 can drive 10 W of continuous RMS power per channel into an 8-Ω speaker up an ambient temperature of 70°C without extra heatsink required.

Take a comparison of 2-layer PCB vs. 4-layer PCB. the 2–layer PCB layout was tightly controlled with a fixed amount of 2 oz. copper on the bottom layer of the PCB. 25 thermal vias of 13 mil (0.33mm) diameter were drilled under the PowerPad and connected to the bottom layer. The top layer only consisted of traces for signal routing. A 1.0in x 1.0 in square 2 oz. Copper can give you about 27□C/W thermal resistance. Since for 2-layer board, there are some traces also run on the bottom layer, you can not expect laying a big square of copper area, 27°C/W is enough thermal resistance for LX1725 drive two 8ohm speakers. If 4Ω speakers are driven, because of higher power dispassion (described above), a at least 12°C/W heatsink is needed (Figure 10). The 4–layer PCB layout was also tightly controlled with a fixed amount of 2 oz. copper in middle VNEG or GND layer (depended on the dual supply or single supply configuration). The top layer only consisted of traces for signal routing. The middle layers were left blank. 25 thermal vias of 13 mils (0.33mm) diameter were drilled under the PowerPad and connected to the middle layers (Figure 11).

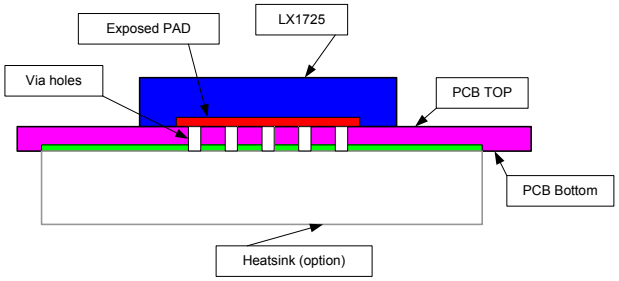

Figure 10 – 2-Layer PCB thermal design

The 4-Layer PCB's middle layers act as a heatsink copper, A 3in x 3in square copper can give close to 20°C/W thermal resistance, could cover 3W power dispassion which allows almost 30W output power. Since there are no traces running in the middle layers, you can lay as big metal copper for heatsink as you can (of cause limited by PCB size) to enhance the package power dispassion capability.

PCB DESIGN GUIDELINES

One of the key efforts in implementing the MLP package on a pc board is the design of the land pattern. The MLP has rectangular metallized terminals exposed on the bottom surface of the package body. Electrical and mechanical connection between the component and the pc board is made by screen printing solder paste on the pc board and reflowing the paste after placement. To guarantee reliable solder joints it is essential to design the land pattern to the MLP terminal pattern, exposed PAD and Thermal PAD via. There are two basic designs for PCB land pads for the MLP: Copper Defined style (also known as Non Solder Mask Defined (NSMD)) and the Solder Mask Defined style (SMD). The industry has had some debate of the merits of both styles of land pads, and although we recommend the Copper Defined style land pad (NSMD), both styles are acceptable for use with the MLP package. NSMD pads are recommended over SMD pads due to the tighter tolerance on copper etching than solder masking. NSDM by definition also provides a larger copper pad area and allows the solder to anchor to the edges of the copper pads thus providing improved solder joint reliability.

DESIGN OF PCB LAND PATTERN FOR PACKAGE TERMINALS

As a general rule, the PCB lead finger pad (Y) should be designed 0.2-0.5mm longer than the package terminal length for good filleting. The pad length should extended 0.05mm towards the centerline of the package. The pad width (X) should be a minimum 0.05mm wider than the package terminal width (0.025mm per side), refer to figure 11. However, the pad width is reduced to the width of the component terminal for lead pitches below 0.65mm. This is done to minimize the risk of solder bridging.

