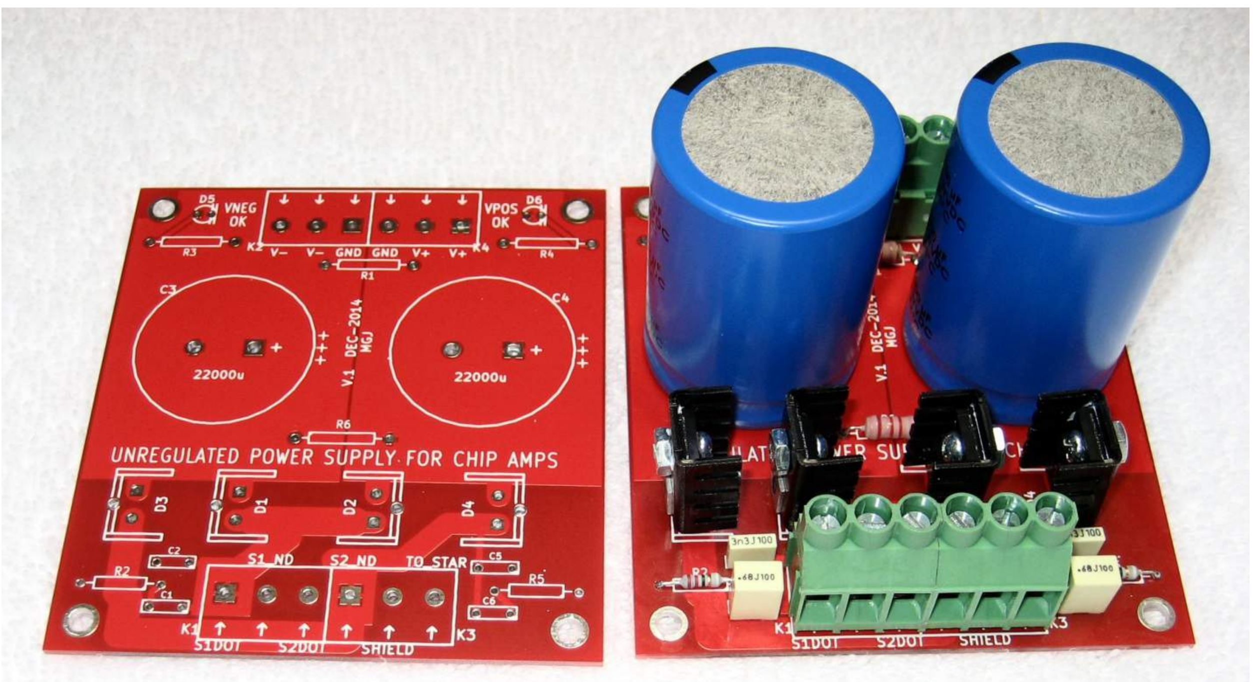
RingNot: an Unregulated Power Supply PCB for LM3886 Chip Amps

19 June 2015

Mark Johnson



Board Description

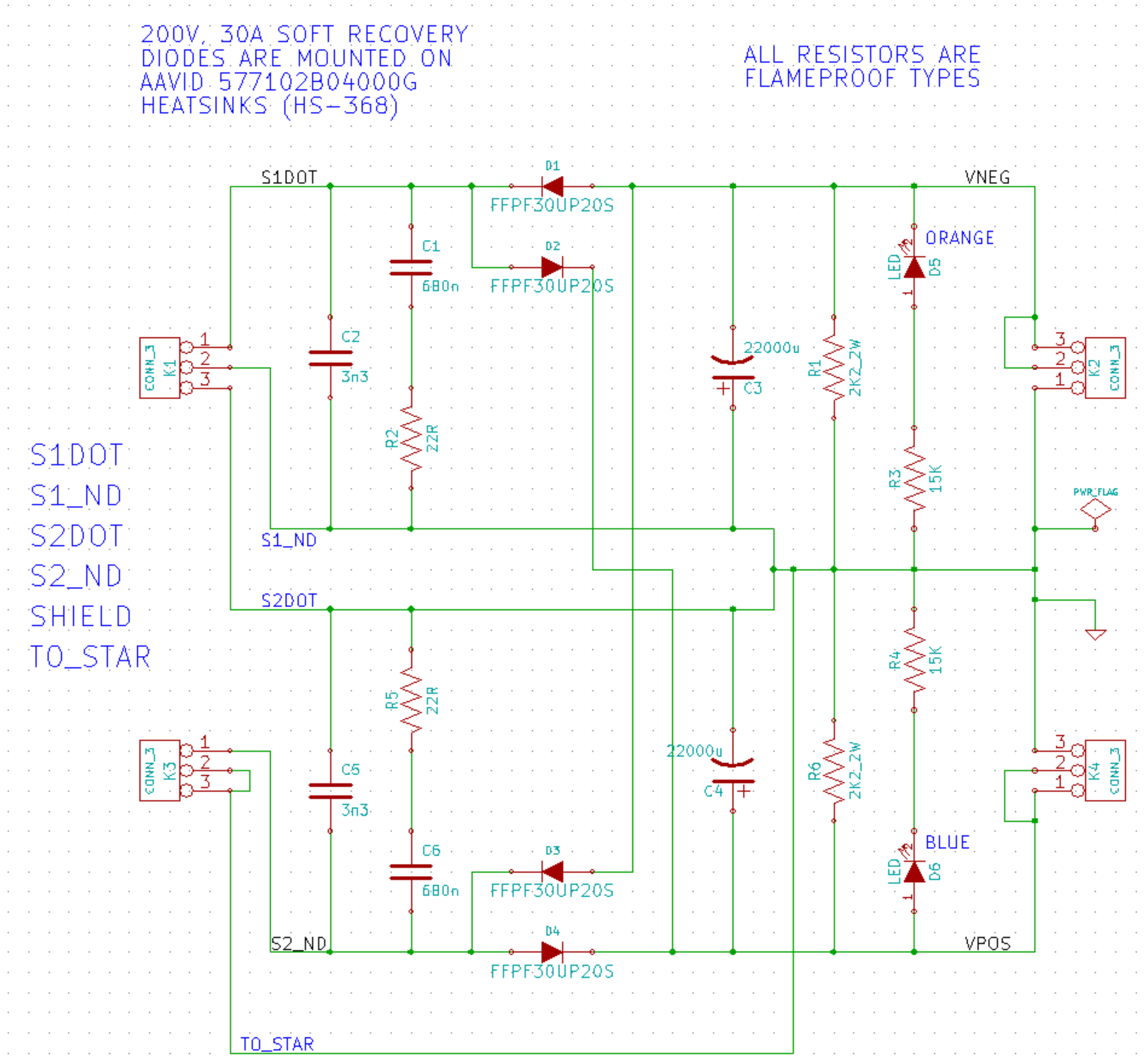
The RingNot PCB provides ±28V unregulated DC, to power LM3886 audio amplifiers. It must be used with a 200VA, dual 22V secondary, toroidal transformer from Antek. Their model AS-2222 (shielded) and/or model AN-2222 (unshielded) are the *only* transformers approved for use with the RingNot PCB.

The board uses two independent approaches to lower, and then eliminate, oscillatory ringing in the power transformer's secondary. These are (i) Soft Recovery rectifier diodes; and (ii) full CRC snubbers. The combination of these two technologies completely eliminates transformer ringing, as oscilloscope photos later in this document demonstrate.

The RingNot board can power two LM3886 integrated circuits, each operating at max output power. It supports the standard stereo configuration, with one LM3886 per stereo channel. RingNot also supports a single channel of bridge configuration, where two LM3886s drive one loudspeaker in push-pull. *Do not attempt to power more than two LM3886 chips from one RingNot PCB*. Do not attempt to power three channels (Left, Center, Right) of LM3886 amplifiers from a single RingNot. Do not attempt to power two channels of bridge configuration (with a total of four LM3886 chips) from a single RingNot PCB.

The board includes design upgrades that are absent from conventional PSUs: Four individual 30 ampere Soft Recovery Diodes are used, instead of a lower cost and lower performance bridge rectifier assembly. Two full CRC snubbers are included, for complete and total elimination of ultrasonic ringing in the transformer secondary. Power-is-on LED indicators are provided for both negative and positive DC outputs, making assembly and checkout easier.

Circuit Schematic



The two wires of secondary winding #1 are named "S1DOT" (the phase-dot end of the winding) and "S1_ND" (the winding end with No Dot). Secondary winding #2's wires are named "S2DOT" (the end with the phase-dot) and "S2_ND" (the end with No Dot). "SHIELD" is the electrostatic shield of the AS-2222 transformer, and "TO_STAR" is a wire that runs from the RingNot PCB to the equipment chassis-ground.

