NEW POWER AMP MODULES

By Erno Borbely
Contributing Editor

The DC-102 is a DC-coupled power amplifier, with output power determined by the number of devices, the heatsink, and the power supply. With three pairs of TO-3P output MOSFETs, it can deliver more than 100W into 8Ω with less than 0.01% total harmonic distortion (THD) across the audio range. Typical output power into 4Ω is 150W. If the load impedance is less than 4Ω, use the full complement of five pairs of output devices and reduce the output-stage supply voltage to ±40V for reduced quiescent power dissipation.

Circuit Judge

The driver circuit (*Fig. 9*) is an improved version of the DC-100. The original input FETs, the NPD5566 and AH5020CJ, are not truly complementary devices. Although they perform satisfactorily as simple followers, they cannot offer optimum performance in terms of linearity, offset, and noise. Replacing them with the Toshiba 2SK240/2SJ75 or the 2SK389/2SJ109 is not possible because of these devices' higher input capacitance, which causes instability and high-frequency distortion. The solution is to connect a second FET in cascode, which reduces the input capacitance to a very small value. (The DC-102's input capacitance is 5.3pF, which also includes track capacitances on the PC board.) Since these devices are complementary, they also improve linearity across the entire audio range.

I kept the input stage bias voltage at ±20V; however, it is now supplied by LM317T/LM337T regulators rather than the dual-transistor current source and the string of 5.1V zener diodes. This significantly reduces the amplifier's cost with-

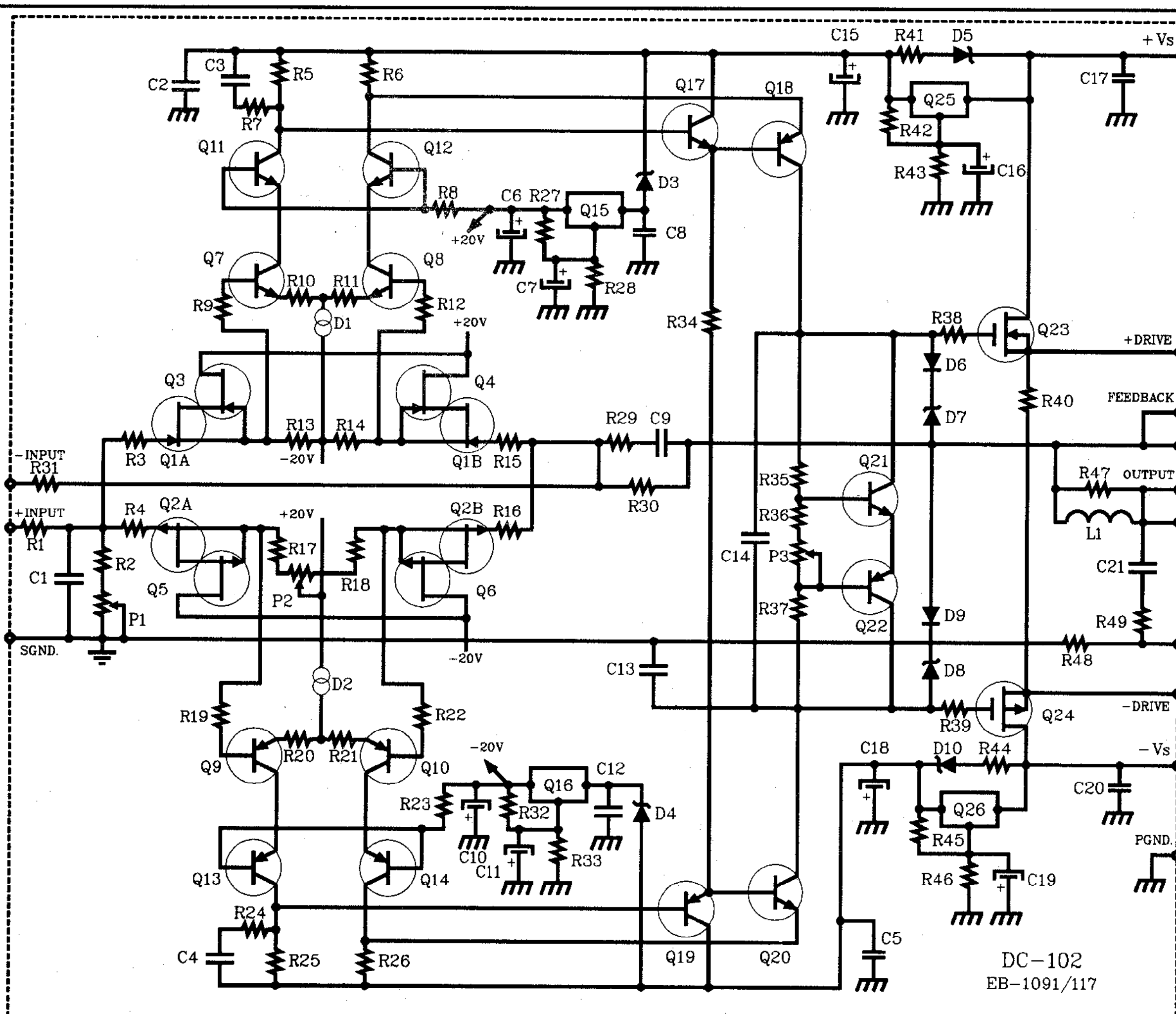

FIGURE 9: DC-102 power amplifier driver board.

out affecting DC stability. The zener diodes D3 and D4 are unnecessary if the supply voltage is less than ±55V. A small heatsink placed on regulators Q15 and Q16 will improve temperature stability.