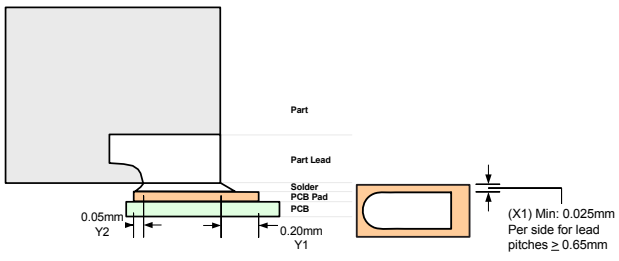

Figure 11 – PC Board Land Pattern Geometry for MLP Terminals

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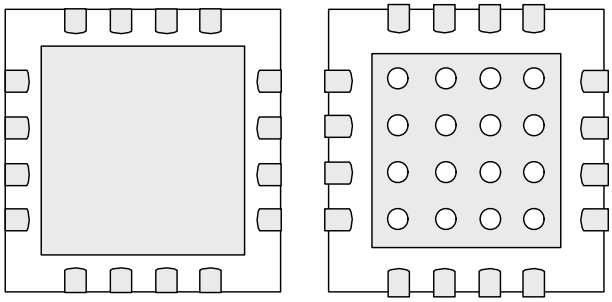
EXPOSED PAD PCB DESIGN

The construction of the Exposed Pad MLP enables enhanced thermal and electrical characteristics. In order to take full advantage of this feature the exposed pad must be physically connected to the PCB substrate with solder.

The thermal pad (D2th) should be greater than D2 of the MLP whenever possible, however adequate clearance (Cpl > 0.15mm) must be met to prevent solder bridging. If this clearance cannot be met, then D2th should be reduced in area. The formula would be: D2TH >D2 only if D2TH < Gmin - (2 x Cpl).

THERMAL PAD VIA DESIGN

There are two types of on-board thermal PAD design, one is using thermal vias to sink the heat to the other layer with metal traces. Based on Jedec Specification JESD 51-5, the thermal vias should be designed like 12. Another one is the no via thermal PAD which is using the same side copper PAD as heatsink, this type of thermal PAD is good for two layer board, since the bottom side is filled with all other kinds of trace also, it's hard to use the whole plane for the heatsink. But you still can use vias to sink the heat to the bottom layer by the metal traces, then layout a NMSD on which a metal heatsink is put to sink the heat to the air.



Micro Lead Quad Package Land Pattern

Land Pattern for Four Layer Board with Vias

Figure 12 – Comparison of land pattern theory

For LX1701 with MLPQ-4x4 16Lds package, which has ΘJA =38.1°C/W by package itself, with maximum 2W (@4Ω) output it only has 300mW power dispassion (assuming 85% efficiency), which only has 11.4°C temperature rise. So the non-via type thermal PAD is suggested.

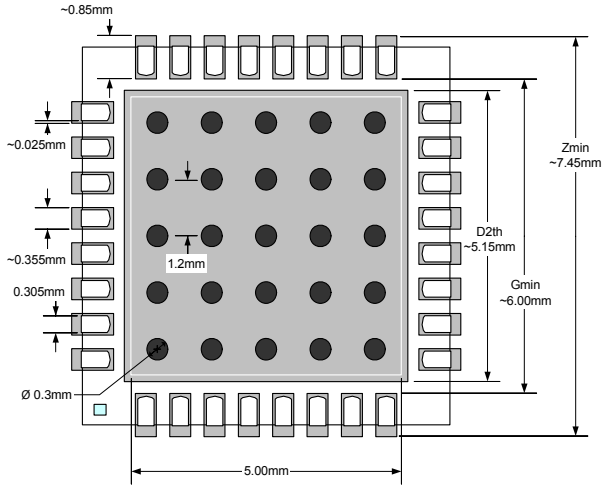


Figure 13 – Recommended Land Pad with Vias for LQ32 (7mm²)

Zmin= D + aaa + 2(0.2)
(where pkg body tolerance aaa=0.15)
(where 0.2 is outer pad extension)
Gmin= D-2(Lmax)-2(0.05)
(where 0.05 is inner pad extension)
(Lmax=0.50 for this example)
D2th max = Gmin-2(CpL)
(where CpL=0.2)

EVALUATION KIT QUICK GUIDE

PCB DESIGN GUIDELINES

The LX1725 Evaluation Board is a fully functional stereo class-D amplifier with dual or single-supply, simply connected to power supply, two speakers and any audio input sources, you can start evaluating the amplifier right way.