Each secondary winding has its own CRC snubber: C2-R2-C1, and C5-R5-C6. Their values are optimized for the Antek AS-2222 and AN-2222 toroidal transformers. Diodes D1-D4 are Soft Recovery types, which further reduce transformer ringing. The main filter capacitors, C3 and C4, are rated for 50 volts + 7.6 amps of ripple current, and the PCB layout accommodates capacitors as large as 41 mm diameter. Bleeder resistors R1 and R6 discharge these capacitors when the power is switched off, which avoids "dielectric absorption" and protects service personnel against accidental shocks.

Indicator LEDs D5-D6, with their current limit resistors R3-R4, glow when power-is-on, a handy feature during installation and checkout. The LEDs also warn service technicians if the large filter capacitors are not yet fully discharged.

The four wire-to-board I/O connectors K1-K4 are rated for 30 amperes per position, and can accept any diameter wires between AWG-24 and AWG-10.

Bill of Materials

I built quite a few RingNot PCBs using components sourced from DigiKey (US); here is the BOM using DigiKey part#s. Although you probably already have four machine screws and hex nuts in your junkbox, they are included here (in packs of 100!) too.

ID	qty	Description	dimensions	MFR part#	DigiKey part#
K1-K4	4	3 position terminal block, 30 amps, AWG10	6.35mm spcg	OSTT7030150	ED2676-ND
C2, C5	2	Film capacitor, 3.3nF 100V	5.0 mm spcg	R82EC1330AA50J	399-6034-ND
C1, C6	2	Film capacitor, 680nF 100V	5.0 mm spcg	R82EC3680AA70J	399-6039-ND
C3, C4	2	22,000 uF 50V electrolytic cap, 7.6 amps	D=35, S=10 mm	380LX223M050A052	338-2254-ND
R2, R5	2	Flameproof resistor, 22 ohms, 0.25 watts	D=2.4, L=6.3 mm	FRM-25JR-52-22R	22DSCT-ND
R1, R6	2	Flameproof resistor, 2.2K, 2 watts	D=3.9, L=9.0 mm	FMP200JR-52-2K2	2.2KZCT-ND
R3, R4	2	Flameproof resistor, 15K, 1 watt	D=2.4, L=6.3 mm	FMP100JR-52-15K	15KWCT-ND
D1-D4	4	Soft Recovery Diode 30A 200V TO220	TO220 FullPack	FFPF30UP20STU	FFPF30UP20STU-ND
D5	1	LED (orange), >1000 mcd	T-1, 3mm	WP710A10SEC	754-1588-ND
D6	1	LED (blue), >1000 mcd	T-1, 3mm	WP710A10QBC/D	754-1596-ND
HS1-HS4	4	TO220 Heatsink with PCB attachment pin	0.375" fin	577102B04000G	HS368-ND
--	4	4-40 hex nuts		HNZ 440	H216-ND
--	4	4-40 pan head machine screws, 1/4" long	0.25" long	PMS 440 0025 PH	H342-ND
PCB	1	Printed Circuit Board, 2 sided			

However, some builders may prefer to purchase components from other suppliers. Thus two alternative Bills of Materials are presented; one for Mouser Electronics, and the other for Newark / Element14 / Farnell (the company has different names in different countries):

ID	qty	Description	dimensions	MFR part#	Mouser part#
K1-K4	4	3 position terminal block, 30 amps, AWG10	6.35mm spcg	1714968	651-1714968
C2, C5	2	Film capacitor, 3.3nF 100V	5.0 mm spcg	R82EC1330AA50J	80-R82EC1330AA50J
C1, C6	2	Film capacitor, 680nF 100V	5.0 mm spcg	R82EC3680AA70J	80-R82EC3680AA70J
C3, C4	2	22,000 uF 50V electrolytic cap, 7.6 amps	D=35, S=10 mm	380LX223M050A052	5985-85-50V22000
R2, R5	2	Flameproof resistor, 22 ohms, 0.25 watts	D=2.4, L=6.3 mm	FRN25J22R	279-FRN25J22R
R1, R6	2	Flameproof resistor, 2.2K, 2 watts	D=3.9, L=9.0 mm	PR02000202201JR500	594-5083NW2K200J
R3, R4	2	Flameproof resistor, 15K, 1 watt	D=2.4, L=6.3 mm	PR01000101502JR500	594-5073NW15K00J
D1-D4	4	Soft Recovery Diode 30A 200V TO220	TO220 FullPack	FFPF30UP20STU	512-FFPF30UP20STU
D5	1	LED (orange), >1000 mcd	T-1, 3mm	WP710A10SEC	604-WP710A10SEC
D6	1	LED (blue), >1000 mcd	T-1, 3mm	WP710A10QBC/D	604-WP710A10QBC/D
HS1-HS4	4	TO220 Heatsink with PCB attachment pin	0.375" fin	577102B04000G	532-577102B04000G
--	4	4-40 hex nuts		5721-440-SS	5721-440-SS
--	4	4-40 pan head machine screws, 1/4" long	0.25" long	5721-440-1/4SS	5721-440-1/4SS
PCB	1	Printed Circuit Board, 2 sided			

ID	qty	Description	dimensions	MFR part#	Element14 part#
K1-K4	4	3 position terminal block, 30 amps, AWG10	6.35mm spcg	1714968	71C4092
C2, C5	2	Film capacitor, 3.3nF 100V	5.0 mm spcg	FKS2D013301A00KSSD	94M7298
C1, C6	2	Film capacitor, 680nF 100V	5.0 mm spcg	R82EC3680DQ70K	87X9215
C3, C4	2	22,000 uF 50V electrolytic cap, 7.6 amps	D=35, S=10 mm	380LX223M050A052	12C7441
R2, R5	2	Flameproof resistor, 22 ohms, 0.25 watts	D=2.4, L=6.3 mm	MCF 0.25W 22R	38K0350
R1, R6	2	Flameproof resistor, 2.2K, 2 watts	D=3.9, L=9.0 mm	PR02000202201JR500	94C2466
R3, R4	2	Flameproof resistor, 15K, 1 watt	D=2.4, L=6.3 mm	PR01000101502JR500	94C2310
D1-D4	4	Soft Recovery Diode 30A 200V TO220	TO220 FullPack	FFPF30UP20STU	31Y1429
D5	1	LED (orange), >1000 mcd	T-1, 3mm	MCL034SAC	14N9382
D6	1	LED (blue), >1000 mcd	T-1, 3mm	MCL034SBLC	14N9384
HS1-HS4	4	TO220 Heatsink with PCB attachment pin	0.375" fin	577102B04000G	18M8197
--	4	M3 hex nuts		M3-HFST-Z100-	53M8681
--	4	M3 pan head machine screws, 1/4" long	0.25" long	M36 CSSTMCZ100-	53M8775
PCB	1	Printed Circuit Board, 2 sided			

Assembling the PCB

◯ 1. Slide together a pair of 3-position terminal blocks (using the mating slots along the sides), to make a 6-position terminal block. Repeat with the other pair.

◯ 2. Apply a very thin film of thermal grease (Wakefield 120 or AAVID ThermalCote) to the backs of the four diodes. Attach the diodes to the heatsinks using machine screws + hex nuts. Either 1/4 inch long 4-40, or 6mm long M3, will work. If desired, apply threadlocker adhesive such as Loctite Blue to the threads before tightening the nuts. See Photo1 below. On the left is a Soft Recovery diode with thermal grease; on the right is an assembled diode + grease + heatsink.