Further improvement is offered by 2SA1210/2SC2912, the new second-stage transistors (or 2SA1407/2SC3601). These high-frequency video devices have very low collector-base capacitance which reduces high-frequency distortion. H_{FE} linearity is very good to approximately 20mA collector current, and the TO-126 package allows easy heatsinking. If you have the 2SK216/2SJ79 driver FETs on the board, with all four devices mounted on the simple heatsink, the temperature will be too high. In this case, use a wider aluminum and mount small, finned heatsinks under the MOSFET drivers.

Due to space limitations, I added only standard LM317T/LM337T regulators (Q25 and Q26) to the board to supply the driver circuit with ±45–55V regulated voltage. The raw supply voltage must be 5–10V higher than this. You can set the output voltage either with resistors, as indicated on the schematic, or with a string of zener diodes replacing R43/R46. At these high voltages, the regulators are not short-circuit protected. They will fail if the maximum input-output voltage difference (40V) is exceeded due to a short circuit on the board. If you do not need them, omit their associated components and place a shorting wire between each regulator's input and output pin.

You can build your own regulator for the driver board. Depending upon your preference, this can be either a Boak- or Ryan-type (Kit Ryan, "A Power Supply Regulator For the Adcom GFA-555," *TAA* 4/89, p. 34). Using the Servo-50's discrete regulator as an off-board regulator is another possibility.

The stuffing guides, both with and without drivers, and driver board layouts are offered through *TAA* (see Resources box). Use the stuffing guide with the driver MOSFETs mounted on the board with the output-stage stuffing guides from Part I. This version is also a drop-in replacement for the DC-100, using TO-3 metal-can transistors. Mounting the driver MOSFETs on the output board is the preferred method.

In summary, the EB-1091/117 driver board can be used with either the 2SK135/2SJ50 or 2SK175/2SJ55 metal-can MOSFETs, as well as with a number of TO-3P devices. In any case, keep the distance between board and devices at a minimum, preferably less than 2". Using the EB-391/109 or 110 boards also allows you to mount the 2SK216/2SJ79 drivers on the main heatsink with the output devices. (Refer to the discussion of MOSFETs in Part I.)

The DC-102's open-loop gain is typically about 90dB, and the open-loop frequency response is 2kHz. You can decrease the former by connecting a 100k resistor from the collector of Q18 and Q20 (both sides of the bias circuit) to ground. This reduces the gain to approximately 72dB and increases the frequency response to nearly 20kHz. These resistors are accommodated for on the layout. Since I have been unable to either measure or hear any difference using them, I have not included them on the schematic or stuffing guide.

Power Supply

The transformer should be 400VA or larger. Regardless of whether you use the regulators on the driver board or an off-board discrete regulator, you should use separate windings for the driver (2 × 46V RMS/200mA) and output stages (2 × 38–40V RMS/5A). The output-stage filter capacitors should be a minimum 20,000µF/75V, and 1,000µF/100V for the driver stage. Both supplies must be

TABLE 4

DRIVER BOARD PARTS LIST

PART	DESCRIPTION
Capacitors	
C1	560pF/160V PP, PS
C2, 5, 14, 21	0.1µF/160V PP
C3, 4	1,000pF/160V PP, PS
C6, 7, 10, 11	10µF/35V TA
C8, 12, 17, 20	0.1µF/100V cer.
C9	47pF/630V PP, PS
C13	150pF/630V PP, PS
C15, 18	100µF/63V ROE EKR (if supply <±55V) 100µF/100V siemens
Resistors	
R1	100
R2	100k 499 (for balanced operation)
R3, 4, 8–12, 15, 16, 19–23, 38, 39	100
R5, 25	2.21k
R6, 26	200
R7, 24	221
R13, 14	20.5k
R17, 18	15.8k
R27, 32	121
R28, 33	1.82k
R29	Shorted
R30	10k, 1.4W
R31	523 (for 26dB gain with single input) 1k (for balanced input)
R34	22k, 1.4W
R35, 37	1.5k

PART	DESCRIPTION
R36	681 (for 2SK405/2SJ115 "O"-type) 499 (for 2SK405/2SJ115 "Y"-type)
R40	75, 1W
R47	1, 9W (two 2Ωs paralleled, 4.5W each)
R48	10, 1.4W
R49	10, 9W (two 20Ωs paralleled, 4.5W each)
Semiconductors	
Q1A/1B	2SK389BL/V
Q2A/2B	2SJ109BL/V
Q3, 4	2SK246BL
Q5, 6	2SJ103BL
Q7, 8	2SC3381GR/BL (MAT01, 2N2920, 2x2SC1775)
Q9, 10	2SA1349GR/BL (MAT03, 2N3811, 2x2SA872)
Q11, 12, 17	2N5551
Q13, 14, 19	2N5401
Q15	LM317T
Q16	LM337T
Q18	2SA1210 or 2SA1407
Q20	2SC2912 or 2SC3601
Q21	MPSA06
Q22	MPSA56
Q23	2SK216
Q24	2SJ79
D1, 2	J508 2.4mA current diode CR200 2mA current diode 1N5305 2mA current diode