Board Settings:

1. Power and Ground Connections: The terminal TB3 is for the power supply connection. For dual supply version (LX1725D), VPOS is connected to the positive polarity of the power supply (6V ~ 15V), VNEG is connected to the negative polarity of the power supply (-6V ~ -15V) and V5V is simply connected to a 5V supply, the GND is connected to the ground of the power supply. For single supply version (LX1725S), VPOS is connected to the positive polarity of the power supply or battery (12V ~ 30V), V5V is simply connected to a 5V supply, the GND is connected to the negative polarity of the power supply or battery.

2. Speaker Connections: TB1 and TB2 are the speaker outputs. TB1 is for the CH1 output and TB2 is for CH2 output. Connect speaker "+" and "-" to "OUT1+ / OUT2+" and "OUT2- / OUT2-" of TB1 / TB2. For the BTL (Bridged-Tied-Load) configuration, just simply connect the speaker "+" to "OUT1+" of TB1 and connect the speaker "-" to "OUT2-" of TB2. Please pay attention that this evaluation board is designed for the maximum power 30W, so 8ohm load is suggested for BTL configuration under full rail of supply voltage, if 4Ω load is applied, 18V (±9V) rail supply voltage is suggested.

3. Audio input connections: J1, J2 and RCA1, RCA2 (only for 2-layer board) are the audio input connections, simply apply positive of audio source into "IN1+ / IN2+" and negative into "IN1- / IN2-". When audio inputs are differential, the header connectors (J1 and J2) are suggested. JP1 and JP2 jumpers are the option for input signal grounding if the input has different ground with the evaluation board (for example, the battery operated audio device), default is "OPEN".

4. Standby Selection: JP5 is the jumper selection for standby. Close to "STBY" will force the evaluation board into the zero current mode.

5. "Master/Slave" selections: JP6 is a selection for "MNORMAL" (Master Normal), "MQUICK" (Master Quick start for production test purpose), "SQUICK" (Slave Quick start for production test purpose), "SNORMAL" (Slave Normal) 4 different combinations. Default is "MNORMAL", "SNORMAL" is for synchronization application, please refer to "Function Description" on Page 10.

6. "MUTE / GAIN" Selection: JP7 is a multi-level jumper selection for "MUTE" and 14/20dB gain switch, default is 20dB. One thing must be paid attention, the "MUTE" and "STBY" start up sequence is very important for the turn ON/OFF "POP" noise, maybe you can hear the "POP" noise when you turn ON / OFF the board because there is no timing sequence circuit on the board. You should close the jumper to "MUTE" of JP7 and "STBY" of JP5 when you turn the power supply, then close to "NORMAL" of JP5 to enable the system, final remove the "MUTE" of JP7, to eliminate the "POP" noise.

7. "SYNC / FLAG": "SYNC" is used for synchronization of multi devices (refer to "Function Description on Page 10.), "FLAG" is the system mode indicator, indication the system fault conditions, logic level output, can be applied to any logic level controlled device to make the further actions.

8. "Filterless": "Filterless" can only be used for BTL output configuration, applied for both dual supply and single supply conditions. Simply short the L1/L2 and remove the C18/C19 to drive the speaker directly. Aslo, tie "IN1+" with "IN2+" and "IN1-" with "IN2-". BTL configuration refers to "Board Settings" 2. Speaker Connections on this page.

9. "High Gain" Mode. Which give (default is open) you 0dB extra gain. If the jumper is closed to "+6dB" position it will boost gain output by 6dB.

