SDS Labs Headphone Amplifier

By Sheldon D. Stokes

A couple of years ago, I bought a set of the now-famous Grado SR-60 headphones. I use them when I travel or when I don't want to bother anybody with music at home. But my reference system doesn't have a headphone jack except on my CD player, and it doesn't have a volume control. And if that wasn't bad enough, the headphone amp isn't very good quality. So I needed a good quality headphone amp that I could use for all my sources.

A problem with the Grado headphones is their low impedance. They present about a 32 ohm load on the amplifier driving them. My first thought was to use tubes, and drive the headphones with a cathode follower. but with the 32 ohm impedance, this isn't very practical unless you're building a large OTL amp. Scott Dorsey is building a tube headphone amp that looks promising, I suspect that you will see it in print soon. So I decided to build a solid state headphone amp. The circuit shown here is an adaptation of Walt Jung's headphone amp described in the Audio IC Op-Amp Applications book. From what I've heard, this book is out of print.

My Headphone Amp Prototype

The changes I've made in Walt Jung's circuit are that I have replaced the bipolar output transistors with MOSFET's, and I changed the biasing method for the MOSFETs. I also designed the power supply. But the essence of the circuit remains unchanged. The heart of the circuit is a dual op-amp. Which drives a pair of push pull output MOSFETs. The output from the MOSFETs is included in the feedback loop of the op-amp, so the distortion is very low. The gain of the amp is set at a value of two, and it includes an input pot for volume adjustment.

The headphone amp circuit is basically a simple non-inverting op-amp gain stage with external buffering. I find that for op-amps to sound their best, they should not be operated at the edge of their drive capabilities. Many commercial headphone products use op-amps directly to drive a pair of headphones. While it can be done this way, I have found that adding a buffer to the output of the op-amp reduces the harshness and stridency dramatically (two common complaints about op-amp based designs). I rarely use op-amps for serious audio design, due to what I consider to be questionable sonic merits of op-amps. But in this circuit, the op-amp is running at a very low gain setting, and is not driving the headphones directly. These two factors make this headphone amp a very neutral and musical device. The headphone amp also uses a low impedance, regulated power supply. For such a small amplifier regulation is practical and the sonic benefit is quite noticeable. This amplifier is direct coupled as well, so there isn't any capacitors in the signal path.

The amplifier uses a zener diodes to provide the bias current for the output FET's. The output stage is biased fairly heavily for such a small amplifier. I find that FET's sound their best when they have fairly high bias currents. This amp will run class A up to two watts. Each device is dissipating a watt of power at idle, and should be mounted on a heat sink. The biasing portion of the circuit also has the provision for limiting the amplifier output by using a pair of LED's (per channel). If voltage swing gets too large, the LED turns on and the output signal is reduced. I don't use the LED's in my prototype of this circuit, they shouldn't degrade the sound quality of the amplifier, but I left them off just because I didn't think I'd need them, and I try to keep as little in the signal path as possible.

This amplifier is powerful enough to also drive an efficient set of speakers. It produces about 4 watts of power before clipping. This amp clips asymmetrically, as the gates of the MOSFETs are not driven in their potential center. The reason I have done this is that I have found that op-amps sound the best when they sink a bit of output current. Many folks put a resistor on the output to one of the voltage rails to "bias" the op-amp into class "A" operation. By tying the output of the op-amp to one of the gates instead of the middle of the two gates, the op-amp output is sitting at about 4.5 volts above ground potential, and thus is "biased" into class A.

This may seem to contradict what I said earlier about needing to buffer the output of the op-amp so it doesn't drive difficult loads. In this case, the op-amp is still only driving the gates of the MOSFETs, and the load it's output stage sees is essentially the same as if it were connected to the center of the MOSFET gates.

The asymmetrical clipping is not a problem for a headphone amp because your ears will bleed long before the MOSFET clip. If you are going to use this design for driving speakers, you should tie the op-amp output the center of the MOSFET gates using a pair of 450 ohm resistors. I listened to this amp driving my Quad ESL's and it's quite promising. This amp sounds very good, if you own a set of Grado headphones and are driving them with an op-amp based headphone amp, I believe that the buffering the op-amp with a pair of MOSFET's (per channel) will result in much improved sound quality. I haven't heard a more transparent sounding headphone amp available at a reasonable cost.

The circuit board layout, population guide, schematic and parts list are included below. The MOSFETs I chose are somewhat arbitrary, as long as you choose well matched complimentary pairs with decent power handling and similar specs.