PART	DESCRIPTION
D3, 4	20V zener, 1W (not required if supply voltage is less than ±55V; use jumper)
D6, 9	1N4148
D7, 8	15V zener, 1W
Trimpots	
P1	1k (for balanced operation)
P2	10k multiturn cermet
P3	5k (for 2SK405/2SJ115 "O"-type) 2k (for 2SK405/2SJ115 "Y"-type)
Output Coil	
L1	1.7µH (int. diam.: 16 mm, length: 20 mm, wire diameter: 1.5–1.8 mm)
Miscellaneous	
EB-1091/117 PC Board	
Heatsink for Q18, 20 (100 mm × 25 mm × 2–2.5 mm). If Q23 and Q24 are mounted on board, use 30–35-mm-wide aluminum and put finned heatsinks under Q23 and Q24.	
Solder pins, 6.3 mm (¼") flat connectors, terminal blocks, eyelets for signal and power connection.	
Positive and negative regulator	
R41, 44	Shorted
R42, 45	121
R43, 46	4.7k, 1.4W (for ±50V regulated supply) 5.1k, 1.4W (for ±55V regulated supply)
C16, 19	10µF/63V ROE EKR
Q25	LM317T
Q26	LM337T
D5, 10	30V zener, 1W

Note: All resistors 0.5W/1% metal film, ROE MK-2 or equivalent unless otherwise noted.

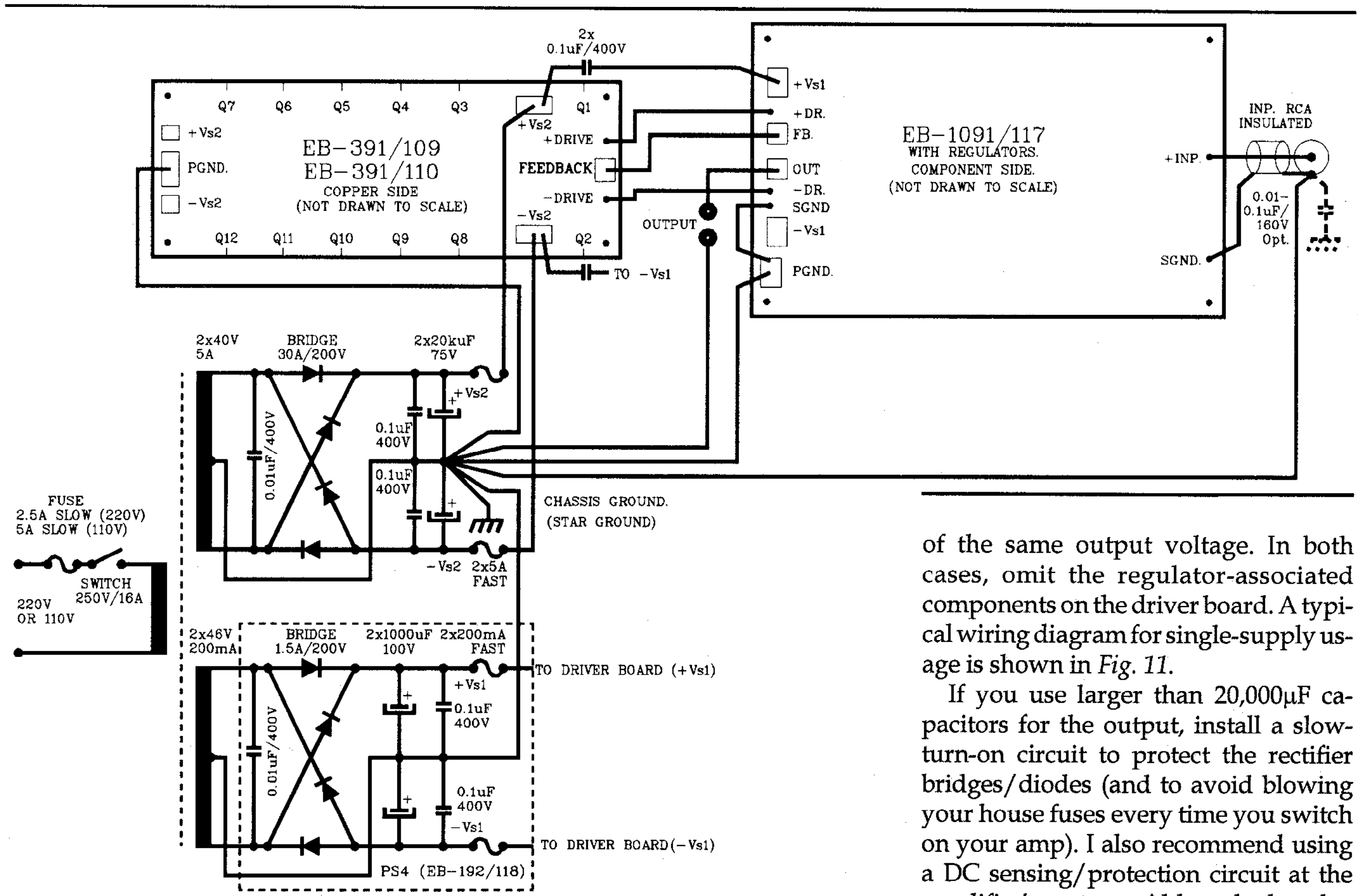

FIGURE 10: Proposed wiring diagram for monoblock with dual power supply.

grounded at the same point (e.g., at the PGND of the driver board, or a star-ground point elsewhere). *Figure 10* shows a typical wiring diagram for a DC-102 monoblock using a dual supply.

You can also use one supply for both the driver and output stages. You can run them either from a high-current, unregulated supply of ±50–55V DC or from a common, high-current regulator of the same output voltage. In both cases, omit the regulator-associated components on the driver board. A typical wiring diagram for single-supply usage is shown in *Fig. 11*.