EVALUATION KIT SCHEMATIC

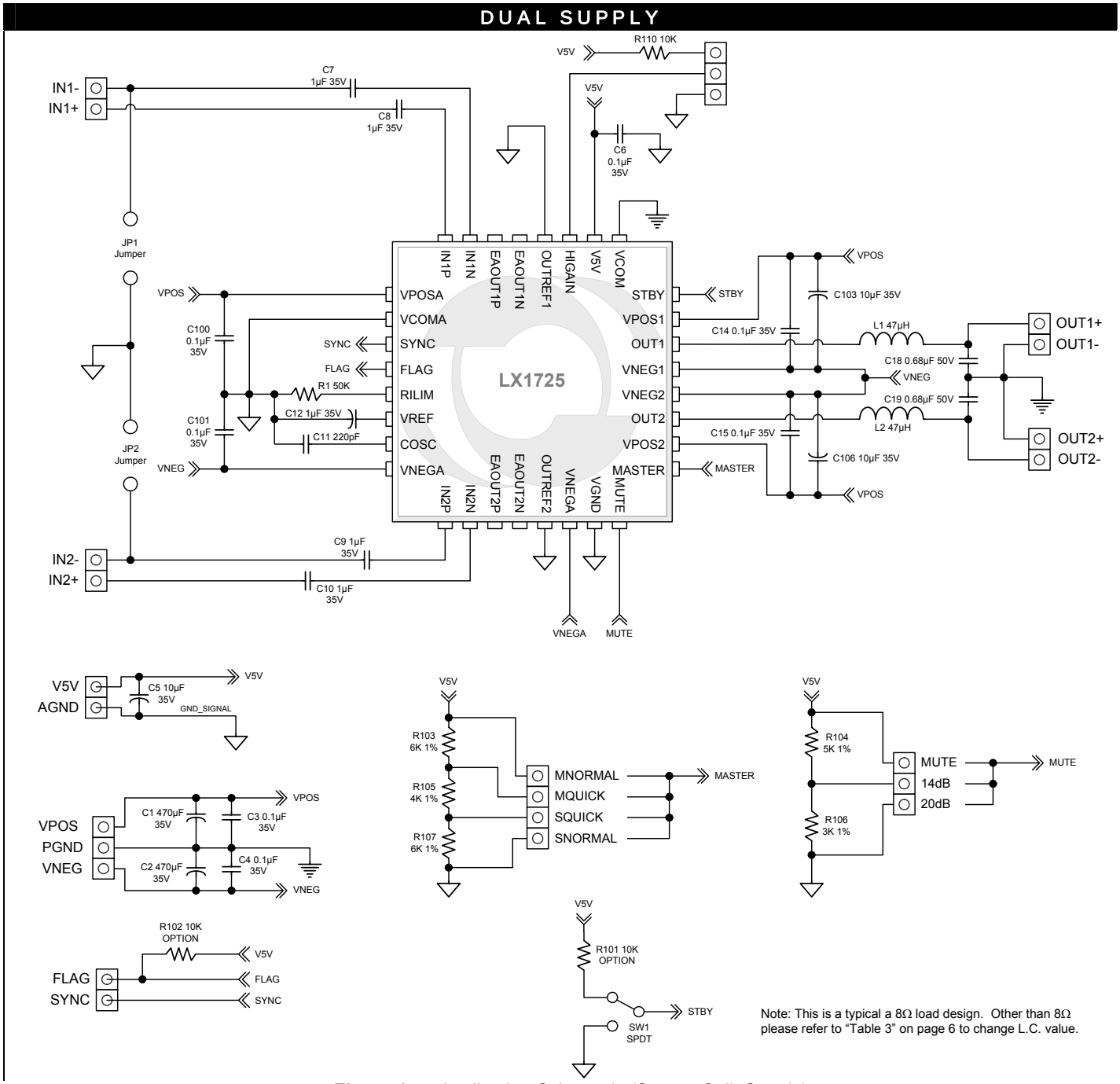
