PART 1

NEW POWER AMP MODULES

By Erno Borbely
Contributing Editor

Since I introduced the 60W amp in 1982, and the Servo-100 and DC-100 in 1984, a number of you who have built these amplifiers have given me some positive feedback. I have also received some comments and suggestions indicating there is room for improvement. So I have been continuously monitoring their performance and updating the designs.

I designed the original DC-100 with two pairs of output devices, addressing the more traditional speaker loads of 5–8Ω. Since many of you are using lower-impedance loads (some going as low as 1Ω), I have added higher-current devices to the output which allow loads in the 2–4Ω region. Due to the high supply voltage, a significant heatsink increase is required to cope with the increased power dissipation. For high-current, low-impedance applications, the new power amp operates from a lower voltage than previous versions.

One problem with the old unit was the wiring of the TO-3 metal-can output devices. Although a pinout was published, it is easy to reverse a couple of

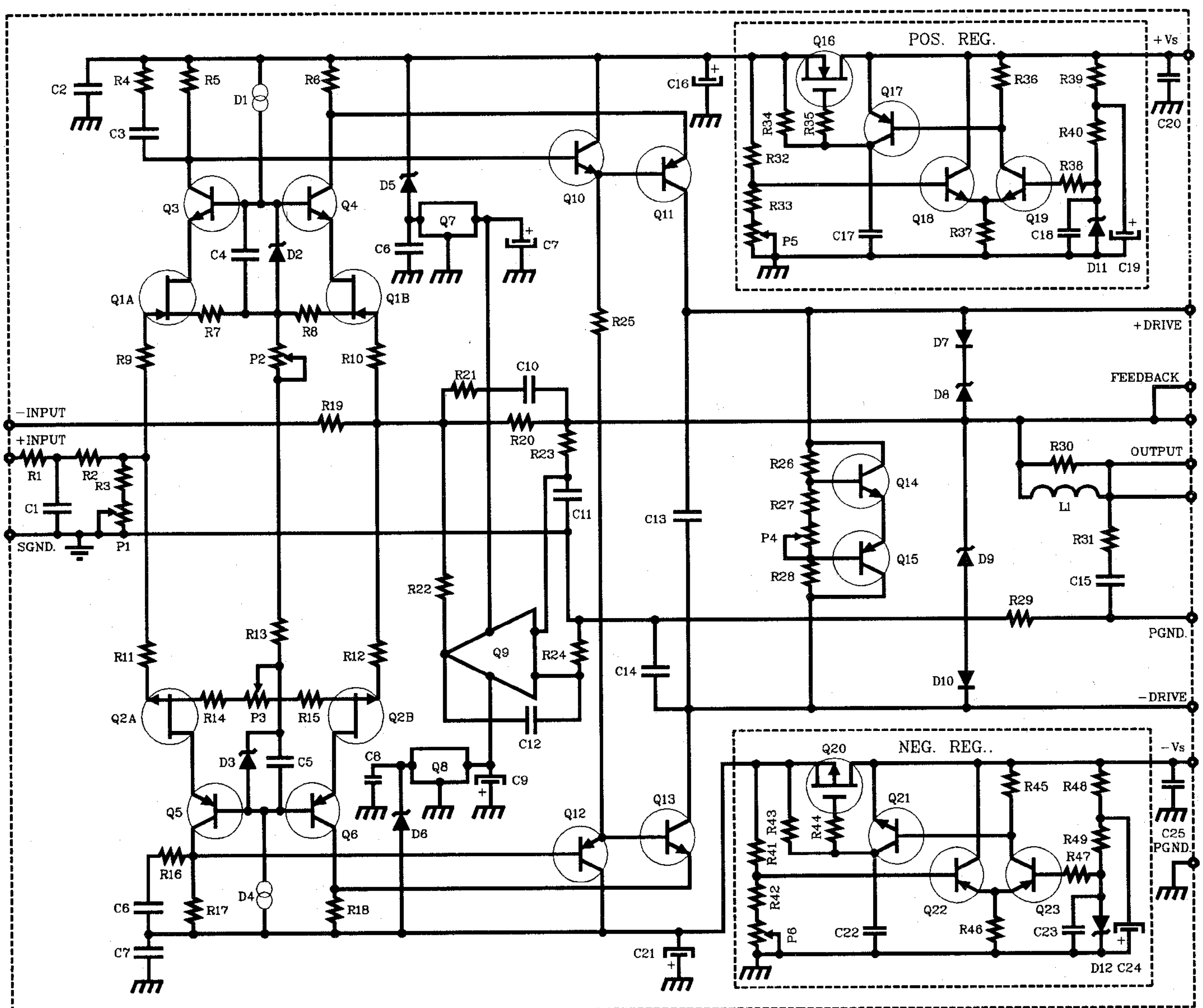

FIGURE 1: Servo-50 EB-691/125 driver board.

TABLE 1

TO-3P MOSFETs

MOSFET PAIRS	PIN	D-S Volt	I_{DMAX} Amp	P_D Watt	$V_{GS(OFF)}$ Volt
2SK1058/2SJ162	GSD	160	7	100	0.15–1.45
2SK405/2SJ115	GDS	160	8	100	0.8–2.8
2SK1529/2SJ200	GDS	180	10	120	0.8–2.8
2SK1530/2SJ201	GDS	200	12	150	0.8–2.8
2SK414/2SJ119	GDS	160	8	100	2–5
2SK400/2SJ114	GDS	200	8	100	2–5
IRFP241/IRFP9241	GDS	150	12	150	2–4

Note: The first four types are especially suitable for audio use.

wires, which results in catastrophic failure. I have been monitoring the development of the TO-3P plastic package and believe they are now reliable enough for audio use. Different versions are available, making them suitable for most applications. Plastic devices offer several advantages: they have only one hole and are easy to mount; when combined with specially designed output boards, the pin connections are practically fool-proof.

