solid state

A Simple Audio System,

Part 3: Class A Transistor Amp

By Aren van Waarde

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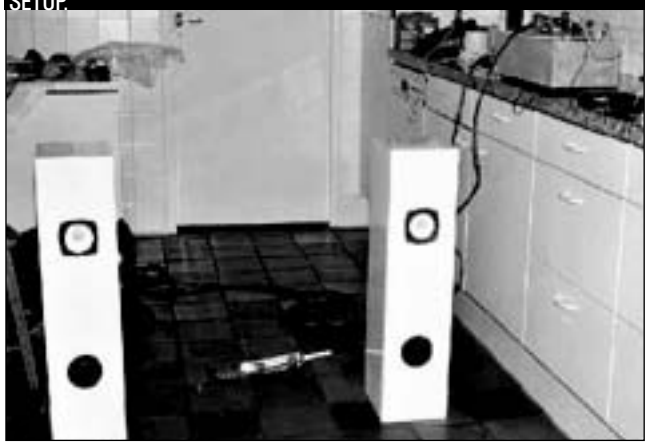
In this series final, the author presents a solid-state alternative to the single-ended tube amp and matching pair of speakers presented previously.

PHOTO 1: BUILDING A SOLID-STATE VERSION OF THIS TUBE-BASED SETUP.



The idea for this project came about when I discovered an interesting website on the Internet: the "RED Free Circuits Page[1]." My curiosity was aroused by that name. In what sense can circuits be red?

It turned out that "RED" is an acronym for "Ricerche Elettroniche Dellepiane," or, in English "Dellepiane Electronics Research." Flavio Dellepiane, the maker of the site, is a friendly Italian from Campomorone, 20km north of Genoa. He is an electronics hobbyist who has been building audio equipment for at least 30 years. His well-documented site includes almost 100 projects. Some of his designs have been published in the British magazine *Electronics World* (formerly *Wireless World*) and have been recognized with honors.

A RED CIRCUIT

RED Circuit 80 grabbed my attention. The header of the web page read: "3–5W Class A Amplifier. Behaves like a valve amplifier. Simple circuitry. No crossover distortion." The text continues: "In the old valve days, most commercial audio amplifiers in compact record play-

FIGURE 1: AMPLIFIER SCHEMATIC (BOTH CHANNELS ARE IDENTICAL).