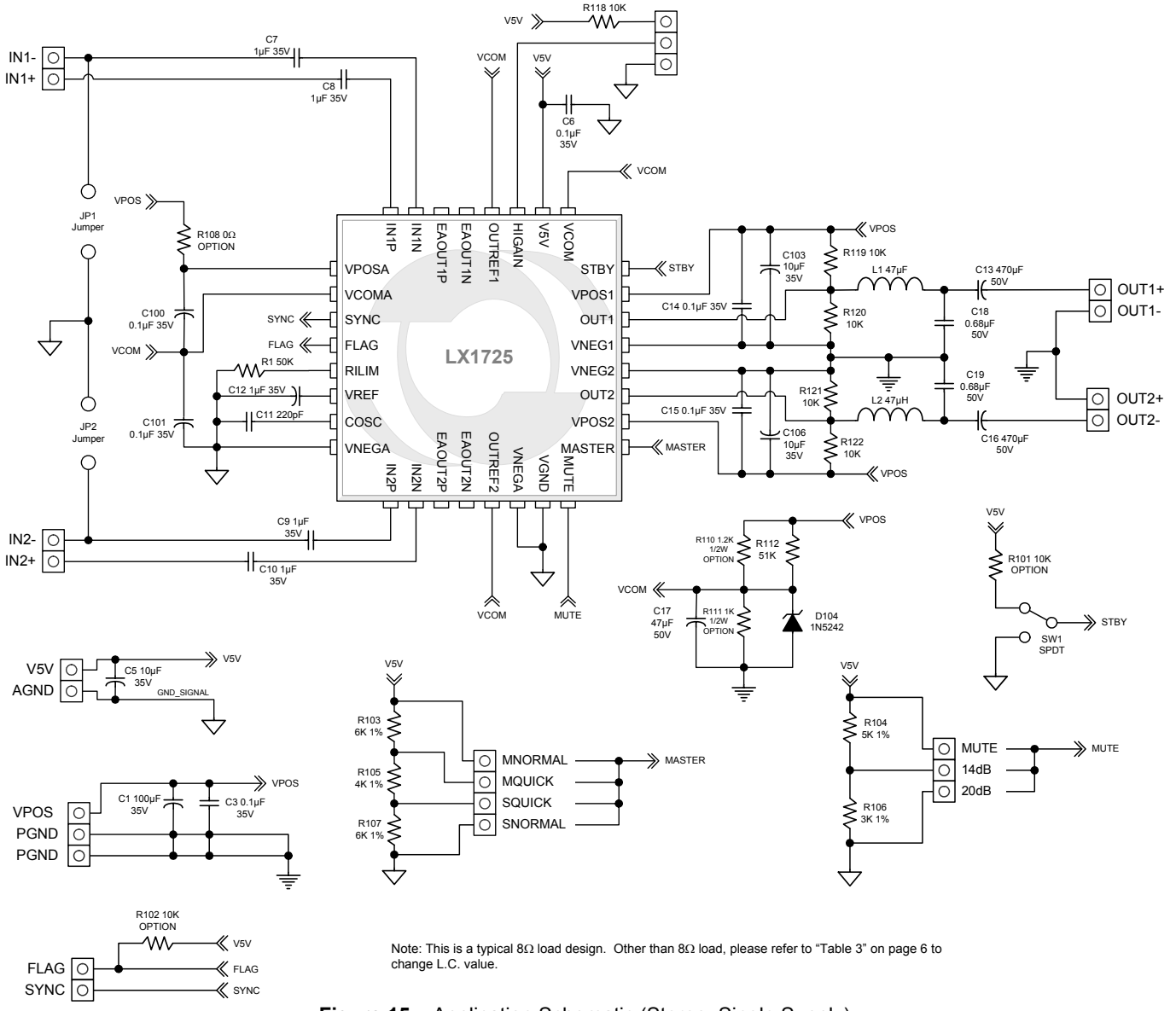