If you use larger than 20,000µF capacitors for the output, 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 also recommend using a DC sensing/protection circuit at the amplifier's output. Although the plus and minus fuses should protect your load, you can accidentally install a much smaller fuse on one side. When this fuse blows, the output sitting at the other supply voltage might destroy your speakers. This can also happen if a component

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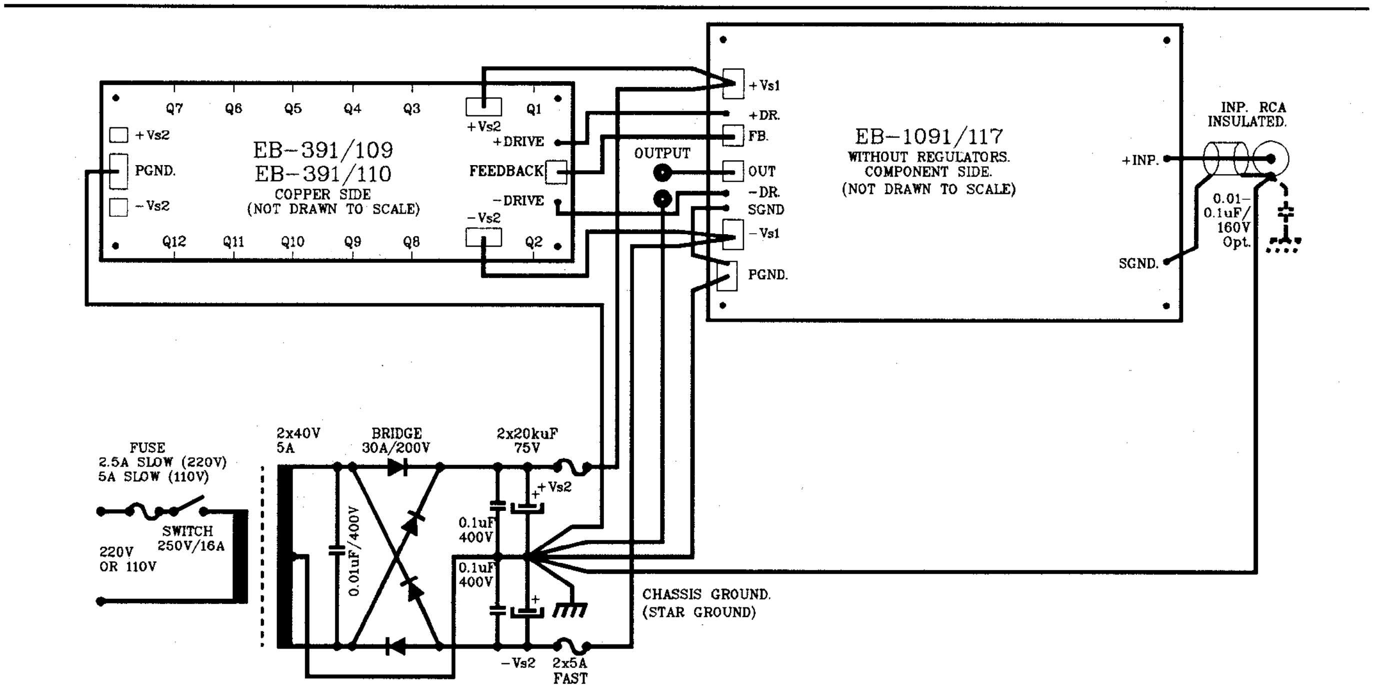

FIGURE 11: Proposed wiring diagram for monoblock with single supply.

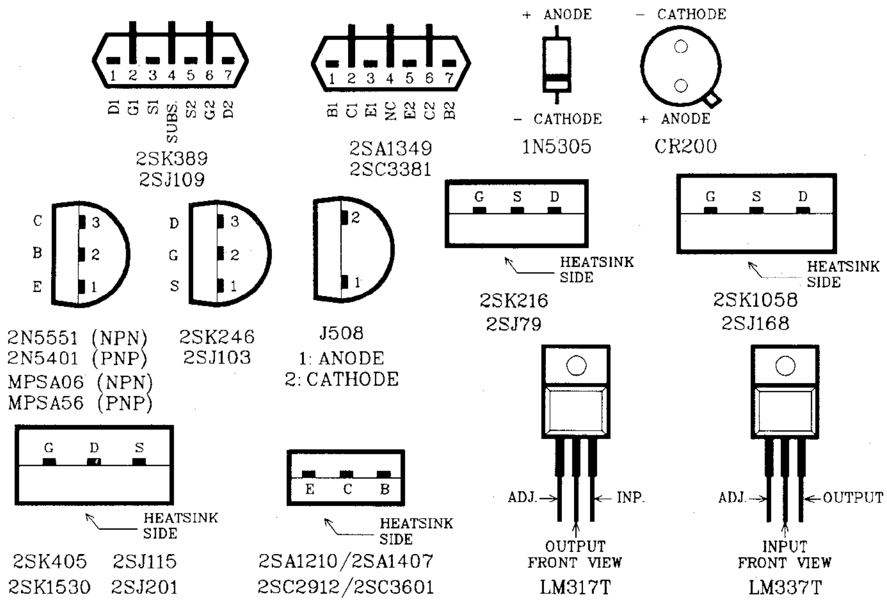

FIGURE 12: Pin configuration for devices used in DC-102. All devices are shown bottom view unless otherwise noted.

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fails. Remember, amplifiers can deliver high currents into very low impedances.