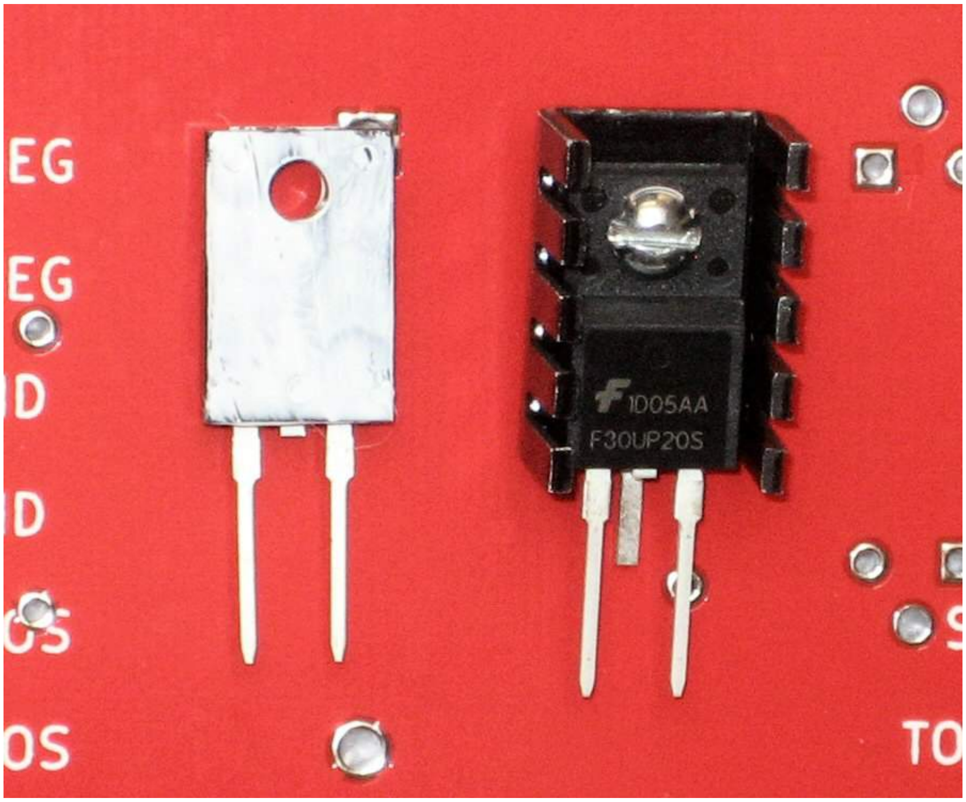


Photo 1: Diode With Thermal Grease Applied (left); Completed Assembly (right)

◯ 3. Wipe off any excess thermal grease from the heatsink assemblies, using Q-tips and >90% isopropyl alcohol. Set the heatsinks aside to dry for at least 30 minutes, while stuffing and soldering other components.

◯ 4. Insert one of the 6-pin terminal block assemblies into the PCB and secure it with masking tape, so it remains flush with the PCB surface during soldering. Repeat with the other terminal block.

◯ 5. Solder both terminal blocks to the PCB. Remove the masking tape. Don't bother to trim the leads.

◯ 6. Use a digital multimeter on ohms setting, to double-check the values of the six resistors. Stuff all six resistors, bending their leads on the solder side of the PCB so the resistors are held firmly in place before soldering.

◯ 7. Stuff the four film capacitors C1, C2, C5, C6, bending their leads on the solder side of the PCB so the capacitors are held firmly in place before soldering.

◯ 8. Solder the 6 resistors and 4 film capacitors. Trim the leads.

◯ 9. Insert diode D1 and its heatsink. Bend one lead to the left and the other lead to the right, so the diode is held firmly in place during soldering. Stuff the other 3 diodes+heatsinks and bend their leads the same way.

◯ 10. Solder the diode leads but *do not the solder heatsink attachment pins* (yet). When all diode leads are soldered, invert the board and study the diodes. Are they perpendicular to the PCB, or are they angled slightly? Adjust the positions of the diodes to make them vertical, and then solder the heatsink attachment pins. Trim the diode leads. Don't bother to trim the attachment pins.

◯ 11. Insert the orange LED in position D5. The LED cathode (shorter lead) is indicated on the PCB silkscreen with two parallel lines. The LED anode (longer lead) goes into the hole without two parallel lines. When the PCB is rotated such that D5 is at top left and D6 is at top right, D5's cathode (shorter lead) goes into the right hole and D5's anode (longer lead) goes into the left hole. Bend the leads flush with the board.

◯ 12. Insert the blue LED in position D6. The LED cathode (shorter lead) is indicated on the PCB silkscreen with two parallel lines. Bend the leads flush with the board.

◯ 13. Solder D5 and D6 in place and trim the leads.

◯ 14. Use a metal screwdriver to short together the pins of electrolytic capacitor C3, then short the pins of C4. These may have retained charge during shipping (and shorting them may produce a spark!), through a mechanism known as "dielectric absorption". Short them before assembly, for safety. Once C3 and C4 are soldered to the board, "bleeder" resistors R1 and R6 ensure they remain discharged.

◯ 15. Snap C3 and C4 into the PCB, carefully observing their polarity. Turn the PCB upside down and let it rest on the capacitors. Push the board down onto the capacitors so they are completely snug and flush with the board, and then bend the capacitor leads to hold the caps snugly in place during soldering.

◯ 16. Solder C3 and C4 in place, then use big beefy side-cutting pliers to trim their very thick leads. Don't dull your small, precision cutters on these tree stumps.

◯ 17. Use >90% isopropyl alcohol and a toothbrush to scrub off the excess flux and grime from the solder side of the board. Wipe with a paper towel. If desired, blow with a hair dryer on medium or low heat.

Tracing and Labeling the Transformer Windings

The Antek AN-2222 and AS-2222 have two primary windings and two secondary windings. Unfortunately, Antek's color scheme is ambiguous; it does not tell you which two wires are Primary Winding #1 and which two wires are Primary Winding #2, for example. So we will trace the windings ourselves, using a digital multimeter (ohms setting), and we'll mark them with pieces of colored tape.

Collect two different colors of adhesive tape or other colorful wire-marking supplies. These might include transparent tape (Scotch tape), blue masking tape, black electrical tape, tan adhesive bandage tape (Band-Aids), tan rubber bands, white dental floss, white first-aid tape, and so on. You only need two different colors.

◯ 18. Choose one of the transformer's two red wires, at random. Attach Color1 tape to this red wire. Test both black wires, find the one which has low-ohms continuity to the Color1 red wire. Attach Color1 tape to this black wire. At the transformer, where the wires emerge from the toroid, tape together the Color1 red wire and the Color1 black wire, using Color1 tape (of course!). Taping them together reminds you *these two wires are a pair*. They're the Color1 primary.

◯ 19. Attach Color2 tape to ***the other*** red wire. Test to see that the other black wire has low-ohms continuity to the Color2 red wire. If so, attach Color2 tape to this black wire. . At the transformer, where the wires emerge from the toroid, tape together the Color2 red wire and the Color2 black wire, using Color2 tape (of course!). Taping them together reminds you that *these two wires are a pair*. They're the Color2 primary pair.

◯ 20. Choose one of the two blue wires at random. Attach Color1 tape to this blue wire. Test both green wires, find the one which has low-ohms continuity to the Color1 blue wire. Attach Color1 tape to this green wire. At the transformer, where the wires emerge from the toroid, tape together the Color1 green wire and the Color1 blue wire, using Color1 tape (of course!). Taping them together reminds you that *these two wires are a pair*. They're the Color1 secondary pair.

◯ 21. Attach Color2 tape to ***the other*** blue wire. Test to see that the other green wire has low-ohms continuity to the Color2 blue wire. If so, attach Color2 tape to this green wire. At the transformer, where the wires emerge from the toroid, tape together the Color2 green wire and the Color2 blue wire, using Color2 tape (of course!). Taping them together reminds you that *these two wires are a pair*. They're the Color2 secondary pair.

Spend 60 seconds double checking your color markings with the multimeter. Color1_Red should have low-ohms with Color1_Black. Color2_Red should have low-ohms with Color2_Black. Color1_Blue should have low-ohms with Color1_Green. Color2_Blue should have low-ohms with Color2_Green. Congratulations, you've traced all four windings!

Mounting the Transformer to the Chassis

Figure 1 shows an expanded view of the toroidal transformer mounting system. The bottom rubber pad lays on floor of the chassis, and the toroid rests on the bottom pad. The toroid is positioned such that the primary and secondary wires exit from the top of the toroid (away from the chassis floor). The mounting bolt and hex nut apply force through the pressure plate and rubber pads, securing the transformer firmly against the chassis.