Figure 14 – Application Schematic (Stereo, Split Supply)

EVALUATION KIT SCHEMATIC

SINGLE SUPPLY



Note: This is a typical 8Ω load design. Other than 8Ω load, please refer to "Table 3" on page 6 to change L.C. value.

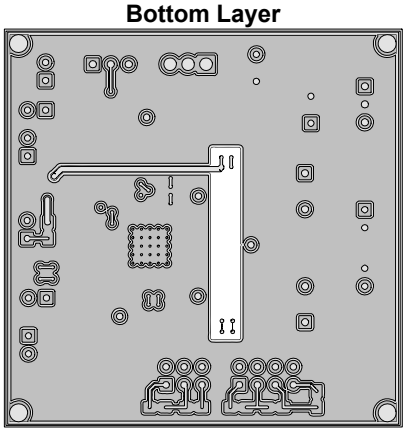
Figure 15 – Application Schematic (Stereo, Single Supply)

LX1725 EVALUATION BOARDS

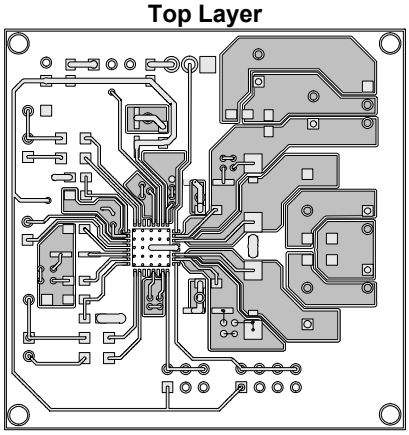
DUAL SUPPLY

Figure 16

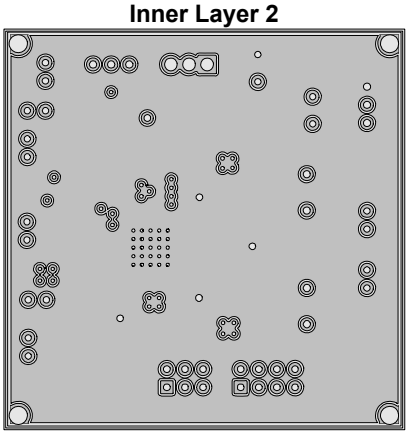
Bottom Layer



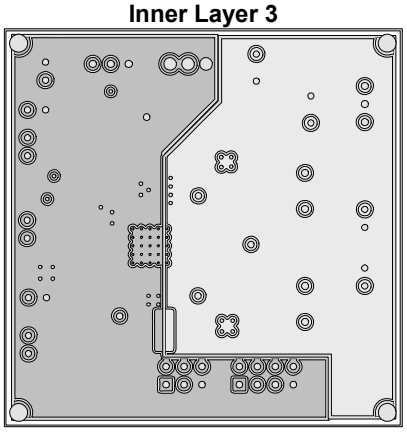
Top Layer



Inner Layer 2



Inner Layer 3



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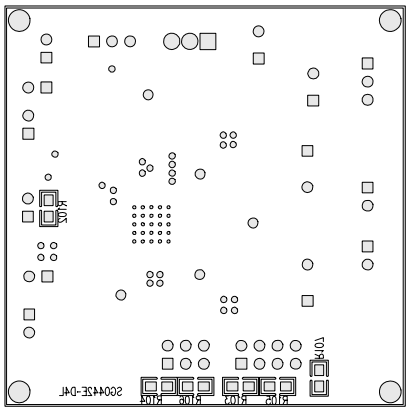

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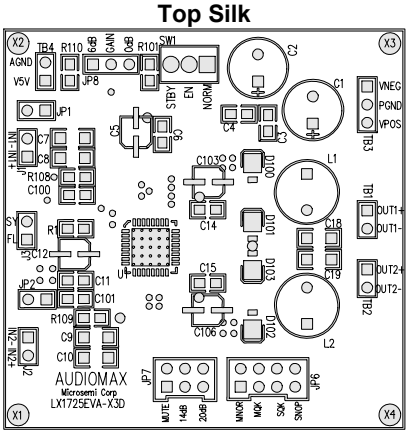
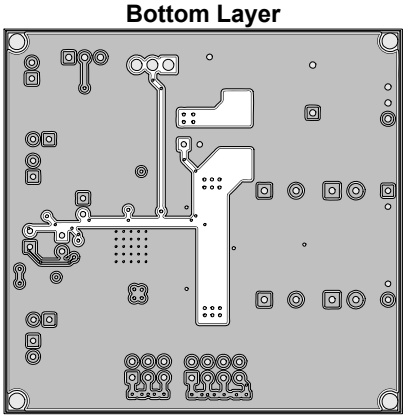


LX1725 EVALUATION BOARDS (CONTINUED)