TABLE 2

EB-691/125 DRIVER BOARD PARTS LIST

REF.	DESCRIPTION
Capacitors	
C1	560pF/160V, PP, PS
C2, 7, 13, 15	0.1µF/160V, PP
C3, 6	560pF/630V, PP, PS
C4–6, 8, 20, 25	0.1µF/100V, ceramic
C7, 9	10µF/35V, TA
C10	56pF/630V, PP, PS
C11, 12	0.22µF/160V, PP
C14	330pF/630V, PP, PS
C16, 21	47µF/63V, low ESR, ROE, EKR
Output Coil	
L1	1.7µH (Int. diam: 16 mm, length: 20 mm, wire diam.: 1.5–1.8 mm)
Resistors	
R1, 7–12	100
R2	shorted
R3, 22	100k (R3 = 499 for balanced operation)
R4, 16	121
R5, 17	1.4k
R6, 18	137
R13	10
R14, 15	75
R19	523 (for 26dB gain, single input) 1k (for balanced operation)
R20	10k/1.4W metal oxide
R21	shorted
R23, 24	1M
R25	22k/1.4W metal oxide
R26, 28	1.5k
R27	681 (for 2SK405/2SJ115 "O"-type) 499 (for 2SK405/2SJ115 "Y"-type)
R29	10/1.4W, metal oxide
R30	1/4.5W, metal oxide
R31	10/4.5W, metal oxide
Semiconductors	
Q1A, 1B	2SK389BL/V or 2SK240BL/V
Q2A, 2B	2SJ109BL/V or 2SJ75BL/V
Q3, 4	2SC3381GR/BL (MAT01, 2N2920, 2 × 2SC1775)
Q5, 6	2SA1349GR/BL (MAT03, 2N3811, 2 × 2SA872)
Q7	78L15
Q8	79L15
Q9	TL071, LF411CN or AD711JN
Q10	2N5551
Q11	2SA1210 or 2SA1407
Q12	2N5401
Q13	2SC2912 or 2SC3601
Q14	MPSA06
Q15	MPSA56
D1, 4	40.2k resistor (when regulator) or J505, CR100/120, 1N5297 current diode
D2, 3	LM336Z-5.0
D5, 6	ZPY20, 20V/1W zener, without reg.
D7, 10	1N4148
D8, 9	ZPY15 or equivalent 1W zener
Trimpots	
P1	1k, P1 is used for balanced op.
P2	200, multiturn cermet
P3	50, multiturn cermet
P4	5k (for 2SK405/2SJ115 "O"-type) 2k (for 2SK405/2SJ116 "Y"-type)
Miscellaneous	
	TO-92 heatsink for Q7, Q8
	8-Pin DIL socket for Q9
	Heatsink for Q11, Q13, Q16, Q20, aluminum, 120 × 25 mm, 2–2.5 mm thickness
	EB-691/125 PC board (120 × 120 mm)
	Solder pins
	6.3 mm/¼" flat connectors
	Terminal blocks or eyelets for signal and power connection
Note	
	All resistors 1%/0.5W metal film, ROE MK-2 or equiv.
Positive and negative regulator	
R32, 41	10k/2W (22k in par. with 22k/1W)
R33, 34, 38, 42, 43, 47	1k
R35, 44	100
R36, 45	681
R37, 46	2.21k
R39, 40, 48, 49	22.1k
P5, 6	1k, multiturn cermet
C18, 23	0.1µF/100V ceramic
C19, 24	10µF/35V TA
C17, 22	560pF/100V ceramic
Q16	2SK216
Q17	MPSA56
Q18, 19	2SC2240
Q20	2SJ79
Q21	MPSA06
Q22, 23	2SA970
D11, 12	LM336Z-5.0

An additional reason for designing the new modules was component availability. The NPD5566 and the AH5020CJ used in the DC-100's input stage, for example, were not available in Europe. This was alleviated when we began selling the kits, but in the meantime some components had been phased out of production.

I have recently introduced three new power amplifier modules: the Mini-Servo, the Servo-50, and the DC-102. Although sonically very similar, they have different applications. The Mini-Servo has relatively limited output power, and is ideal for active loudspeaker systems. The Servo-50 offers tremendous current capability, and will drive multiway passive as well as low-impedance ribbon speakers. The DC-102 is the favored driver for electrostatics. Both the Servo-50 and the DC-102 have the flexibility to drive any speaker given the right combination of power supplies and the appropriate number of output devices.

Servo Circuit

The Servo-50 is a high-current power amplifier, nominally rated at 50W into 8Ω. With a full complement of five output device pairs, it delivers 100W into 4Ω, and, depending on your power supply, close to 200W into 2Ω. It can drive a peak current of more than ± 40A into 0.88Ω.

The 60W amp and the Servo-100 both use the same driver topology, with bipolar transistors in the input stage. Based on my experiences with the Class A preamp module ("Measuring Nonlinear Distortions," *TAA* 3/90, p. 8), I selected its topology for the new servo driver circuit. The Mini-Servo and Servo-50 circuits are practically identical. [*See Resource Box for details.--Ed.*]

The Servo-50 driver schematic is shown in *Fig. 1.* I used either dual 2SK240BL/2SJ75BL or monolithic dual 2SK389BL/2SJ109BL Toshiba JFETs for the input devices, and monolithic dual 2SC3381GR/BL and 2SA1349GR/BL bipolar, low-noise transistors for the cascode input stage. Rated at 80V breakdown, they are suitable for most power amp inputs. I biased the cascode transistors with 5V reference diodes. These are floating with the Q1 and Q2 source voltage, which practically eliminates the voltage change across the input FETs and reduces the input capacitance to very low value. I set the input stage current to 2mA with P2, and adjusted the input offset with P3.

The second stage, consisting of Q11 and Q13, is the well-known folded cascode circuit. As an extension of the input cascode circuit (through the use of resistors R8 and R18), it shows very good linearity; however, transistor selection is critical. Q11 and Q13 must have very low collector-base capacitance, low saturation voltage, and good linearity at the operating current. They must also have high breakdown voltage in order to cope with the high supply voltage.