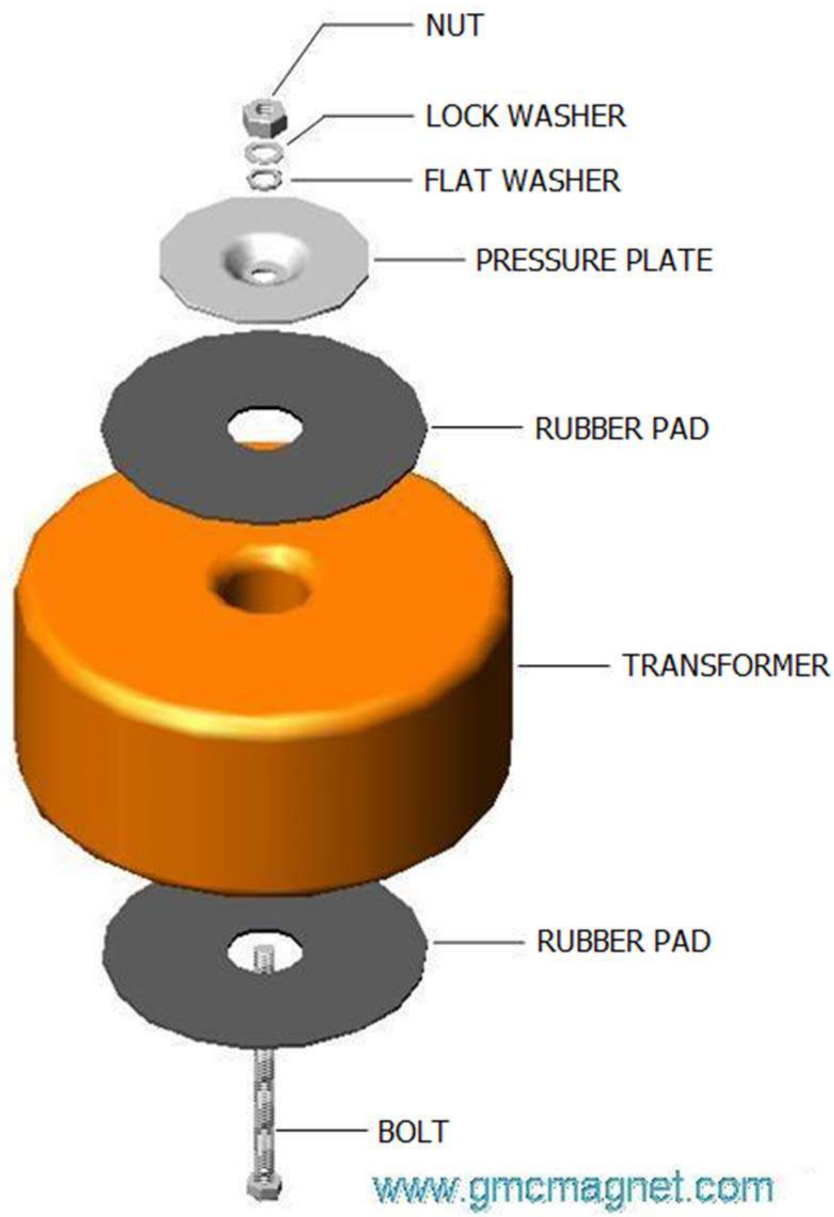


Figure 1: Expanded View of Transformer Mounting Hardware

Since the bolt makes contact with the chassis bottom, it is imperative that the nut should NOT be in electric contact with the chassis. That would create an unwanted and disastrous extra winding on the transformer, called a *shorted turn*, which would conduct enormous amounts of current and immediately blow the primary fuse.

EDN magazine published an article on toroid mounting, which included some cautionary diagrams of what NOT to do. Figure 2 is a shorted turn through the bracket and chassis, and Figure 3 could become a shorted turn if the top cover is pressed at the arrow, such that it contacts the mounting nut.

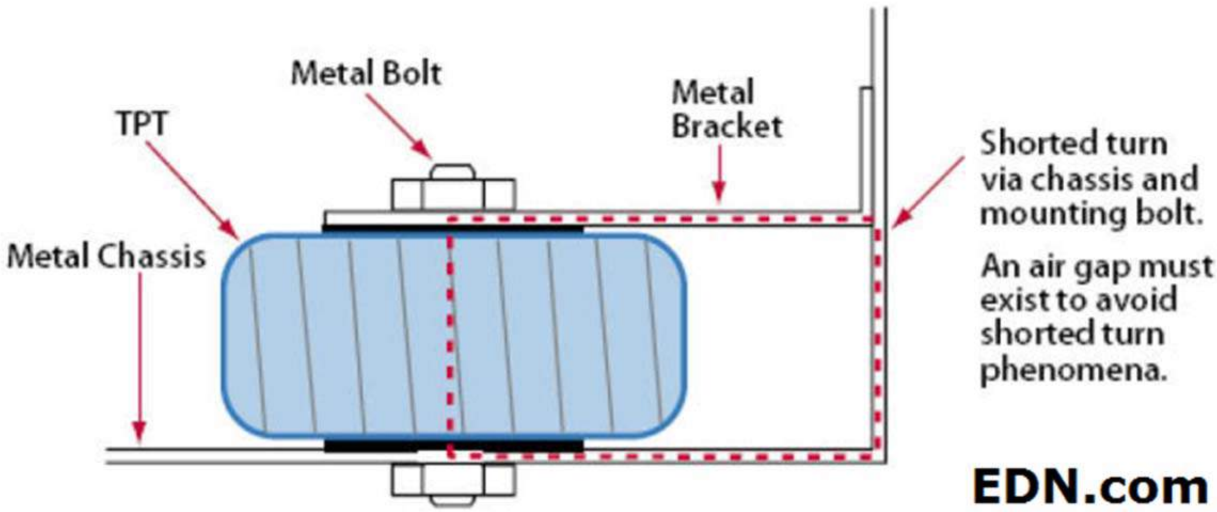


Figure 2: Do NOT Mount a Toroidal Power Transformer This Way!

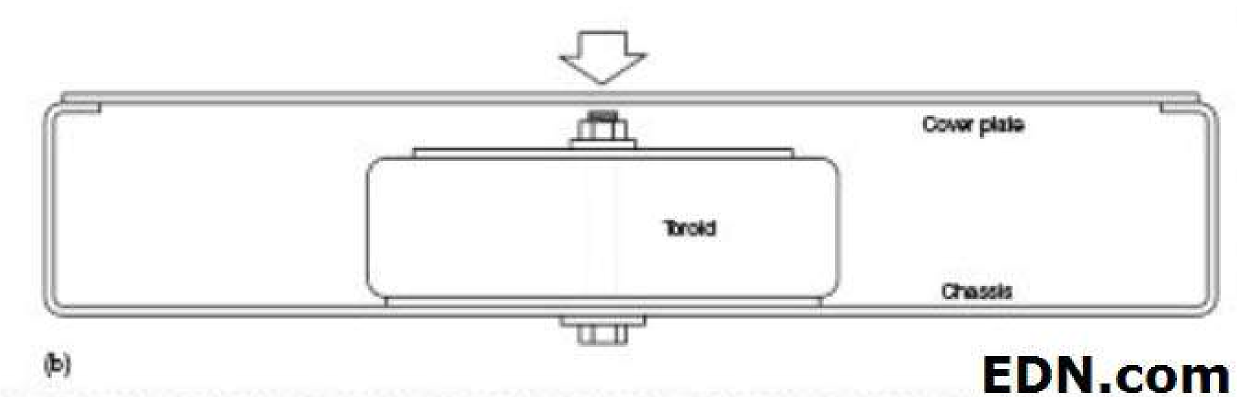


Figure 3: Don't Mount a Toroidal Transformer This Way Either!

Connecting the RingNot PCB to the AC Mains

Figure 4 shows how the power supply PCB connects to an Antek AS-2222 and to the 115VAC mains