Set-Up Procedure

You should invest in a variable transformer (VARIAC—500VA should be adequate), as it can save you some expensive output devices not to mention the aggravation of replacing blown transistors and other components. Before turning on the mains, place P3 in its maximum resistance position and P2 in midposition. If you have an 8Ω load resistor with a minimum rating of 50W, connect it to the output. Connect the minus and plus inputs to the 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. Turn on the mains very slowly using the VARIAC. The measured current should not exceed a few hundred milliamps, and the DC voltage at the output should stay close to 0V.

Connect the DC voltmeter across resistor R5 (or R25) and check the voltage drop. It should be approximately 2.2V, or as much as 2.7V if you are using the J508 current diode. Reconnect the DC voltmeter to the output and, with P2, adjust the DC offset to 0V. When using high-bias output transistors which are completely off, you might have problems with this, so momentarily leave the offset and adjust the bias. Adjust it initially to approximately 500mA, monitoring the current through the output transistors with the ammeter. Now return to the DC offset and adjust it as close as possible to 0V with P2.

With the basic DC adjustments complete, 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, without high-frequency oscillation. If you have a THD analyzer, perform the usual measurements at different frequencies.

Once the amp is running properly, you can connect it to your system. To get the best sound, you must experiment with the bias. Assuming that you are using large heatsinks, adjust it to 100–250mA per pair of output devices. Minimum total quiescent current should be 500mA. If you use 250mA per pair, with three pairs of output devices and a supply voltage of ±55V, the quiescent power dissipation will be in excess of 80W. This will require a heatsink with a 0.25–0.3°C/W thermal resistance at 25°C ambient temperature. The SK56 heatsink is sufficient for approximately 80W dissipation. I recommend using a thermal breaker with a cut-out temperature of around 70°C on the heatsink.

Loudspeaker Protection

Nearly all semiconductor power amplifiers use plus/minus supplies and are DC-coupled to the loudspeaker. While advantageous in terms of sound quality, this can be dangerous for your speakers. If you accidentally insert a low-value fuse in one of the supply lines and it blows, the output will likely travel to the other supply voltage. The

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resulting current flow may be sufficient to kill the speaker. Similarly, if one side of the output stage blows up and shorts the output to the supply line, the DC voltage might damage the speaker.

Power-on and power-down can also cause problems. The DC voltages inside amplifiers change in discrete steps during the power supply ramp up and down, causing DC thumps at the output. Although these are not usually harmful to the speakers, they are annoying.

These problems can be solved by inserting a relay between the power amp output and the speaker. At power-on, the relay is not energized and the speaker is not connected to the amplifier. After a predefined delay, the relay turns on and the amp works normally. If a DC voltage occurs at the output, the relay turns off and the speaker disconnects.

DC Protection and Delay Circuit

The delay circuit (*Fig. 13*), as suggested by Jean-Claude Gaertner, is built around the well-known 555 timer (Q4). The time delay is defined by P2 + R14 and capacitor C5. With the values shown, it can be set between six and twelve seconds; a reasonable delay is approximately ten seconds. If you wish to allow more time before the speakers are connected, you can increase the P2 + R14 value and/or capacitor C5. R15 and C6, connected to the trigger pin (Pin 2), simulate a reset pulse and allow the timer to start counting. Pin 5 is decoupled through a 0.1µF/100 ceramic capacitor.

The relays are connected between output Pin 3 and the positive supply. For this circuit, I am using two relays in parallel in order to cope with high-current/high-power amplifiers; however, the contacts are connected in antiparallel to minimize rectifying effects. A green LED, which is connected across the relays, can be mounted on the front panel to indicate proper power amp operation.

Q1A/Q1B (a dual, FET-input op amp) is configured as a double-sided "window" detector. Q1B's positive input is connected to a reference voltage of approximately +2V, while Q1A's negative input is referenced to – 2V. Q1B's negative input and Q1A's positive input are connected to form the DC sensing input. Both outputs will be positive, and both level-shifting transistors Q2 and Q3 will be off, provided the DC input is within the "window" defined by the +2V/–2V references.

When the DC input moves outside the "window," either output will change to –12V, pulling current through the resistor chain R7–R8. Q2/Q3 turn on, and Pins 6/7 and timer Pin 2 are pulled to 0V through D7/D8. This resets the timer, and the relays disconnect the speaker from the amplifier. When the DC offset is removed from the input, the op amp output returns to +12V and Q2/Q3 turn off. The timer can now resume counting and, after the predefined delay, the relays will switch on the speaker.

Your power amp output has audio signals which must be removed from the input of the DC sensing circuit. This is done with a single-pole RC network consisting of R1 and C1–C2. You must select the –3dB point low enough to avoid triggering the circuit by low-frequency audio signals, but not so low that the circuit is too slow. If you select 1µF for C1, the circuit will activate at 50Hz with 100W into 8Ω—unacceptable in most applications. With 6.8µF, I measured full power down to 10Hz without triggering the circuit. With C1 equal to approximately 11µF (two 22µF caps in series), the –3dB point is at 0.15Hz and full power is available down to 5Hz. When

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. EB493, Peterborough, NH 03458-0576.