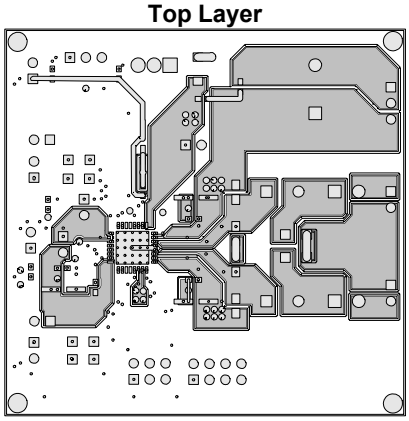
SINGLE SUPPLY

Figure 17

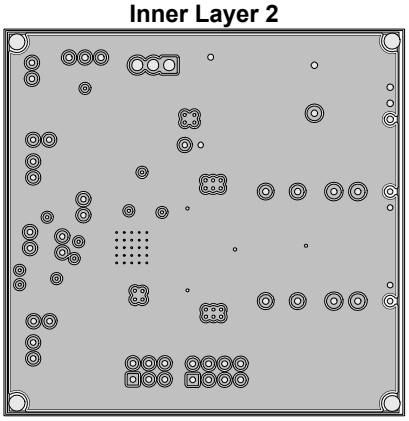
Bottom Layer



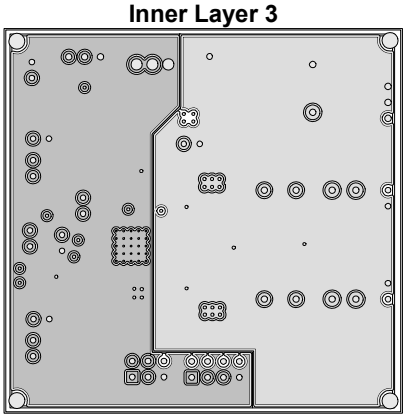
Top Layer



Inner Layer 2



Inner Layer 3



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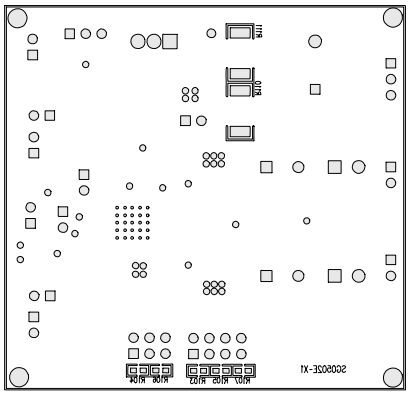

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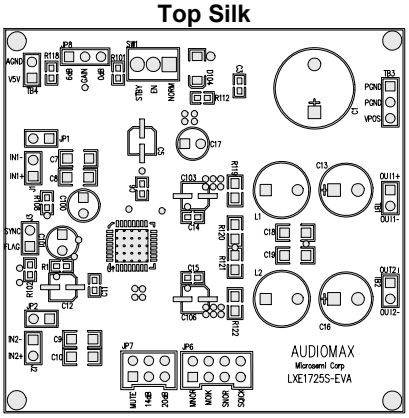

Microsemi
Integrated Products
11861 Western Avenue, Garden Grove, CA. 92841, 714-898-8121, Fax: 714-893-2570

LX1725D (DUAL SUPPLY) BILL OF MATERIALS

1 MISCELLANEOUS COMPONENTS

Line Item	Part Description	Manufacturer & Part #		Case	Reference Designators	Qty
1	Stereo Class-D 20W Amplifier IC	MICROSEMI	LX1725CLQ	MLPQ	U1	1
2	Inductor, 47µH	ISI	RL622-470K		L1, L2	2
3	Header 2pin, .100"	AMP	87220-2		J1, J2, J3, JP1, JP2, TP1, TP2, TP4	8
4	Header 3pin .100"	AMP	87220-3		JP8, TP3	2
5	Header, Double Row, .100" 3x2	AMP			JP7	1
6	Header, Double Row, .100" 4x2	AMP			JP6	1
7	Shorting Jumpers	3M	929955-06		JP6, JP7	2
8	SWT MS Toggle SPDT 3P 10TA810	MOUNTAIN SWT	10TA810		SW1	1
9	PCB	MSC-IP	ESG1725X3D4L			1

CAPACITORS

Line Item	Part Description	Part Description		Case	Reference Designators	Qty
1	Capacitor, Elect, VZ, 470µF, 25V 10x13	PANASONIC	UVZ1E471MPD		C1, C2	2
2	Capacitor, Elect, VS 10µF, 35V	PANASONIC	ECE-V1VA100WR	SMD	C5 C103, C106	3
3	Capacitor, 0.1µF, 50V	TDK	C2012X7R1H104M	0805	C3, C4, C6, C12, C14, C15, C100, C101	8
4	Capacitor, 1µF, 50V	TDK	C3216X7R1C105M	1206	C7, C8, C9, C10	4
5	Capacitor, 200pF, 50V	AVX	06035A221JAT2A	0603	C11	1
6	Capacitor, 680nF, 25V	VENKEL	C1206X7R250-68KNE	1206	C18, C19	2