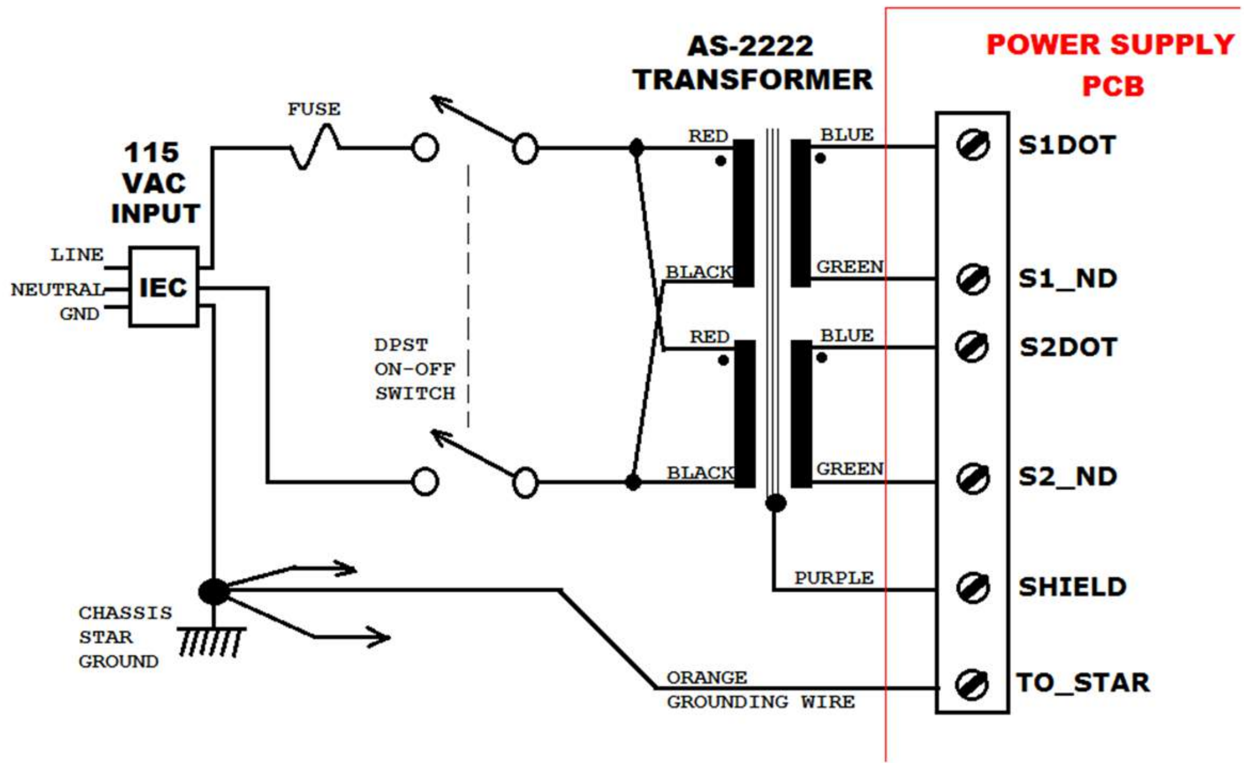


Figure 4: Transformer and Mains connections for 115VAC operation

The "phase dots" are marked on Figure 4; these dots show which ends of the four windings are in phase. The printed labels on the power supply PCB, explicitly call for these phase dots (the labels appear on both the top and the underside of the PCB):

S1DOT	**Dot** end of Secondary#1	Blue wire	Color1 tape
S1_ND	**N**o**D**ot end of Secondary#1	Green wire	Color1 tape
S2DOT	**Dot** end of Secondary#2	Blue wire	Color2 tape
S2_ND	**N**o**D**ot end of Secondary#2	Green wire	Color2 tape

IMPORTANT! You must connect a safety ground wire from the PSU PCB, to the chassis safety ground's star point. This insulated, stranded wire must be AWG-16 or thicker; it is shown on Figure 4 as the ORANGE GROUNDING WIRE. Of course, any insulation color is acceptable; orange is suggested merely because AS-2222 has no orange wires.

The primary connections for 115VAC are shown in Figure 4; the two red wires are connected together, and the two black wires are connected together. For 115VAC operation a 2.5 Amp, slow-blow fuse is appropriate. An IEC power inlet with built-in fuse holder and EMI filter is recommended.

If you are using the AN-2222 instead of the AS-2222, your transformer has no Purple wire and therefore you make no connection to the "SHIELD" input connector. The example schematic for 230VAC mains in Figure 5, illustrates:

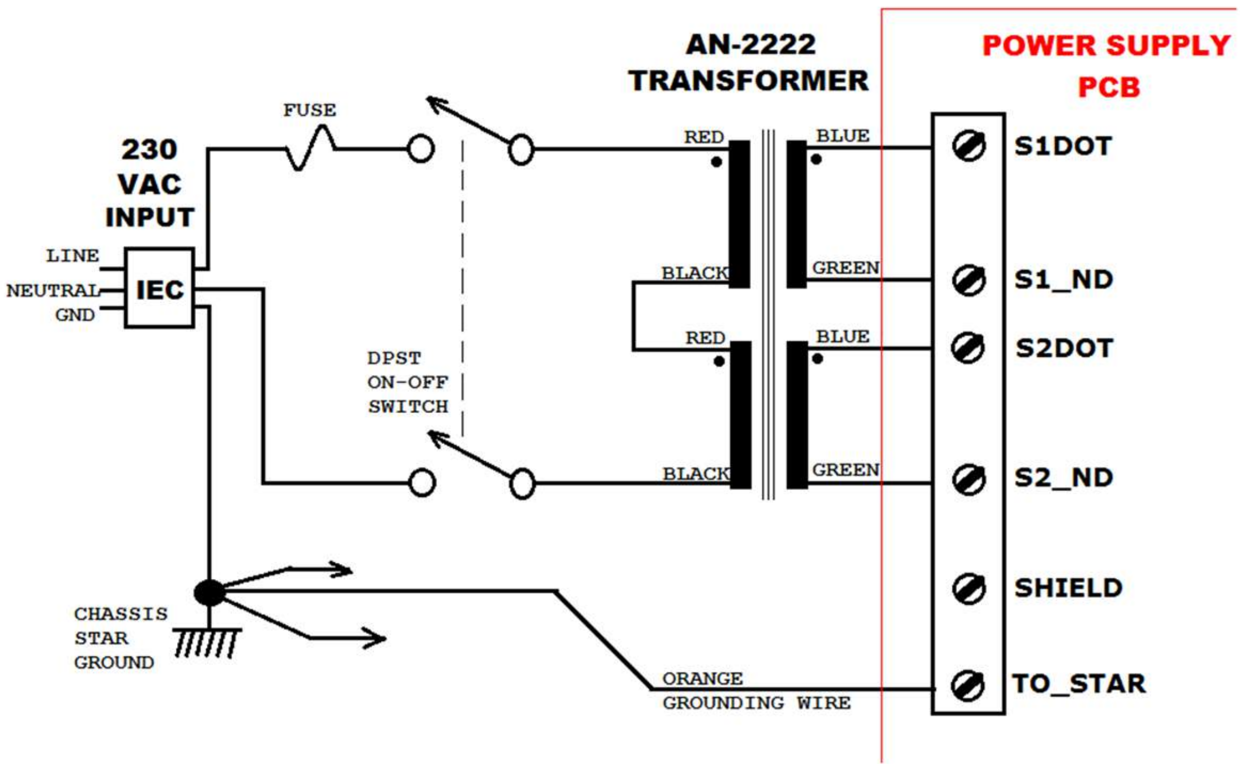


Figure 5: Transformer and Mains connections for 230VAC operation

The primaries are connected in series for 230V; the black wire of secondary #1 connects to the red wire of secondary #2. For 230V operation a 1.2 Amp, slow-blow fuse is appropriate. An IEC inlet with built-in fuse holder and EMI filter is recommended.

Connecting RingNot to the Amplifier Boards

Figure 6 shows the power supply PCB driving a pair of LM3886 amplifier boards, such as the Modulus86 boards from Neurochrome Audio.