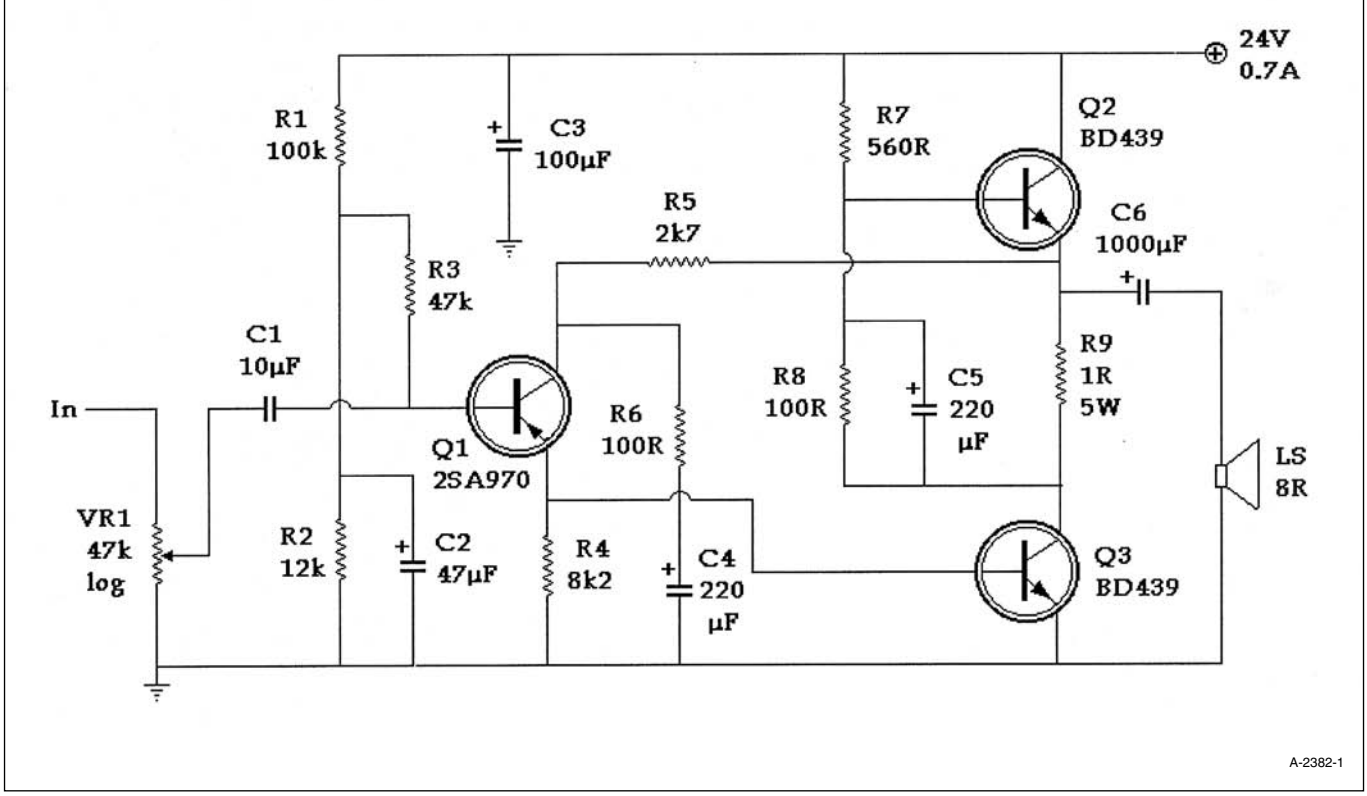
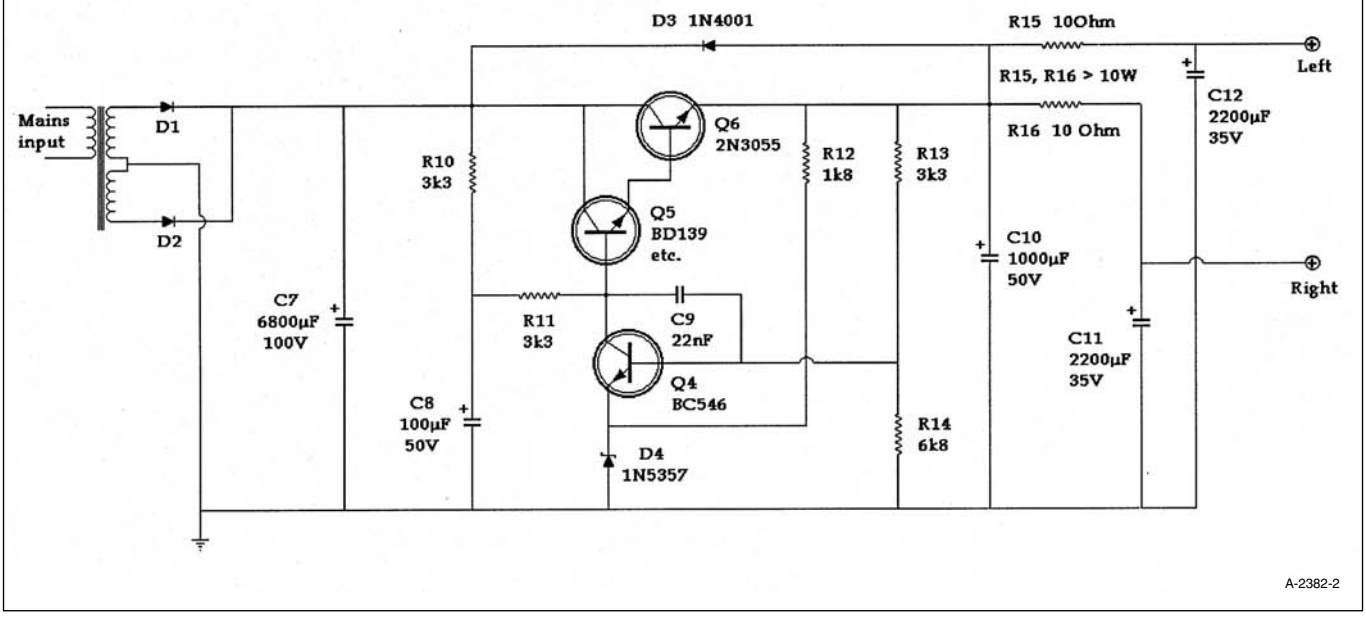