I used BF757/760 video transistors in the original Servo-100 circuit. Some of these 300V devices have rather high saturation voltage at the 10–20mA operating current, but they will eventually be phased out of production. A *TAA* reader suggested I consider Sanyo's 2SC2912/2SA1210 video transistors, which are 200V devices in a TO-126 package with a rated collector current of 140mA and an f_T of 150MHz. They have extremely low collector-base capacitance and a reasonably good saturation voltage up to about 20mA collector current, making them ideal for the second stage.

TABLE 3

EB-391/109 and EB-391/110 OUTPUT STAGE PARTS LIST

REF.	DESCRIPTION
Capacitors	
C1–5, 8–12	0.1μF/100V, ceramic
C6, 7	100μF/63V low ESR, ROE, EKR
C13–17	33pF/100V, cog or dipped mica (Used only for 2SK1058/2SJ162 Hitachi MOSFETs.)
Resistors	
R1, 2	100
R3–12	221
R13	75/1W (for 2SK1058/2SJ162 MOSFETs) 150/1W (for 2SK405/2SJ115 "Y"-type)
Semiconductors	
Q1	2SK216
Q2	2SJ79
Q3–7	2SK1058 Hitachi (0.15–1.45V) 2SK405 Toshiba (0.8–2.8V) 2SK1529 Toshiba (0.8–2.8V)
Q8–12	2SJ162 Hitachi 2SJ115 Toshiba 2SJ200 Toshiba
Miscellaneous	
EB-391/109 PC board for B- and C-type (G-D-S pinout) MOSFETs	
EB-391/110 PC board for A-type (G-S-D pinout) MOSFETs	
Solder pins	
6.3 mm/¼" flat connectors	
Terminal blocks or eyelets for signal and power connections	
Notes	
All Components are mounted on the copper side.	
In case the 2SK216/2SJ79 are mounted on the driver board, leave these and resistors R1, R2 and R13 out.	
For stuffing the board without the drivers, see separate stuffing guide.	

Another complementary pair for this position is the 2SC3601/2SA1407, with an f_T of 400MHz. The second-stage bias transistors, Q10 and Q12, are TO-92 high-voltage devices for which I am using the 2N5551/2N5401.

Q14/Q15 serve as a complementary V_{BE} multiplier for biasing the output stage. I selected this dual-transistor version because of the relatively high bias needs of some of the output MOSFETs.

Driver Boardom

I mounted the source follower drivers on the output board rather than on the driver board for several reasons, the simplest being that I didn't have room for them on the driver board. More im-

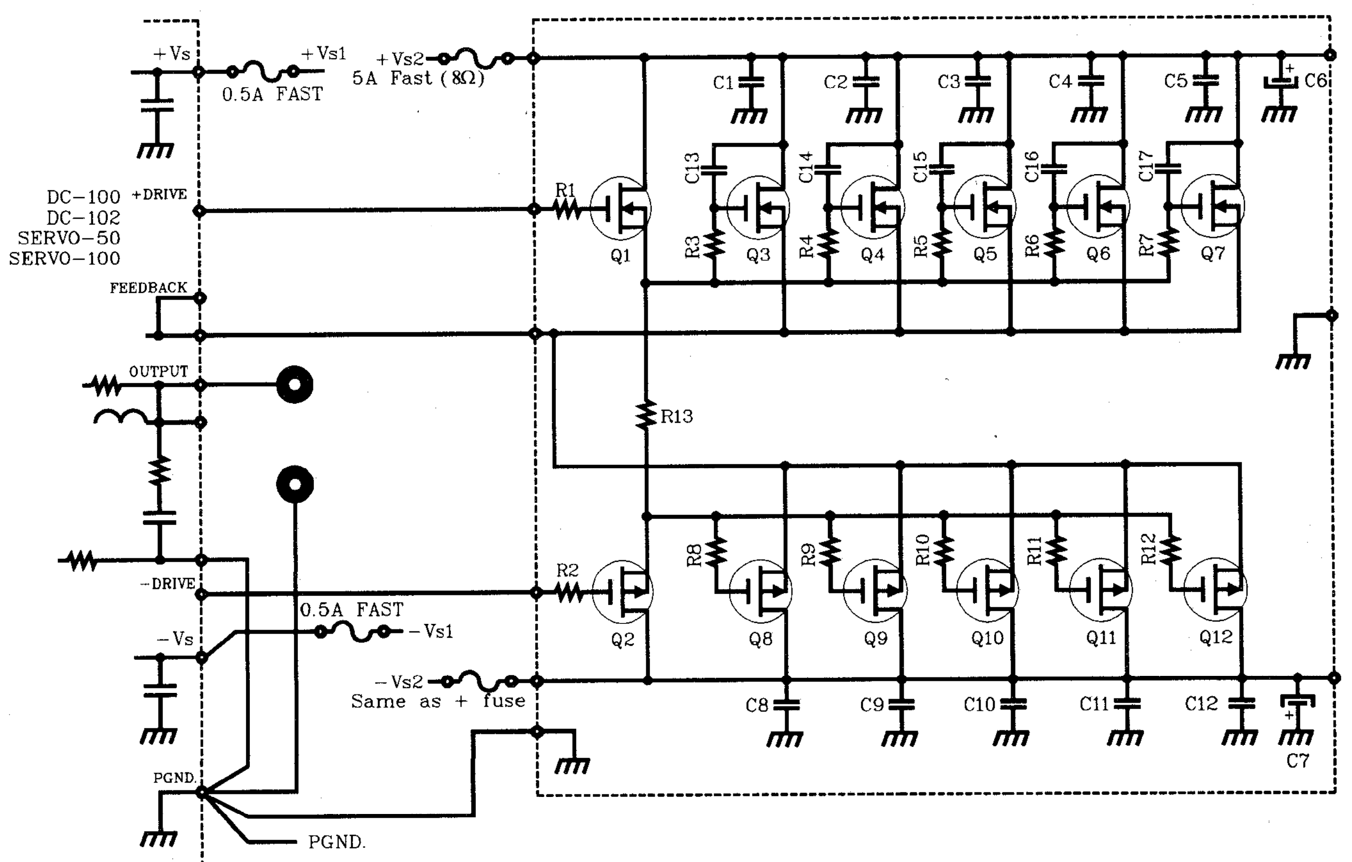

FIGURE 2: High-current output stage (EB-391/109 or EB-391/110). When the 2SK216/2SJ79 drivers are mounted on the driver board, remove Q1, Q2, R1, R2, and R13.