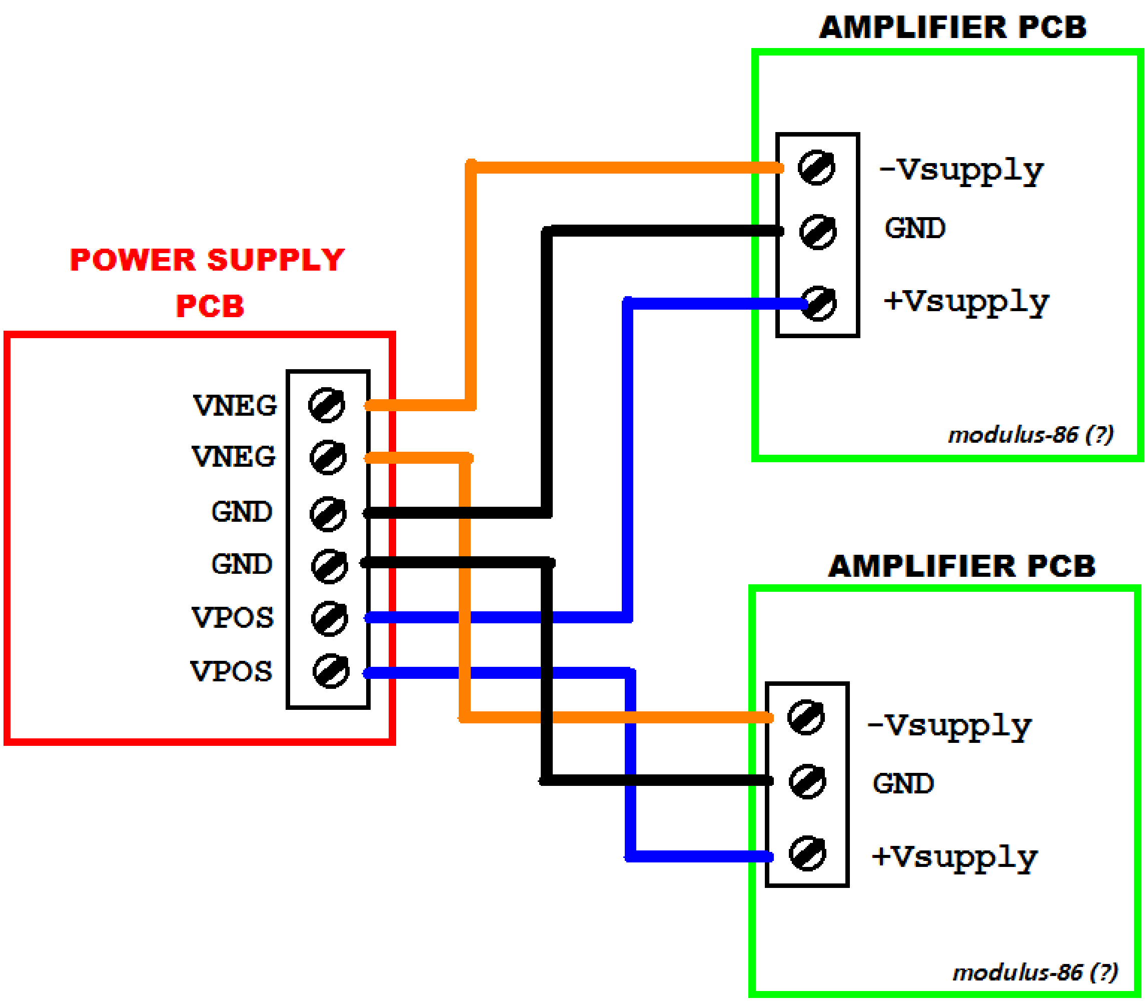


Figure 6: Wiring the RingNot PCB to the Amplifier PCBs

Use stranded, heavy gauge insulated wire, AWG-16 or thicker, to make the six connections between the power supply PCB and the amplifier boards.

Performance Comparison vs. Conventional PSU

To measure the performance benefits of the Soft Recovery Diodes and full CRC snubbers used in the RingNot design, a second PCB was fabricated which omitted them. Instead, this second PCB used a conventional design with a GBU2510 bridge rectifier (mounted on an Aavid Thermalloy 5301 heatsink) and an 0.1uF capacitor directly across each secondary. It is the same basic B.Cordell / D.Self / R.Elliott design used in the Power86 board and many others. The second PCB is shown in Photo2.

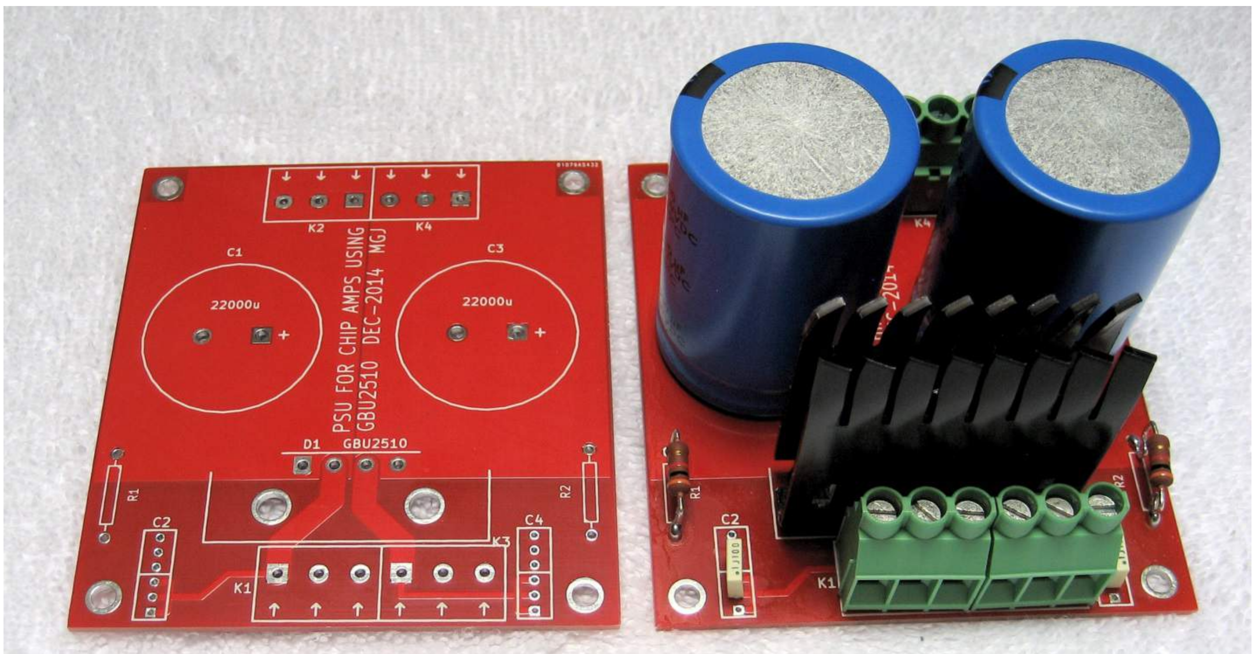


Photo 2: Conventional PSU

Figure 7 is an oscilloscope photo of the conventional PSU (without SR diodes and without CRC snubbers), showing the voltage across the secondary. An ultrasonic oscillation occurs at the instant when the rectifier diodes shut off, and the 0.1uF capacitor ensures it rings with fairly high Q.

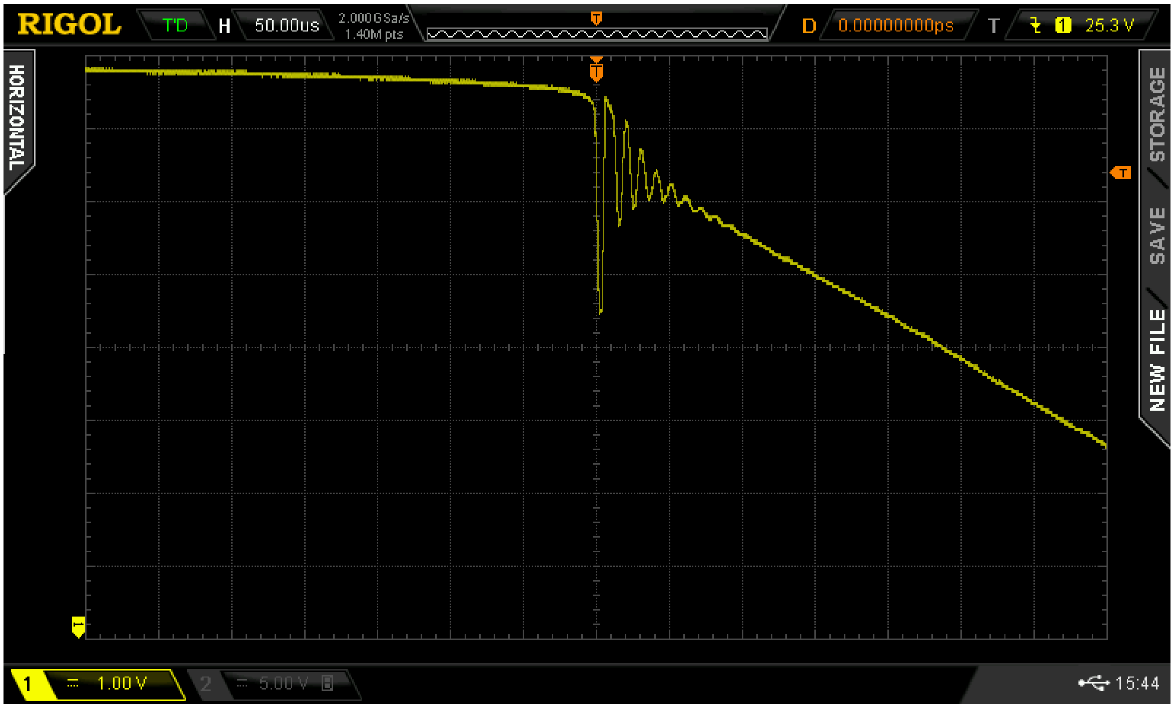


Figure 7: Conventional PSU PCB   50us/div, 1V/div

Figure 8 shows the secondary waveform of the RingNot PSU board, with SR diodes and CRC snubbers, driving the same load and using the same horizontal and vertical scope settings. Observe that ultrasonic oscillation has been *completely eliminated*.