FIGURE 2: POWER-SUPPLY SCHEMATIC.



ers used a single-valve topology. The circuit usually employed a compound valve, e.g., a triode-pentode ECL86. This solid-state Class A circuit is capable of providing a sound comparable to those valve amplifiers, delivering more output power, less THD, higher input sensitivity, and better linearity."

This text was sufficient to get me hooked! Flavio claims that a solid-state amp (with just three bipolar transistors per channel, *Fig. 1*) can produce a sound similar to the valve amp that was the subject of Part 1. Unlikely though this may be, it is not impossible. The Zen series of amplifiers, designed by Nelson Pass, can, in fact, produce tube-like sound. I am the proud owner of a Zen Revisited amplifier (Zen with a pi filter in the power supply and a small amount of negative feedback) that is about five years old and sounds excellent.

Thus, I decided to heat my soldering iron. Initially, I made a single-channel prototype using Japanese transistors from the junkbox: one 2SA970 and two 2SC2581s. Although Flavio used different semiconductors (one BC560C and two BD439s), my first prototype worked exactly as the amplifier on the RED Circuit page: current draw 0.67A (should be 0.7) and voltage at C6 positive 13.78V (should be 13V).

For a second prototype, I used 2SC3263s instead of 2SC2581s, but that turned out to be a poor choice. Because of the low h_{FE} of the 2SC3263s, I could not obtain the right circuit voltages and currents, even after tweaking the values of resistors R2 and R7 (more later). I made my third prototype from a single 2SA970 and two BD439s, which worked out well (current draw 0.7A, voltage at C6 positive 13.7V).

Although BD439 transistors are smaller and have a lower f_T than 2SC2581s, I preferred the sound of prototype 3 over that of prototype 1. So I used another 2SA970 and two BD439s for prototype 4. Now I had two identical channels that I could use as a stereo amplifier. I used 2SA970s instead of BC560Cs because I had them in my

junkbox. Also, rumor has it that the 2SA970 is good for audio.

POWER SUPPLY

A stereo pair of RED Circuit 80s draws a continuous current of 1.4A from a +24V DC power supply. Flavio's site does not give any suggestions for a PSU. I thought it might be worthwhile to use a voltage regulator, not because any change in current draw is to be expected, but because of the hum suppression which a voltage regulator may provide.

A simple but effective three-transistor voltage regulator is presented on the Class A amplifier site[2]. This power supply (*Fig. 2*) is a classic circuit, which may have its origin in a Telefunken (or ITT) application note from the 1960s. Foldback current-limiting or short-circuit protection is not included, but also not required for this application.

I built my own PSU with semiconductors from the junkbox: a Philips BC546, a TFK325 (Eastern European medium power transistor), and an ancient 2N3055 from RCA (mounted on a fairly big heatsink). It showed good regulation. The output voltage dropped only 0.07V (from 24.12V to 24.05V) when the current draw was increased from zero to 1.4A (during this test, the channel-decoupling RC networks had not yet been added, and a 15V instead of a 20V zener diode was built into the power supply). The power transformer I used was a nice potted item, cannibalized from an old TEAC (2 × 40W) amplifier.