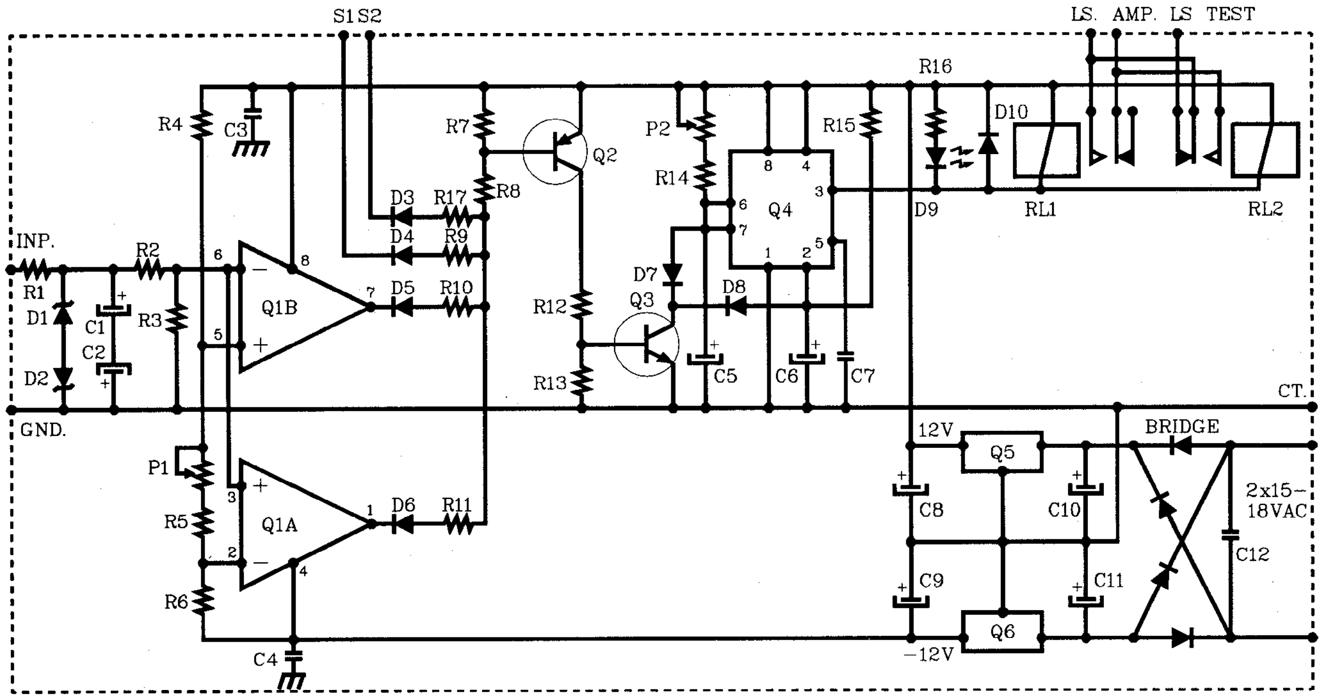

FIGURE 13: Delay and DC protection circuit (EB-192/132).

you drive the amp with 2Hz at full power, the circuit stays permanently shut down. If you wish to prevent subsonic signals from reaching your speakers, try increasing the – 3dB point.

D1 and D2 serve to prevent the caps from charging to a very high voltage, which would take a long time to discharge. More importantly, they protect the op amp inputs by preventing the input voltage from either rising above the +12V or below the –12V rails, which would destroy the ICs. Series resistor R2 limits the input current to the op amps.

DC inputs S1 and S2 can be used as extra logic inputs from other protection circuits. The logic level is the same as the output of the op amps: +12V, or no connection, and –12V. With the former, the circuit simulates normal operation (i.e., it is not activated). With the latter, Q2/Q3 turn on instantly and the speakers are switched off. These inputs can be used for thermal breakers (the contact must be normally open and connected to –12V), for short circuit testing at the output, for power sensing circuits, and so on.

TABLE 5

DELAY AND DC PROTECTION CIRCUIT PARTS LIST

PART	DESCRIPTION
Capacitors	
C1, 2	22µF, 40V Elco ROE EK or equiv.
C5, 8, 9	47µF, 40V Elco ROE EK or equiv.
C3, 4, 7	0.1µF, 100V cer.
C6	4.7µF, 35V TA
C10, 11	220µF, 40V Elco ROE EK or equiv.
C12	0.01µF, 400V cer.
Relay	
RL1, 2	Siemens V23127-B101 12V Gold-plated silver contact
Resistors	
R1	100k, 1W metal oxide
R2, 9–12, 15, 17	10k
R3	1M
R4, 6, 14	100k
R5, 8	22.1k
R7, 13, 16	2.21k
Semiconductors	
Q1A, 1B	LF412CN, TL072CP dual, FET-input op amp
Q2	2SA872
Q3	2SC1775
Q4	555 timer
Q5	7812 +12V reg, TO-220
Q6	7912 –12V reg, TO-220
D1, 2	ZPD10 10V/0.5W zener
D3–8, 10	1N4148
D9	Green LED
Bridge	B250C1500 250V/1.5A
Trimpots	
P1	50k multiturn cermet
P2	100k multiturn cermet
Miscellaneous	
	EB-192/132 PC board
	8-Pin DIL socket for Q1 and Q4
	Solder pins, 6.3 mm (¼″) quick connect, terminal blocks, or eyelets for signal and power connection.

Note: All resistors are 0.5W/1% metal film, unless otherwise noted.

Power is supplied by two 12V TO-220 regulators. AC input is 2 × 12–18V, with center tap, supplied by either the normal power transformer or a separate transformer with a rating of 5–10VA. The relay contacts use generous-size tracks. Be certain you use connectors and wires with very low resistance.