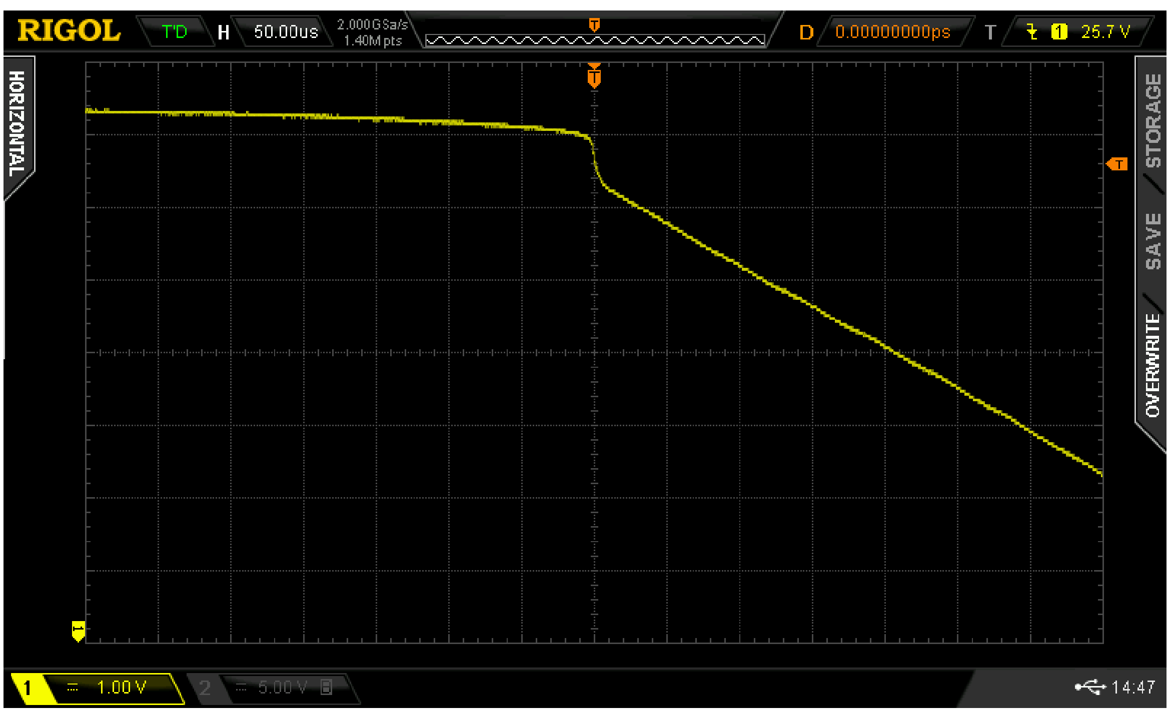


Figure 8: RingNot PSU PCB   50us/div, 1V/div

There is an extra cost, of course: RingNot's four diodes and four heatsinks really do cost more than one bridge rectifier and one (much bigger) heatsink. Four capacitors and two resistors in the snubbers, do cost more than two capacitors. How much more? A total of $8.00 more, if you buy in quantity=1 from DigiKey or Mouser. However the mantra of DIY audio equipment is: *make it as good as you possibly can!* This is why DIYers build amplifiers with sub 0.0004% THD, sinewave generators with sub 0.0001% THD, and preamp power supplies with output impedances below a micro-ohm.

Make it as good as you possibly can! If that costs an extra $8, so what? This is DIY perfectionist audio, not retail cutthroat dung-in-a-box. If the extra parts cost really, really bothers you, one way to offset the extra $8 is to purchase your PCBs from a lower cost, overseas fab. The website http://www.pcbshopper.com can help you find several PCB manufacturers who will fabricate qty=10 PCBs, 9.9cm x 9.9cm (larger than this board), for less than $40.00 including shipping to the US. That's $10 less than the price of one power supply PCB from some vendors, AND you'll have nine leftover boards to sell or give away. I'll give you the Gerber files of this design (the electronic representation of the board layout, which is the input to the PCB fab), for free.

There's one more scope photo. Figure 9 shows the conventional PSU, at higher resolution:

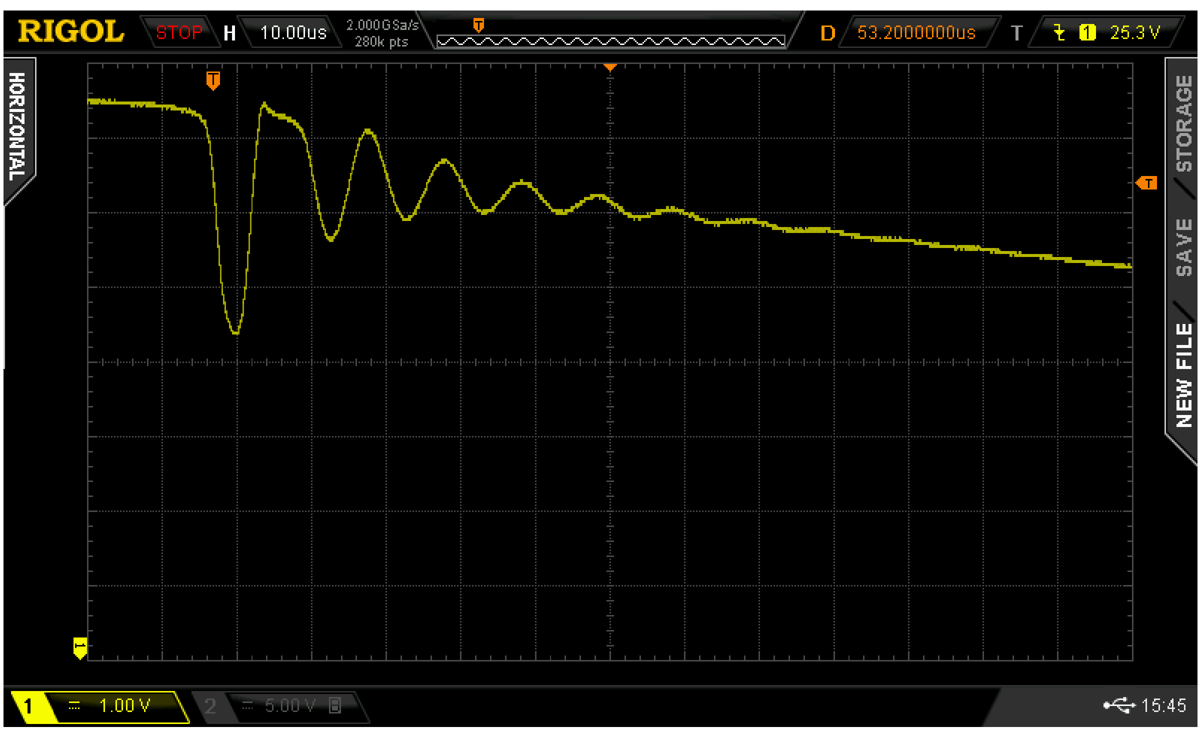


Figure 9: Conventional PSU, zoomed in 10us/div, 1V/div

Optional Material: More About Phase Dots

This section of the manual discusses a potential problem that is exceedingly unlikely to appear in real life, and then offers a solution. Don't read it unless you're paranoid.

Antek's AN-2222 and AS-2222 have two primary windings and two secondary windings. It is crucial that *these windings must be connected in the correct phase*, otherwise truly enormous currents will flow, limited only by the resistance of the copper wiring. Fuses will blow, the transformer will overheat, tempers will flare.