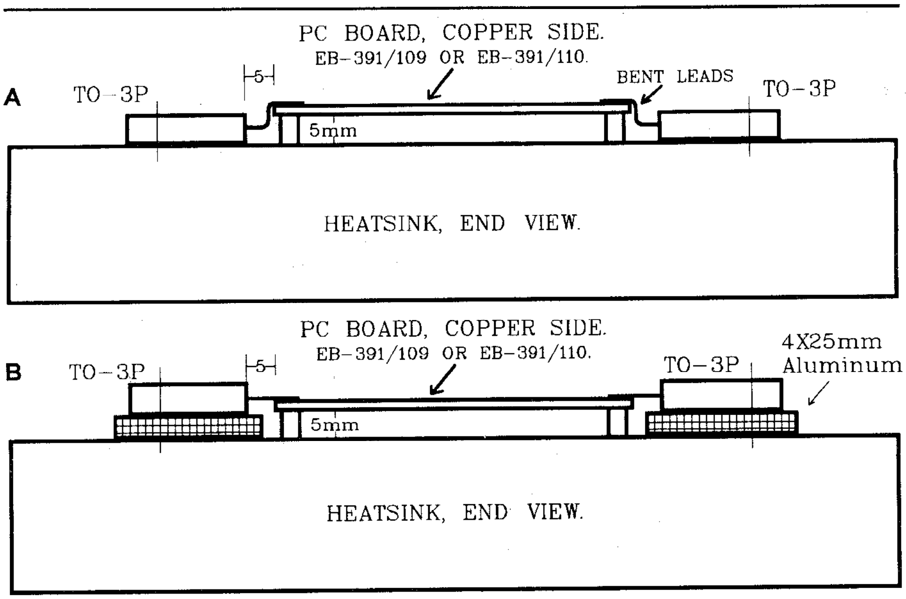

FIGURE 3A: Transistors mounted directly on heatsink. **B:** Transistors mounted with straight legs on 4 × 25 mm aluminum. Note: Aluminum and heatsink must be flat for good thermal contact.

portantly, mounting them as I did reduces the distance between the driver and output transistors, which in turn reduces the risk of high-frequency oscillations. The third reason is thermal stability. Some of the output MOSFETs have positive temperature coefficients, while the 2SK216/2SJ79 drivers have negative temperature coefficient when operated above 20mA drain current. Mounted on the same heatsink, they tend to compensate each other. Finally, you can run the drivers at higher current for improved linearity without heatsinking problems.

The Servo-50, Mini-Servo, and DC-102 driver circuits have high open- loop gains in the order of 85–90dB, with an open-loop frequency response of about 2kHz. The Class A topology with a source follower output results in a second stage with very little loading (only the source followers' input capacitance), and consequently high gain. The advantage of high gain and plenty of feedback at midfrequencies is that they reduce the by-products of nonlinearities which are outside the audio band.

You can reduce the open-loop (OL) gain by loading the second stage. For example, two 100k resistors connected from the second stage collectors (one from each side of the bias circuit for symmetry) will reduce the OL gain to about 70dB and increase the OL frequency response to close to 20kHz. Increasing the input stage source resistors will further reduce the gain. (I have not been able to verify the sonic advantages of these modifications, and so have not included them in my designs; however, please try them and report the results.)

Theoretically, the Servo-50 is a DC-coupled amplifier. JFETs have a much higher temperature drift than bipolars, however, and this causes DC offset. If you are running your amp at a constant (and relatively low) temperature, simply trim the DC offset to zero with P3. If the temperature range is expected to vary widely, I recommend installing servo amp Q9, which is supplied with ±15V by Q7 and Q8. D5 and D6 are connected in series with Q7 and Q8 to protect them from input/output (I/O) overvoltage, although they are unnecessary if the supply voltage across C16 and C21 is less than or equal to ±50V.

Driver circuits can benefit from regulated supplies, although I am not convinced that the output stages need them. "Pos. Reg." and "Neg. Reg." in *Fig. 1* are discrete regulators comprised of a differential input stage, a driver, and a MOSFET output stage. The MOSFET and Q11/Q13 second-stage transistors are mounted on the same heatsink. The reference voltage is supplied from D11 and D12, which are LM336Z-5.0 reference diodes. P5/P6 trimpots in the feedback circuit adjust the output voltage over a 35–50V range.

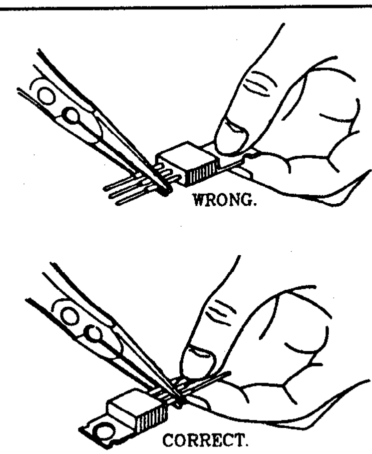

FIGURE 4: Bending transistor leads.

The input voltage to the regulator must be a minimum of 5V higher than the output voltage. Thus, the regulated supply voltage requirements are: regulated output supply for the drivers of ±45V (±40V output voltage plus 5V) and ±50V input voltage (±45V plus 5V). I recommend operating the regulators with ±55V input voltage and adjusting the regulated voltage to ±45–48V. Due to circuit simplicity, the regulators are not short-circuit proof, but they tolerate higher I/O voltage differences than IC regulators.

The generous-sized output pads on the PC board offer a number of connection possibilities: ¼″ Quick Connect connectors; the dual, screw-type terminal blocks with 5 mm or 0.2″ pin spacing; or normal solder pins. You can also solder your cable directly to the board.