DC Protection Circuit Set-Up

You should test the board before installing it. Connect 2 × 12–15V AC to the AC terminals and the center tap to the CT terminal. Measure the voltages after regulators Q5/Q6 (across C8/C9); they should be +12V and –12V, respectively. It should take between six and twelve seconds for the relay to click without DC signal at the input. With P2, adjust the time delay to ten seconds, or to an appropriate value. The green LED should light when the relay is operated. If the relays don't click, you might see a fault indication from the "window" detector.

Connect a DC voltmeter between Q1B's Pin 6 and ground. With P1, adjust the voltage to approximately +2V. The voltage on Q1A's Pin 2 should be close to –2V. With no DC voltage at the input, the op amps' output Pins 7 and 1 should be at +12V. The voltage drop across R7/R13 should be zero. Apply +12V to the input; the voltage at Q1B's Pin 7 should be –12V, and the relays and LED should switch off. Remove the +12V and wait until the relays are again energized and the LED is lit. Connect –12V to the

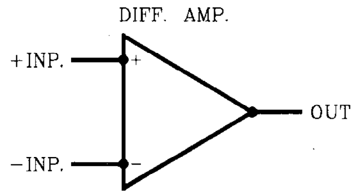

FIGURE 14: All amplifiers have + and − input.

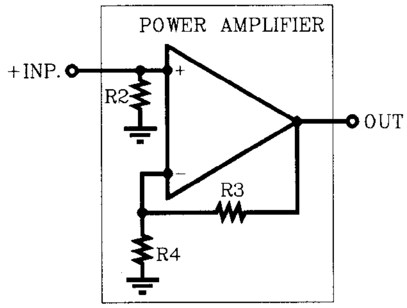

FIGURE 15: The negative input is normally used for feedback.

input; Q1A's Pin 1 should be −12V, and the relays and LED should switch off. Remove the −12V and check that the relays and LED switch on after the predefined delay.

Connecting the Circuit

In order to minimize the wire length, place the board close to the amplifier output and the output connector. Connect the amp output to the "AMP" pad and the output connector to the "LS" pad on the PC board. Use an output wiring cable, which you can solder di-

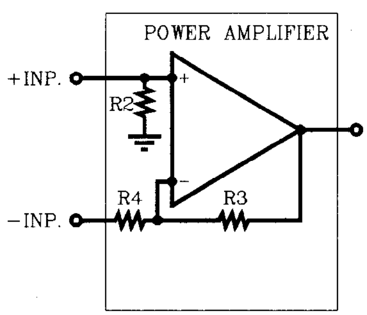

FIGURE 16: You can lift up R4 to access the negative input.

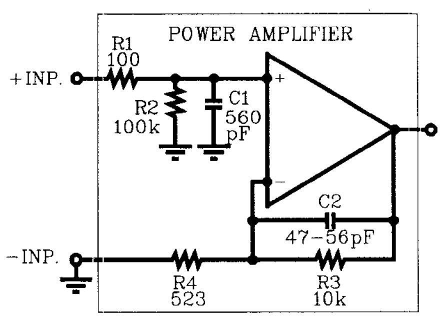

FIGURE 17: Single-input operation.

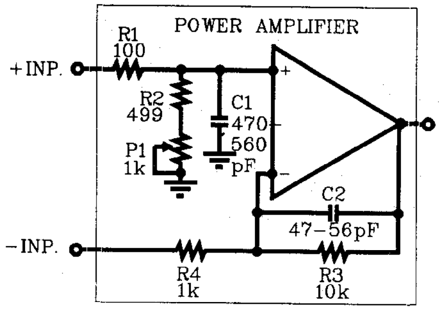

FIGURE 18: Balanced input with 1k input impedance on both inputs.

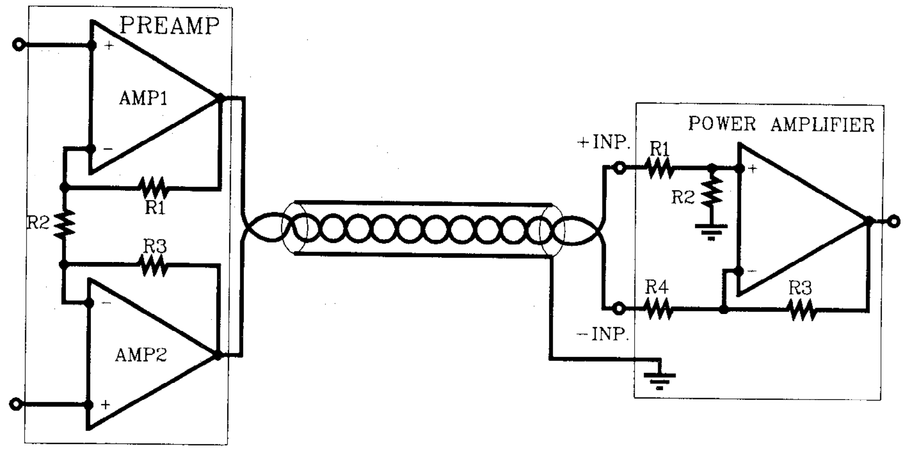

FIGURE 19: You can feed this power amp from a balanced preamp.

rectly to the pads. You can also use solder pins, 6.3 mm (¼") Quick Connects, or screw-type terminal blocks for the connection. The ground connection remains the same as before the board's installation.

Prepare a twisted pair of 18–20 AWG hook-up wire, and connect the amplifier output to the input of the protection circuit. Take the ground connection from the amplifier star-ground. If these wires must be near the power amp input, use a shielded cable rather than the twisted pair. Connect the 2 × 12–15V AC and the center tap to the board to complete the installation. Switch on your power amp and check the delay circuit operation. The DC protection circuit will work only if you have unwanted DC offset at the output. Hopefully, this will not be a frequent occurrence.