If you are interested in getting a circuit board or information on any of my other projects (DAC's, pre-amps, Quad ESL repairs etc.), I can be reached at the following locations:

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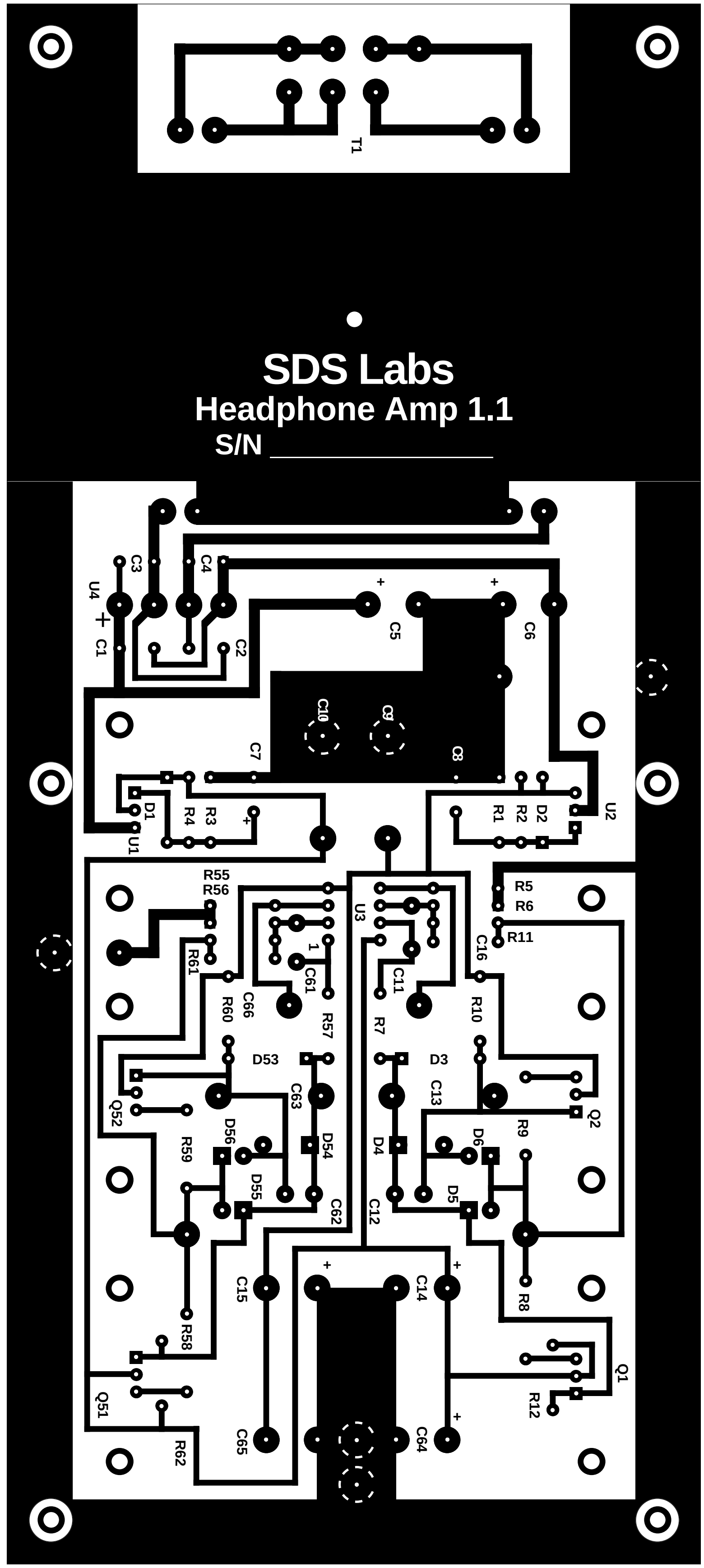
stokes@exis.net
http://www.clarkson.edu/~stokessd

References:

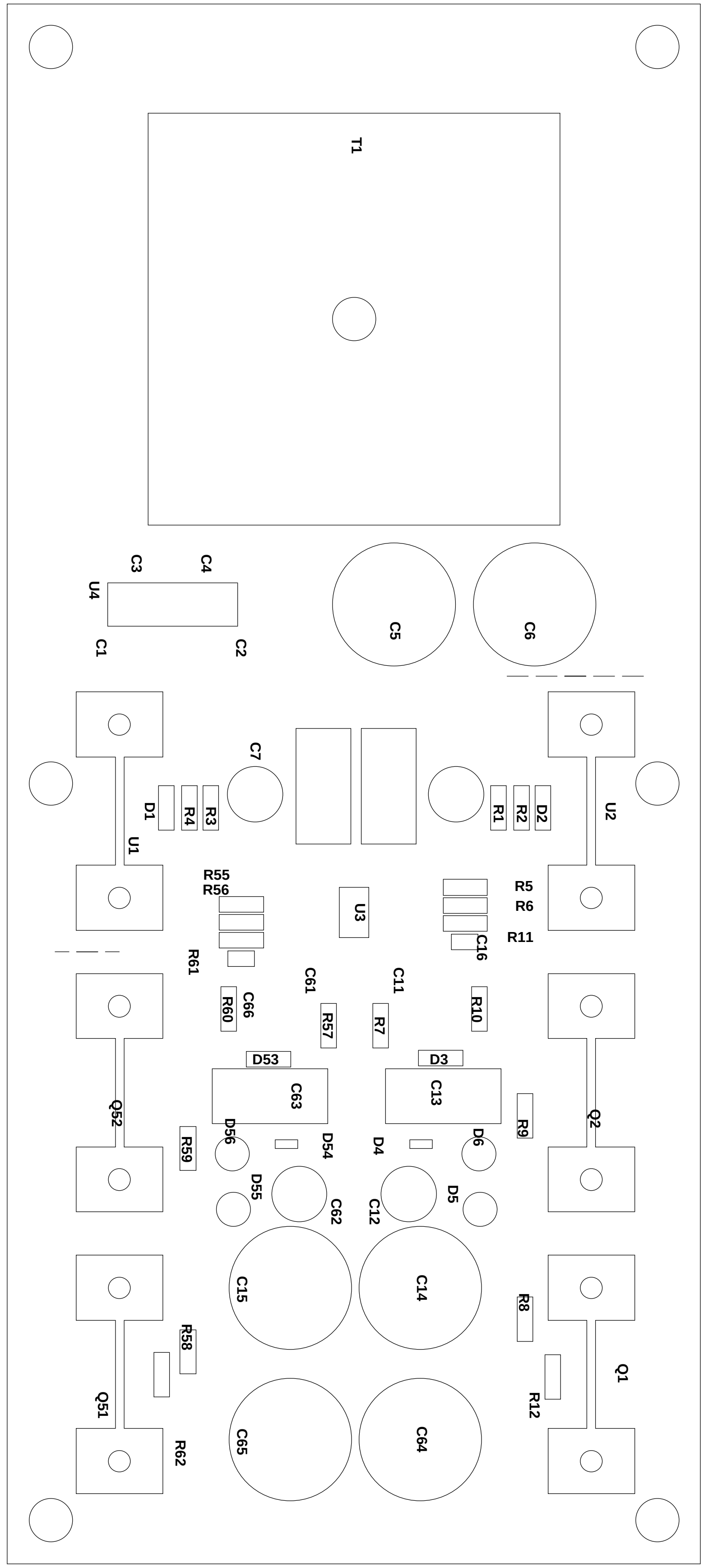
Jung, Walter G. Audio IC Op-Amp Applications . Howard Sams & Co. 1987 Indianapolis In.
ISBN: 0-672-22452-6