Resistors Reduplicated

Feedback resistor R19 appears twice in the stuffing guide. If you use the amp with single input, the 523W resistor should be mounted in the R19 (1) position. For use with balanced inputs, install the 1.1k resistor where R19 (2) is shown. Obviously, both can be mounted, but only one can be active at a time. The heatsink for second-stage transistors Q11/Q13 and regulator transistors Q16/Q20 is 120 × 25 × 2 mm aluminum.

I suggest you begin the board assembly by testing and adjusting the two regulators. First, place the common heatsink of Q11, Q13, Q16 and Q20 on the board, then mount pass transistors Q16 and Q20 on the heatsink.

With the positive regulator components in place, connect a 470Ω/5–10W resistor across C2 or C16, and a voltmeter across the resistor. Apply +55V unregulated voltage to +Vs. Depending on P5's position, the output voltage should be between 30–55V. Adjust the regulated voltage to +45V with P5, then disconnect the load resistor and recheck the voltage. The same reading should ap-

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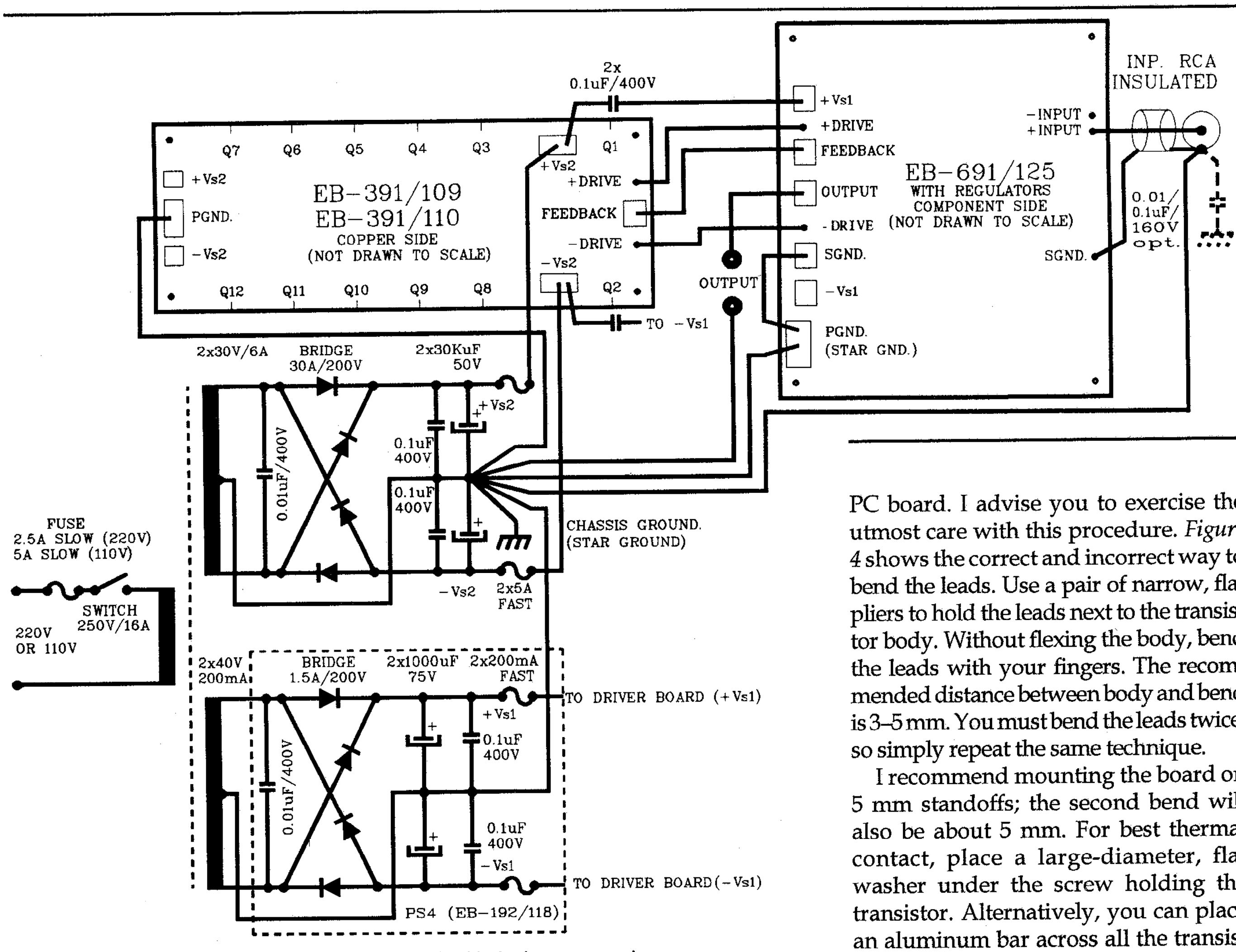

FIGURE 5: Proposed wiring diagram for monoblock with dual power supply.

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pear between the loaded and unloaded voltage on a 3½-digit DVM set to 200V.

If you can't adjust the voltage, or if the difference is greater than 0.1V, recheck all components for correct placement/orientation. Set your scope on AC and the highest possible sensitivity. Connect it across the load resistor and check for output oscillation. When you have mounted all of the negative regulator components, repeat this procedure. You can then assemble the components on the board. Mount the output coil last, as some of the components are mounted partially under it. Make certain that the four heatsink transistors are insulated with mica, or the newer inert plastic isolators.

Prepare to Mount

The EB-391/109 and 110 output boards (and their mini companion, the EB-792/111) have been developed for output stages using TO-3P output devices. The two versions have two different pin configurations: G-D-S for the 109 and 111, and G-S-D for the 110. The boards also incorporate the 2SK216/2SJ79 drivers, enabling you to mount them on the main heatsink with the output MOSFETs. (If the drivers are mounted on the driver board, you can leave them out.) The output stage schematic is shown in *Fig. 2*.