RESISTORS

Line Item	Part Description	Part Description		Case	Reference Designators	Qty
1	Resistor, 3K, 1%	SAMSUNG	RC1608F3001CS	0603	R106	1
2	Resistor, 4K, 1%	SAMSUNG	RC1608F4001CS	0603	R105	1
3	Resistor, 5K, 1%	SAMSUNG	RC1608F5001CS	0603	R104	1
4	Resistor, 6.04K, 1%	SAMSUNG	RC1608F6041CS	0603	R103, R107	2
5	Resistor, 10K, 5%	SAMSUNG	RC1608J103CS	0603	R101, R102, R110	3
6	Resistor, 50K, 5%	SAMSUNG	RC1608J503CS	0603	R1	1

Orange Highlighted components for Test purpose only.

LX1725S (SINGLE SUPPLY) BILL OF MATERIALS

MISCELLANEOUS COMPONENTS

Line Item	Part Description	Manufacturer & Part #		Case	Reference Designators	Qty
1	Stereo Class-D 20W Amplifier IC	MICROSEMI	LX1725CLQ	MLPQ	U1	1
2	Inductor, 47µH	ISI	RL622-470K		L1, L2	2
3	SWT, SPDT 3P STD	MOUNTAIN SWT	MS 24L244		SW1	1
4	Header 2pin, .100”	AMP	87220-2		TB1, TB2, TB4, J1, J2, J3, JP1, JP2	8
5	Header 3pin .100”	AMP	87220-3		TB3, JP8	2
6	Header, Double Row, .100” 3x2	AMP			JP7	1
7	Header, Double Row, .100” 4x2	AMP			JP6	1
8	Shorting Jumpers	3M	929955-06		JP6, JP7	2
9	PCB	Microsemi				

CAPACITORS

Line Item	Part Description	Part Description		Case	Reference Designators	Qty
1	Capacitor, Elect, VS, 10µF 35V	PANASONIC	ECE-V1VA100WR	SMD	C5, C103, C106	3
2	Capacitor, 0.1µF, 50V	TDK	C2012X7RH104M	0805	C3, C6, C12, C14, C15, C100, C101	7
3	Capacitor, 1µF, 50V	TDK	C3216X7R1C105M	1206	C7, C8, C9, C10	4
4	Capacitor, 1000µF, 35V 12.5x25	NICHICON	UVZ1H102MHH		C1	1
5	Capacitor, 220pF, 50V	AVX	06035A221JAT2A	0603	C11	1
6	Capacitor, 680nF, 25V	VENKEL	C1206X7R250-684KNE	1206	C18, C19	2
7	Capacitor, ELEC VZ, 470µF, 25V, 13x10	NICHICON	UVZ1E471MPD		C13, C16	2
8	Capacitor, 47µF, 35V, 5x11	PANASONIC	UVR1V470MDD		C17,	1

RESISTORS

Line Item	Part Description	Part Description		Case	Reference Designators	Qty
1	Resistor, 0Ω, 5%	SAMSUNG	RC1608J000CS	0603	R108	1
2	Resistor, 3K, 1%	SAMSUNG	RC1608F3001CS	0603	R106	1
3	Resistor, 4K, 1%	SAMSUNG	RC1608F4001CS	0603	R105	1
4	Resistor, 5K, 1%	SAMSUNG	RC1608F5001CS	0603	R104	1
5	Resistor, 6K, 1%	SAMSUNG	RC1608F6001CS	0603	R103, R107	2
6	Resistor, 10K, 5%	SAMSUNG	RC1608J103CS	0603	R101, R102, R118, R119, R120, R121, R122	7
7	Resistor, 50K, 5%	SAMSUNG	RC1608J503CS	0603	R1	1
8	Resistor, 1K, 5%	DALE	CRCW2010-1KJNT1	2010	R110, R111	2
9	Resistor	NA			R112	1

Orange Highlighted components for Test purpose only.