TABLE 1

PARTS LIST (AMPLIFIER)

PART NO.	VALUE
Q1	2SA970 or BC560C
Q2, Q3	BD439
R1	100k
R2	12k (see text)
R3	47k
R4	8k2
R5	2k7
R6, R8	100Ω
R7	560Ω
R9	1Ω 5W
VR1	Potentiometer 47k, audio taper
C1	10µF 100V foil cap (MKP or MKT)
C2	47µF 35/40V electrolytic
C3	100µF 35/40V electrolytic
C4, C5	220µF 35/40V electrolytic
C6	1000µF 35/40V electrolytic

Parts for a single channel; both channels are identical.
All resistors ½W 5% unless otherwise noted.

When fed by this simple PSU, the stereo amp is completely quiet. Even with my ears directly in front of the speakers, I heard no hum or noise.

THE SOUND

Since I am a tube enthusiast, I was biased against this fleapower "sand amp," expecting it to sound grainy and (at best) two-dimensional. But I changed my view. Strange though it may seem, this minimalist design is one of the few transistor amplifiers that tube lovers will immediately accept. It is a great performer for a few bucks, with a clear family relationship to the Zen series of amplifiers—or the Linsley-Hood class A from the late 1960s—but with less power. Yet, there is more than adequate power for my *Petite* speakers (in fact, enough to upset the neighbors).

Strings and percussion instruments sound sweet, with beautiful tonal colors. However, this sweetness appears not to be acquired by the masking of small details. Right now, I am listening to twentieth-century classical music by the Dutch composer Alphons Diepenbrock (recorded on Chandos 8821 and 8878), who wrote complex works in a late romantic style, with a very dense orchestration. On many audio systems, his music is amalgamated into an amorphous mass, making its appreciation difficult.

Not so with Flavio's amp. Individual instruments and voices stand out from a wide and deep soundstage. Yet, there is a sense of wholeness, a harmonious unity to the sound.

Direct comparisons are difficult to make (I cannot do immediate A/B switching), but I imagine hearing the following differences between the transistor and the valve amp.

1. Bass of the transistor amp is superior to that of the valve amp; it's more tightly controlled and more extended.
2. The intelligibility of voices and of vocal lines seems to be slightly better on the valve amp (although voices sound natural on both amplifiers, without artificial sibilants, crossover hardness, or electronic glare).
3. Both amps produce a lively and three-dimensional sound, but the soundstage of the transistor amp seems to be more "forward" than that of the valve amp. Soloists seem to be in front of, or between, the speakers, whereas with the valve amp their apparent positions are behind and between the speakers. I don't have an explanation for this phenomenon.
4. Instrument sizes are not reproduced in the same way. On some recordings of a solo harpsichord, the instrument seems bigger on the transistor amp than on the tube amp. Once more, I cannot explain the reason for this.

Considering the overall performance, I seem to prefer (slightly) the transistor amp over the PCL82 SE amplifier of Part 1. Don't set too high a value to this preference. The tube amp might have won if I had used more expensive output transformers to build it. Yet, this preference indicates the excellent subjective qualities of Flavio's cheapskate amp. For its modest cost, it is a real winner.

CONSTRUCTION NOTES

Since both the amplifier and the power-supply circuits are very simple, I used the "dead bug" style to construct them. Using an unetched piece of printed-circuit board as a groundplane, I glued all components that were not mounted on heatsinks to this groundplane with

TABLE 2

PARTS LIST (POWER SUPPLY)

PART NO.	VALUE
D1, D2	Rectifier diode 100V 2A or greater[#]
D3	1N4001 (50V 1A)
D4	1N5357 (20V zener)
Q4	BC546
Q5	BD139 or equivalent[*]
Q6	2N3055
R10,R11,R13	3k3
R12	1k8
R14	6k8
R15, R16	10Ω wire-wound (10W or greater)
C7	6800µF 100V electrolytic
C8	100µF 50V electrolytic
C9	22nF 63V foil
C10	1000µF 50V electrolytic
C11, C12	2200µF 35V electrolytic
Tr	Power transformer, secondary 60V CT[$]

[#] I cannibalized my diodes from a damaged NAD amplifier. They are marked S6K20 (MUR860 look-alikes).
[*] I used a medium-power transistor from Eastern Europe, marked TFK325.
[$] I employed a nice, potted transformer from an old TEAC amplifier. Unloaded voltage of the secondary was 66V AC with center tap.

their wires pointing upward (like dead bugs). I made all circuit connections with the wires of the components themselves, and I used star earthing, with the groundplane of the power supply as the central earth node.