The TO-3P devices bolt directly onto the heatsink with single-hole mounting. Transistor connections are facilitated by the special PC boards, to which all transistors are soldered. Since the PC board must be mounted off the heatsink to avoid short circuits, the transistors will be at a different level (*Fig. 3a*). You can build a pedestal using an appropriate aluminum profile to raise the transistors (*Fig. 3b*), although this method introduces an extra thermal resistance between the transistors and the heatsink. It should therefore be used only when necessary.

If you mount the transistors directly onto the heatsink, you must bend the leads before you can solder them to the PC board. I advise you to exercise the utmost care with this procedure. *Figure 4* shows the correct and incorrect way to bend the leads. Use a pair of narrow, flat pliers to hold the leads next to the transistor body. Without flexing the body, bend the leads with your fingers. The recommended distance between body and bend is 3–5 mm. You must bend the leads twice, so simply repeat the same technique.

I recommend mounting the board on 5 mm standoffs; the second bend will also be about 5 mm. For best thermal contact, place a large-diameter, flat washer under the screw holding the transistor. Alternatively, you can place an aluminum bar across all the transistors and use the individual screws to tighten the bar (and, consequently, the transistors). Use an insulator and a generous amount of silicone grease under each transistor.

Table 1 lists some available TO-3P MOSFETs. The Hitachi 2SK1058/2SJ162 are the plastic equivalents of the well-known 2SK135/2SK50 TO-3 metal cans. Their positive and negative temperature coefficient crossover point is around 100mA, with no thermal runaway if you operate them at higher drain current. The Toshiba 2SK405/2SJ115 have a much higher crossover point and good thermal stability, provided you use the Hitachi 2SK216/2SJ79 drivers mounted on the main heatsink with the output devices.

The 2SK1529/2SJ200 are recommended for very-high-power amplifiers. They have positive temperature coefficient across the entire current range and require special care to ensure thermal stability.[1]

The last three MOSFET pairs are also suitable for audio applications. Their primary difference is a significantly

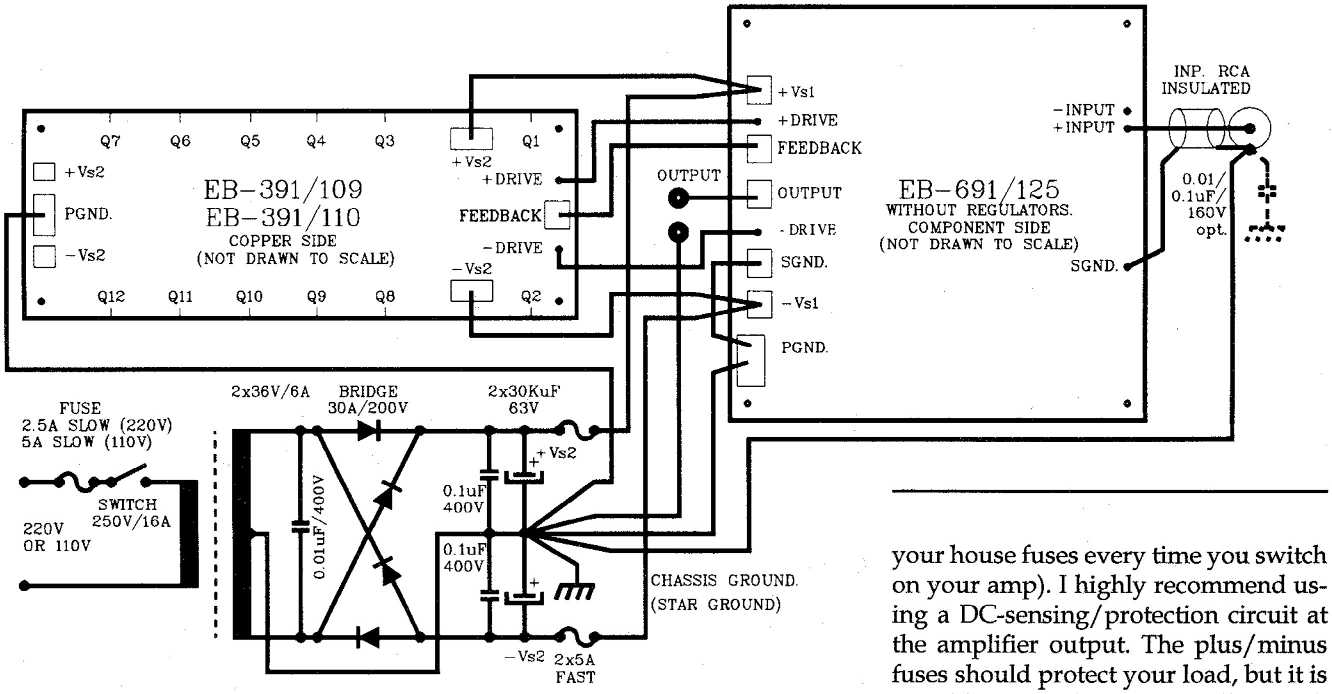

FIGURE 6: Proposed wiring diagram for monoblock with single supply.

higher bias voltage, which you can compensate for by modifying the bias circuit and running the driver circuit at 5–10V higher supply voltage. These devices also have positive temperature coefficient across most of their operating current range, and require the same care for thermal stability as the 2SK1530/2SJ201.

I recommend using two or three pairs of output devices for 8Ω operation, and the EB-792/111 board is laid out for two-pair usage. The minimum for 4Ω is three pair. If your load impedance is likely to drop below 3Ω, use a full complement of five pair. You can operate the output devices with a quiescent current range of 100–200mA per pair, but I advise 500mA as the minimum total current for the output stage.

Power Supplies

Use a 400VA or larger transformer per channel and separate windings for the driver (2 × 40V RMS/200mA) and output stages (2 × 25–30V RMS/6A). With a full complement of output devices, the output stage filter capacitors should be minimum 20,000µF/50V and 1,000µF/63V for the driver stage, with both supplies grounded at the same point (e.g., at the driver board's PGND, or a star-ground point elsewhere). Connect a 0.1µF/160V film capacitor between the board's two supply pins (plus-to-plus and minus-to-minus). This will establish a common high-frequency reference. One possible wiring diagram is shown in *Fig. 5*.