By convention, transformer schematics indicate the polarity of their windings using "phase dots." The dotted ends of the windings are in phase with each other, and out of phase with the not-dotted ends of the windings. The Phase dots are marked on schematics of the Antek AN-2222 and AS-2222 transformers, in Figure 10 below:

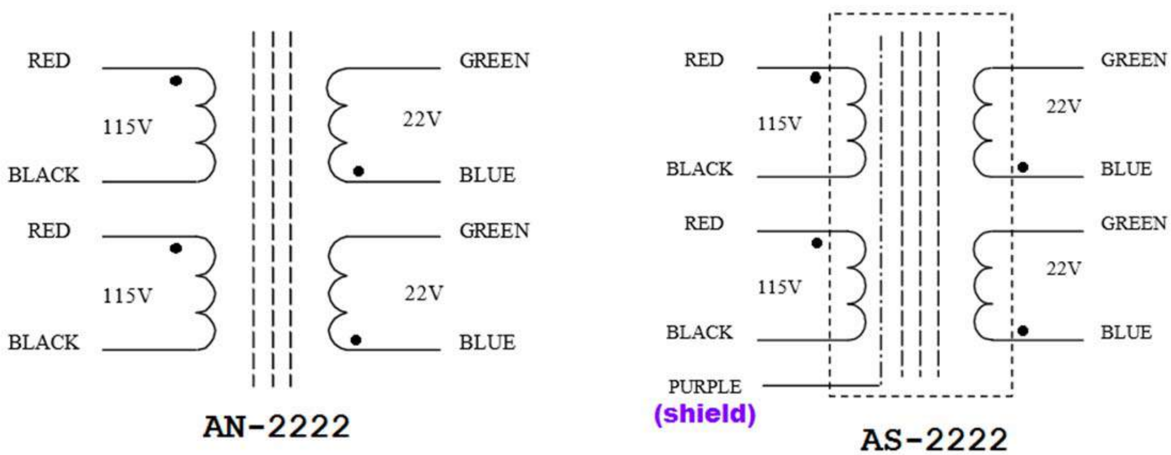


Figure 10. Phase Dots of the Antek Transformers I Personally Tested

Very rarely, a bad transformer will flow all the way through manufacturing testing with one or more windings mislabeled. In other words, its phase dots are wrong. Although this is extremely unlikely, it has been known to happen on cheaper, **non-Antek** transformers. I myself have never seen a transformer whose phase dots were wrong. (Although I have seen quite a few cheap transformers that had no phase dot markings at all!)

The Antek transformers used in this project are high quality devices and there is absolutely no reason to suspect their windings might be mislabeled. However, for those builders who prefer extreme caution, here is a test method to verify phase dots.

The test is quite simple: apply a 150 Hz waveform to one winding and observe it on another winding. If the waveform on the receiver winding is "right side up" (noninverted) then the two windings are in phase. If the observed waveform on the receiver winding is "upside down" (inverted) then the two windings are out of phase:

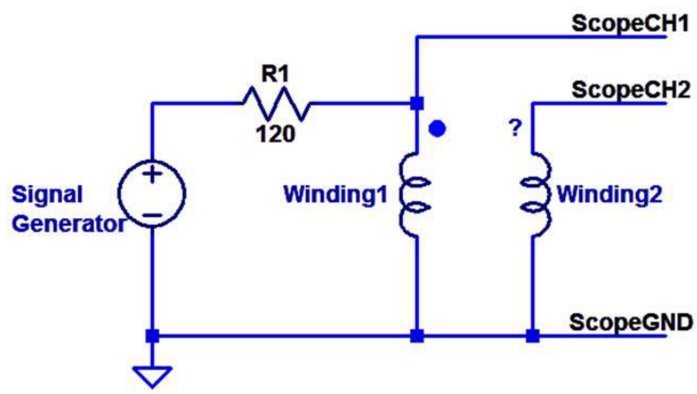


Figure 11: Test Setup to Determine the Correct Phase Dots

A signal generator and current limiting resistor are applied to a winding whose polarity dot is known. In Figure 11 that's Winding 1. (If no dots are known, arbitrarily assign a dot to one end of a primary winding and start with it). You'll get best results if you use a highly asymmetric waveshape; either a sawtooth (not a triangle!) or a square wave with duty cycle less than 20%, works well. Asymmetry makes it easier to distinguish between right side up and upside down. Both windings are observed on an oscilloscope. If CH2 is right side up (same shape as CH1) then Winding2 replaces "?" with a DOT. If CH2 is upside down then Winding2 gets a DOT on the other end. Now disconnect Winding2, connect Winding3, and test again. Repeat for all Windings..

For those builders who are extra cautious, and want to verify their transformer's phase dots, but don't have access to a signal generator and oscilloscope … I suggest you trust Antek and stop worrying. But if you absolutely insist upon testing your transformer, there is a small homemade tester called "Phase Dots" on the diyAudio.com website that can help you. It connects to two windings of a transformer, and lights up a green LED if the two windings are in phase, or lights up a red LED if they are out of phase. No oscilloscope and no signal generator are needed. No lab power supply either; it's 9V battery operated.

Figure 12 below, shows the “Phase Dots” tester board connected to Primary1 of an Antek AS-2222 (red + black), and to Secondary1 of the same transformer (green + blue). The green “IN PHASE” LED is illuminated, showing that the top wire of the upper pair (blue) is in phase with the top wire of the lower pair (red). In other words, if red has a Phase Dot, then so does blue. This agrees with the AS-2222 phase dots shown on the schematics in Figures 4, 5, and 10. All the data is consistent. Hallelujah.

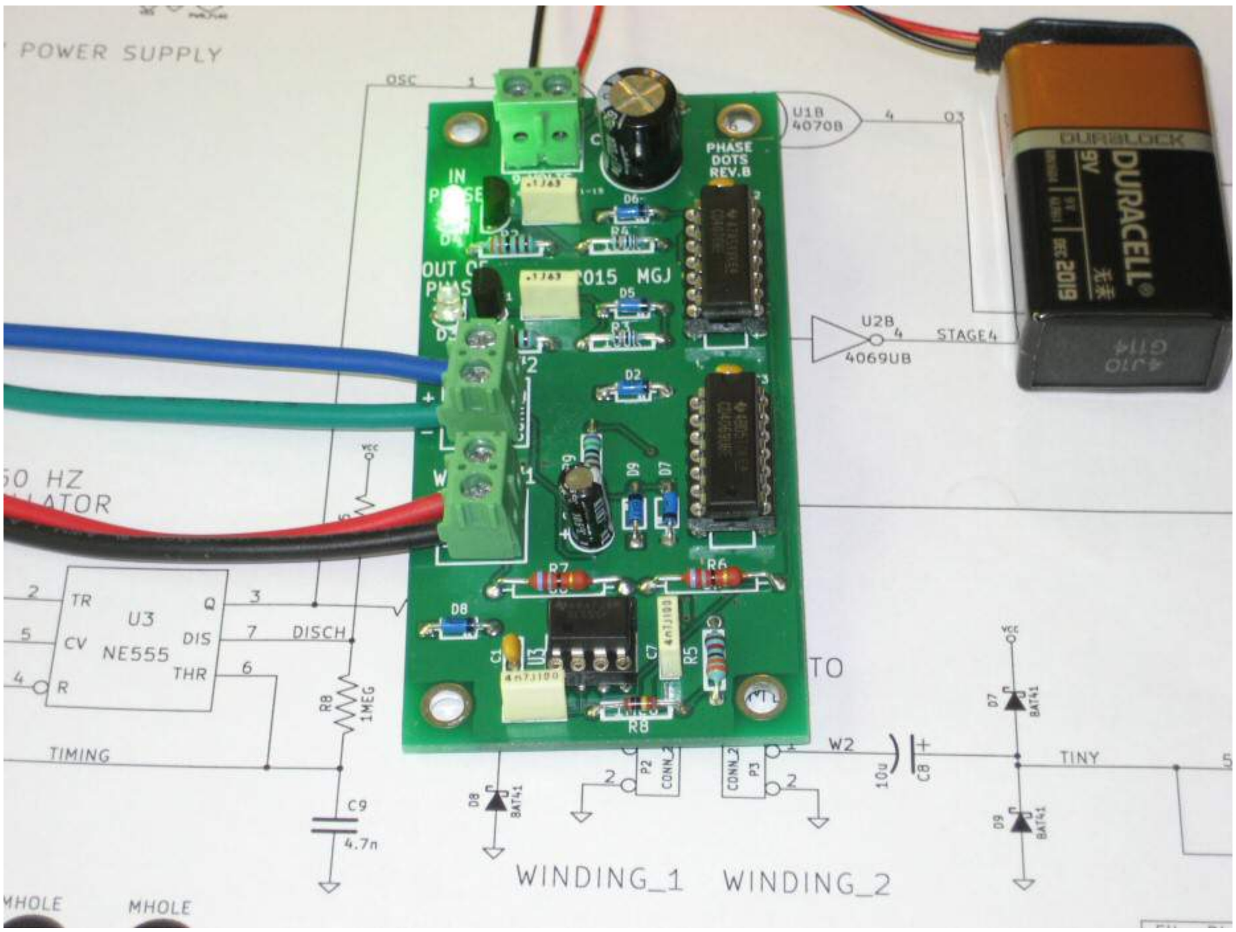


Figure 12: Phase Dots Tester Results on Antek AS-2222 Transformer