Consider Flavio's notes: "If necessary, R2 (the 12k resistor) can be adjusted to obtain 13V at the C6 positive lead." In three prototypes I have built, such adjustment was not necessary. "Total current draw of the circuit, best measured by inserting a meter between the positive output jack of the power supply and the positive input of the amplifier board, should be 700mA. Adjust R7 (560Ω resistor) to obtain this value if necessary." In my three prototypes, this adjustment was also not required.

"Q2 and Q3 must be mounted on a finned heatsink of 120 × 50 × 25mm (minimum) dimensions." At this point, Flavio is correct, but I would like to add that you should mount the heatsink in such a way that the fins are free and air can flow freely around them. I had used much bigger heatsinks (160 × 80 × 50mm, cannibalized from a vintage Sansui amplifier). Initially I made a beginner's mistake by mounting the PC boards together with their heatsinks inside a cabinet. Although the top of this cabinet had many holes for ventilation, the heatsinks became blazingly hot after just 30 minutes of operation.

Because the cabinet sides were made of plywood, I opted for a very simple solution. Using a variable-speed orbital jig saw, I cut square holes in the sides of the cabinet and moved the PC boards, so that the fins of the heatsinks protruded from the cabinet sides. This made a tremendous difference. The heatsinks now become only lukewarm, even after many hours of operation. Use of the jig saw has spoiled the looks of the amp, but strongly improved its operation!

Flavio suggests that you can include a bass-boost facility. "If this is required, a series network of a 1k5 resistor and a 150nF capacitor can be connected in parallel to R5 (2k7 resistor). The 1k5 resistor end should go to the emitter of Q1 and the 150nF capacitor end to the collector of Q2." I have not included this facility, as I tend to dislike tone controls. Moreover, in combination with the *Petite* speakers (covered in Part 2), I don't see the need for bass boost.

You should mount the pass transistor within the PSU (2N3055) on an adequate heatsink, using heat-conductive paste and insulating material. Power dissipation in this device (in watts) is equal to the voltage drop across the transistor (difference between the input and output voltages) multiplied by 1.4 (current draw in amperes). The voltage drop under load should be at least 3V (preferably more), so the heatsink must handle at least 5W. I used a black (anodized) heatsink of 100 × 120 × 25mm.

TABLE 3

Amplifier measurements
(courtesy of Flavio Dellepiane)

Sensitivity:	560mV input for 5.6W output (8Ω resistive load) 850mV input for 5.6W output (idem, + bass boost)
Frequency response:	40Hz . . . >50kHz (−3dB) 100Hz . . . 20kHz (0dB)
— with bass boost:	+5dB at 100, + 3.9dB at 200, + 2.5dB at 400Hz −1dB at 10kHz, −1dB at 20kHz
THD at 1kHz:	0.3% at 0.5W 0.45% at 1W 1% at 5.6W

Unconditionally stable on capacitive loads

CONCLUSION

Experimenting with these very simple valve and transistor circuits was a nice learning experience and great fun. The sonic results have surpassed my modest expectations. Of course, these amps are not perfect. But most recordings are reproduced in a highly enjoyable way. Isn't that what amp building is all about?

Circuit diagrams were drawn with TubePad5, a free program designed by amateur radio operator WD4NKA. ***aX***

REFERENCES

1. RED Free Circuits page, http://www.redcircuits. com.
2. Class A Amplifier site, http://www.tcaas.btinternet. co.uk.