You can always use one supply for both the driver and output stages, either from a high-current, unregulated supply of ±40–45V, or from a common, high-current regulator of the same output voltage. In either case, omit the components associated with the driver board regulators. *Figure 6* shows typical wiring of a Servo-50 monoblock using a single supply.

If you use capacitors larger than 20,000µF, you should install a slow-turn-on circuit to protect the rectifier bridges/diodes (and to avoid blowing your house fuses every time you switch on your amp). I highly recommend using a DC-sensing/protection circuit at the amplifier output. The plus/minus fuses should protect your load, but it is possible to accidentally install a much smaller fuse on one side. This fuse will blow and you will have the output sitting at the other supply voltage, which might permanently damage your speakers. This can also happen if a component fails and the output gets stuck at one of the supply voltages. Remember, these amplifiers can deliver high currents into very low impedances.

A word of caution concerning shorting the amplifier output: the only protection comes from the diode/zener diode current limiter at the input of the driver MOSFETs, which is intentionally kept fully open in order to prevent difficult loads from triggering the current limit. The diodes protect the MOSFET gates only from overvoltage—there is no protection from excessive current or ther-

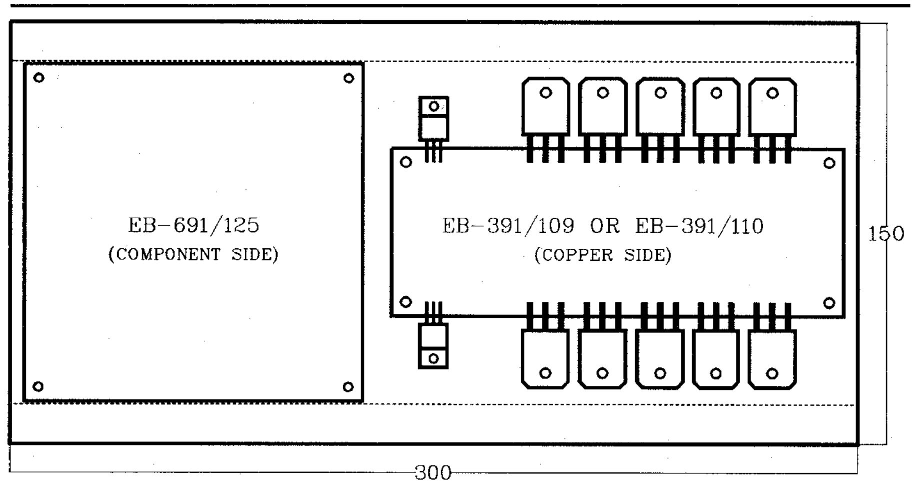

FIGURE 7: Proposed heatsink assembly using SK-56.

Resources For This Article

Please contact the following companies for pricing and other information as shown:

Old Colony Sound Lab, PO Box 243, Dept. A93, Peterborough NH 03458, (603) 924-6371, (603) 924-6526; FAX (603) 924-9467 (24 hours).

1. *PC boards only (less components):*

Servo-50	(EB-691/125)
DC-102	(EB-1091/117)
Output without Drivers	(EB-391/110)
DC Protection	(EB-192/132)

Welborne Labs, 971 E. Garden Dr., PO Box 260198, Littleton CO 80126-0198; (303) 470-6585; FAX (303) 791-7856.

1. *Information about the Mini-Servo and the DC-150.*
2. *PC boards and/or kits:*

Mini-Servo	(EB-692/116)
Little Output with Drivers	(EB-792/111)
Output with Drivers	(EB-391/109)
DC-150	(EB-892/127)

Borbely Audio, Melchior Fanger Strasse 34A, 82205 Neu-Gilching, Federal Republic of Germany; 011-49-8105-5291; FAX 011-49-8105-24605 (24 hours).

1. *PC boards and/or kits:*
   All of the above except Mini-Servo, Little Output, and DC-150.

For those interested in fabricating their own boards, prints of all board patterns and stuffing guides are available on request. Please send a 9" x 12" manilla SASE with postage for 2 oz. (international readers, please include postal coupons) to: *TAA*, PO Box 576, Dept. EB393, Peterborough, NH 03458-0576.