Part no.	Description	Manufacturer	Digikey part number	Cost	No. in package
C1	560 pF ceramic	panasonic	P4033-ND	$0.11	10
C2	560 pF ceramic	panasonic	P4033-ND	$0.11	10
C3	560 pF ceramic	panasonic	P4033-ND	$0.11	10
C4	560 pF ceramic	panasonic	P4033-ND	$0.11	10
C5	4700 µF 25 volt	panasonic	P5724-ND	$3.57	1
C6	4700 µF 25 volt	panasonic	P5724-ND	$3.57	1
C7	330 µF 25 volt	panasonic	P5703-ND	$0.65	1
C8	330 µF 25 volt	panasonic	P5703-ND	$0.65	1
C9	1 µF 100 volt	panasonic	E1105-ND	$0.71	1
C10	1 µF 100 volt	panasonic	E1105-ND	$0.71	1
C11	47 pF 100 volt	panasonic	P4845-ND	$0.18	1
C61	47 pF 100 volt	panasonic	P4845-ND	$0.18	1
C12	1 µF 100 volt	panasonic	E1105-ND	$0.71	1
C62	1 µF 100 volt	panasonic	E1105-ND	$0.71	1
C13	330 µF 25 volt	panasonic	P5703-ND	$0.65	1
C63	330 µF 25 volt	panasonic	P5703-ND	$0.65	1
C14	4700 µF 25 volt	panasonic	P5724-ND	$3.57	1
C64	4700 µF 25 volt	panasonic	P5724-ND	$3.57	1
C15	4700 µF 25 volt	panasonic	P5724-ND	$3.57	1
C65	4700 µF 25 volt	panasonic	P5724-ND	$3.57	1
C16	If needed (not needed with these components)				
C66	If needed (not needed with these components)				
R1	10 KΩ 1/4 watt	yageo	10.0KXBK-ND	$0.11	5
R2	909 Ω 1/4 watt	yageo	909XBK-ND	$0.11	5
R3	10 KΩ 1/4 watt	yageo	10.0KXBK-ND	$0.11	5
R4	909 Ω 1/4 watt	yageo	909XBK-ND	$0.11	5
R5	1 meg 1/4 watt (optional)	yageo	1.00MXBK-ND	$0.11	5
R55	1 meg 1/4 watt (optional)	yageo	1.00MXBK-ND	$0.11	5
R6	1 KΩ 1/4 watt	yageo	1.00KXBK-ND	$0.11	5
R56	1 KΩ 1/4 watt	yageo	1.00KXBK-ND	$0.11	5
R7	100 Ω 1/4 watt	yageo	100XBK-ND	$0.11	5
R57	100 Ω 1/4 watt	yageo	100XBK-ND	$0.11	5
R8	10 Ω 1 watt	yageo	10W-1-ND	$0.27	1
R58	10 Ω 1 watt	yageo	10W-1-ND	$0.27	1
R9	10 Ω 1 watt	yageo	10W-1-ND	$0.27	1
R59	10 Ω 1 watt	yageo	10W-1-ND	$0.27	1
R10	2.21 KΩ 1/4 watt	yageo	2.21KXBK-ND	$0.11	5
R60	2.21 KΩ 1/4 watt	yageo	2.21KXBK-ND	$0.11	5
R11	1 KΩ 1/4 watt	yageo	1.00KXBK-ND	$0.11	5
R61	1 KΩ 1/4 watt	yageo	1.00KXBK-ND	$0.11	5
R12	2.21 KΩ 1/4 watt	yageo	2.21KXBK-ND	$0.11	5
R62	2.21 KΩ 1/4 watt	yageo	2.21KXBK-ND	$0.11	5
D1	diode	gen. inst.	1N4007GICT-ND	$0.08	10
D2	diode	gen. inst.	1N4007GICT-ND	$0.08	10
D3	diode	gen. inst.	1N4007GICT-ND	$0.08	10
D53	diode	gen. inst.	1N4007GICT-ND	$0.08	10
D4	9.1 V Zener Diode	Diodes Inc.	1N5239BCT-ND	$0.22	1
D54	9.1 V Zener Diode	Diodes Inc.	1N5239BCT-ND	$0.22	1
D5	LED (red) (optional for power limit)	panasonic	P300-ND	$0.20	10
D55	LED (red) (optional for power limit)	panasonic	P300-ND	$0.20	10
D6	LED (red) (optional for power limit)	panasonic	P300-ND	$0.20	10
D56	LED (red) (optional for power limit)	panasonic	P300-ND	$0.20	10
U1	Positive adjustable voltage reg.	National Semi.	LM317T-ND	$1.30	1
U2	Negative adjustable voltage reg.	National Semi.	LM337T-ND	$2.45	1
U3	Dual op-amp	Burr Brown	OPA2132P-ND	$6.91	1
U4	Diode Bridge (4 amp)	Diodes Inc.	RS401LR-ND	$1.63	1
Q1	N Channel MOSFET	Harris	*RFP15N05	$0.99	1
Q2	P Channel MOSFET	Harris	*RFP15P05	$6.53	1
Q51	N Channel MOSFET	Harris	*RFP15N05	$0.99	1
Q52	P Channel MOSFET	Harris	*RFP15P05	$6.53	1
T1	Transformer (2 X 15 v secondary)	Telema	TE70063-ND	$18.23	1
POT1	100KΩ Dual Gang Log.	Alps	Radio shack	$1.99	1
	Heat Sinks (need 6)		HS132-ND	$7.74	1
			Total:	$87.35	
Notes:					
You will also need a case, RCA Jacks, and a power entry module.					
I like the Burr-Brown op-amps, either OPA2604 or OPA2132, but any dual op-amp should work					
Only use the power limiting LEDs if you are going to use bipolar transistors					
* The MOSFETs are available from Allied Electronics (800) 433-5700					

Layout:

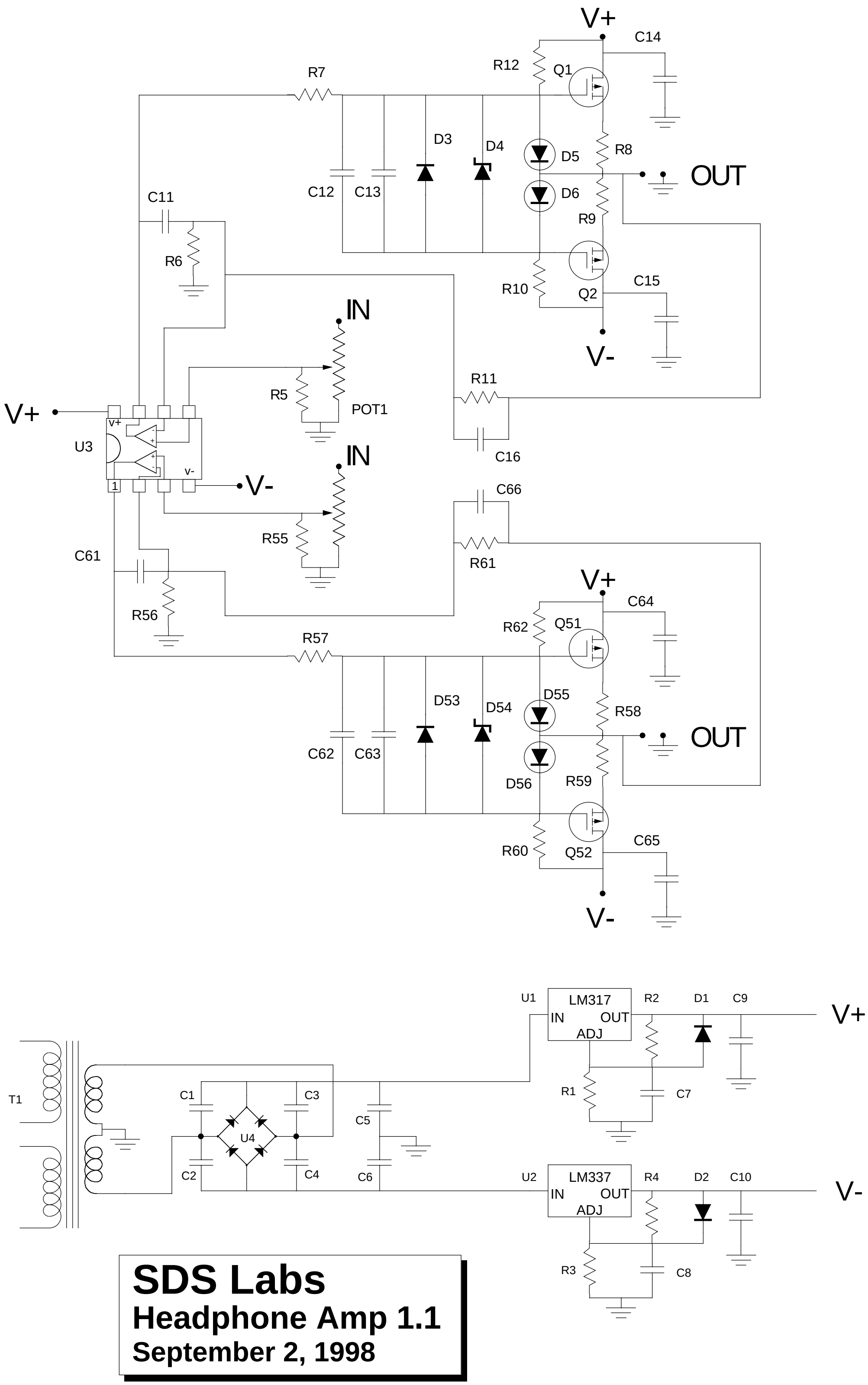


Outlines:



T1
C3
C4
U4
C1
C2
C5
C6
C7
D1
R4
R3
U1
R1
R2
D2
U2
R55
R56
U3
R5
R6
R11
C16
R61
C61
C11
R60
C66
R57
R7
R10
D53
D3
C63
C13
Q52
R9
Q2
R59
D56
D54
D4
D6
D55
C62
C12
D5
C15
C14
R8
R58
Q1
Q51
R12
C65
C64
R62

Schematic:


V+
C14
R12
Q1
R7
D3
D4
R8
D5
OUT
D6
C11
C12
C13
R9
R6
R10
C15
Q2
IN
V-
R11
R5
POT1
V+
U3
C16
IN
V-
C66
R55
R61
C61
V+
C64
R56
R62
Q51
R57
D55
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R58
OUT
C62
C63
D56
R59
R60
Q52
C65
V-
U1
LM317
R2
D1
C9
IN
OUT
V+
ADJ
T1
C1
C3
R1
C7
U4
C5
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C4
C6
U2
LM337
R4
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C10
IN
OUT
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R3
C8
SDS Labs
Headphone Amp 1.1
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