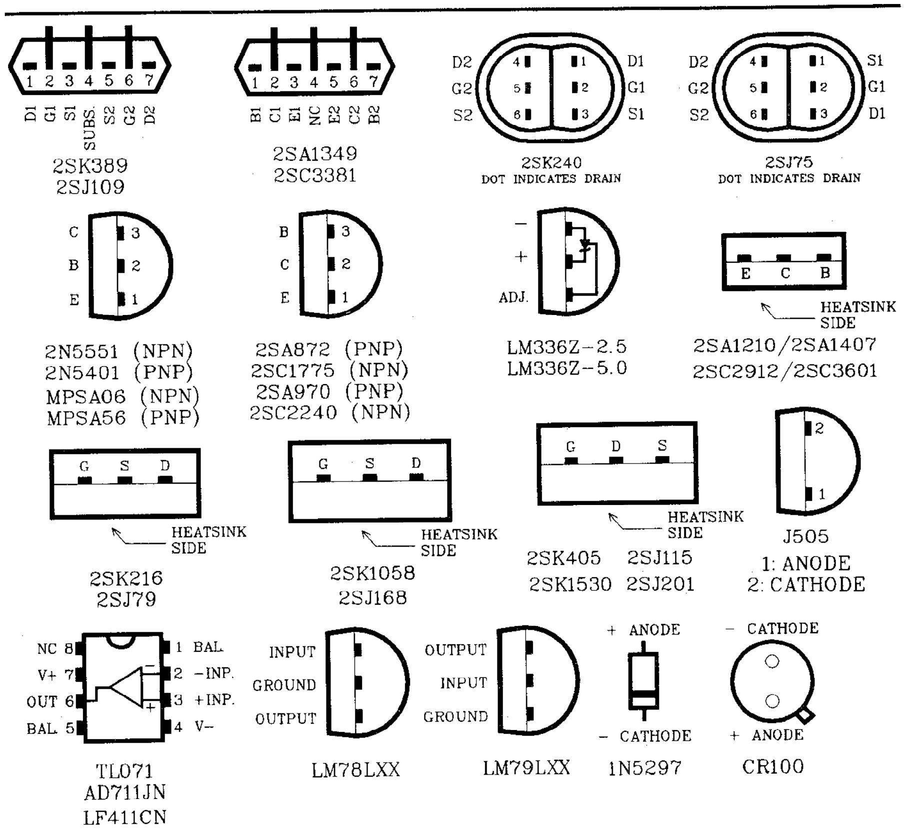

FIGURE 8: Pin configurations for Servo-50 devices. Note: All devices shown bottom view.

mal overload, and the amplifiers will not survive any long-term short at the output. If you expect to encounter short circuits, especially in the testing phase, you should use 10V zeners for current limiting and 2A fast fuses for the plus/minus supplies. Once everything is in working order, you can make adjustments for your particular load condition.

Set-Up Procedure

You should invest in a variable transformer before you start this procedure; a 500VA Variac™ should be adequate. It can save you some expensive output devices, not to mention the aggravation of replacing blown transistors and other components.

Before turning on the AC power, place P2 and P4 in their maximum-resistance positions and P3 in midposition. Don't install Q9 if it is socketed. If you have an 8Ω load resistor with a minimum rating of 50W, connect it to the

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Audio Amateur

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1991 Improve the CDB-650's DAC • Balancing Amps • Active Inverse RIAA Circuit • Simple Curve Tracer (Part 2) • Dalzell on Noise • Electrostatic Headphone Amp • Remote Control Volume/Balance System • Borbely Preamp: The Modules • Heath's IG-72 Sine Wave Generator • Ground Loops Revisited • Phase Coherent Cable • Stepped Attenuator for Balanced Audio Amps • New Control Preamp (Part 1) • IR Remote Slave • Improve Your Power Supply • Build a Video Test Generator •

1992 Salvaged 35W Power Amp • New Control Preamp (Part 2) • Centralized Power Conditioner • POOGE-5: DAC960 Rite of Passage (Parts 1, 2) • Build an A-Weighting Filter • Safe Soldering • Balancing Differential Circuits • Balanced-Jack Differential Audio Project • MOSFET Dyna ST-120 Mod • Pots: Encapsulated Modules • Build the A75 Power Amp (Part 1) • Anti-shock Turntable Cradle • High-Quality AM from Crystal Radio •

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output. Connect the minus and plus inputs to signal ground at the input. Remove one of the output stage supply fuses and connect an ammeter set to 0.5 or 1A across it. If you have a scope and a DC voltmeter, connect both to the output. Slowly turn on the AC power using the Variac. The current measured by the ammeter should not exceed a few hundred milliamps, and the DC voltage at the output should remain around 0V.

Connect the DC voltmeter across resistor R5 (or R17) and adjust the input stage current to approximately 2mA, which will produce a voltage drop across the resistors of 2.8V. If you are lower than 2.8V, short R13. If you are higher, increase R13's value to 200W. (This might be necessary if you are using "V"-type input devices.) Reconnect the DC voltmeter to the output and try to adjust the DC offset to 0V. You might have difficulty with this if you are using high-bias output transistors which are completely off. In this case, leave the offset for the time being and adjust the bias.

Monitoring the current through the output transistors with the ammeter, initially adjust the bias to approximately 500mA. Now return to the DC offset at the output and adjust it as close as possible to 0V with P3. As shown on the schematic, this is actually a DC amplifier, and it can be used as such provided the input FET's ambient temperature doesn't change more than 10–20°C. As FETs drift more with temperature than bipolar transistors, you should always use the servo in high-temperature environments. Switch off your amp and install Q9. With the servo installed, the output offset should be less than a couple of millivolts.

Once you have made the basic DC adjustments, remove the short from the plus input and connect a 1kHz/0.5V RMS signal to it. Turn on the amplifier and observe the output with a scope. It should be an undistorted sine wave, with no high-frequency oscillation. If you have a total harmonic distortion (THD) analyzer, perform the usual measurements at different frequencies.

When the amp is running properly, connect it to your system. To get the best

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Reference

1. *Mospower Applications*, "Temperature Compensated Biasing for Power MOSFETs in Linear Amplifiers" (Siliconix, 1984): 5–14.

Contributing Editor Erno Borbely responds:

You might have an RF oscillation in your amp. Connect an oscilloscope to the output and you should be able to detect any RF oscillation. □

POWER AMP MODULES

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sound, you must experiment with the bias. Adjust it to 100–200mA per pair of output devices if you are using *large* heatsinks. With a full complement of output devices, the total bias current can be in excess of 1A.

If the supply voltage on the output devices is approximately ±40V, the total dissipation is a minimum of 80W, requiring a heatsink with a 0.25–0.3°C/W thermal resistance at 25°C ambient temperature. The SK-56 heatsink shown in *Fig. 7* is sufficient for approximately 80W dissipation with proper air circulation. I recommend using a thermal breaker with a 70°C cut-out temperature on the heatsink. □

THE HEAT'S OFF

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even though you used a new breed of thermal pad and a large heatsink, you can only safely dissipate 52.1W with this thermal design. And despite the fact that it's rated at 100W!

The example illustrates how simple it is to analyze a thermal circuit. All you need is an understanding of the heat transfer modes and appropriate information on the components used to transfer the heat. Implementing proper thermal design techniques will result in a high level of reliability and save time, trouble, and money. □

Ask *TAA*

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optimum performance. After aligning a playback head, I usually check the phase at several frequencies between 1-15kHz. If the phase relationship between the left and right channels varies with frequency, it is indicative of the equalization phenomenon you described. Thanks for sharing this extremely prudent advice with us. □