Balanced Operation

Virtually all amplifiers have a plus (+) and a minus (–) input ("Balanced Audio Amplifiers," *TAA* 1/91, p. 14). The positive input is used as the signal input; negative feedback is connected to the negative input. *Figure 15* shows a typical power amplifier: R3 and R4 form the feedback network, and the feedback is connected to the negative input. Having connected R4 to ground, however, we seem to have lost the amplifier's negative input. Fortunately, this is not a big problem—you can lift up R4's ground side and use it for this purpose, as shown in *Fig. 16*.

The difference between the two inputs in *Fig. 16* lies in the input impedance: for the positive input, it is approximately the value of R2, which can vary for typical power amps between 10k–100kΩ; for the negative input, it equals R4 due to the negative feedback. This resistor's value is significantly smaller than R2, ranging from 100Ω to a couple of kilohms for frequency stability. Obviously, driving an amplifier with an input impedance of 100Ω is difficult, because it requires a small power amp. Even 1 or 2k might cause problems, although this is certainly a more "preamp-friendly" value.

With my previous power amps, the feedback resistor R4 was around 100Ω. The amp's entire frequency compensation must be reworked to allow the change to 1k. My goal for the new amps was to use 1kΩ for R4. Since their input capacitance is very small, the increase does not affect the frequency stability.

Normally, I also have a resistor in series with the positive input (R1 in *Fig. 17*). I use the values shown for normal, single-input operation with the negative input or R4 connected to ground. Together with the source's output impedance and C1, R1 forms the usual low-pass filter at the amplifier's input. C1 might be considered too high a value if your source has a high output impedance; you may wish to experiment with this in your setup.

Figure 18 shows the input and feedback circuit modified to operate directly with a balanced source. In order to satisfy the equal input impedance requirements, I have changed R1 + R2 + P1 to approximately 1k. P1 is adjusted for best common-mode rejection ratio (CMRR) at mid frequencies; C1 should be adjusted for best CMRR at 20kHz. This power amp now has balanced inputs with approximately 1k input impedance on both. If your preamp has balanced outputs which are capable of driving 1kΩ loads, you can connect it directly to this power amp (*Fig. 19*). The preamp and power amp combination forms an instrumentation amplifier, as shown in *Fig. 16* in *TAA* 1/91 (p. 18).

My preamp modules previously de-

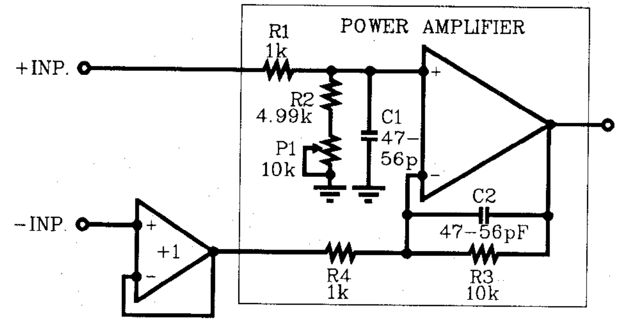

FIGURE 20: You can increase the input impedance on the negative input by using a buffer.

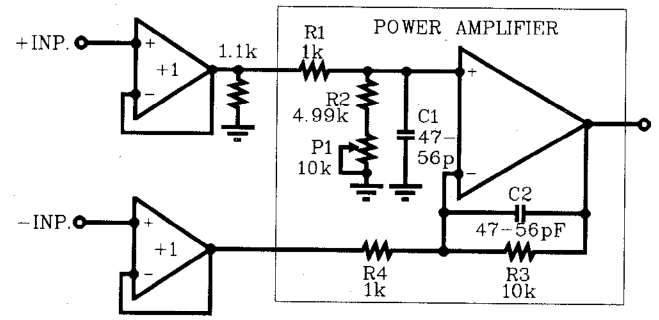

FIGURE 21: Buffers on both inputs allow you normal high-impedance operation.

scribed in *TAA* are all capable of driving this power amp setup in balanced mode. If your preamp can't drive 1k loads, you might consider isolating the negative input with a buffer (*Fig. 20*), an approach used in many high-end amps. I have modified the positive input to offer a 10kΩ input impedance, which should be within the capabilities of most preamps. The unity-gain buffer, capable of driving a 1k load, should have the same input and output impedances as the positive input (10k). Borbely Audio also offers a number of suitable buffers, and one-half of the dual Class A lineamp is also applicable for this purpose.

If you have two buffers of the same type, the circuit in *Fig. 21* will give you a close-to-ideal result. They represent equal load to your lineamp and equal source impedance to the power amp's two inputs. Also, with the 1.1k load at the positive buffer's output, both buffers are loaded equally, ensuring equal THD generation. The even-order THD products will therefore be eliminated in the differentially connected power amplifier.

When making your own buffers, be certain you don't arbitrarily select the IC op amps. Many high-end power amps fail to live up to expectations because they are driven from low-quality ICs. For this demanding job, you should use either high-quality devices or, preferably, discrete buffers.

Class A Push-Pull Operation

For those of you who wish to operate your amplifier in Class A, understanding the DC current and power dissipation requirements is important. Basically, a Class A amplifier will idle at twice or more its rated output. A 20W Class A amplifier will therefore have a minimum quiescent dissipation of 40W; a 50W amplifier will have a minimum of 100W.

In a practical amplifier, the dissipation will always be larger than this theoretical value as a result of losses in the output stage and, to a lesser degree, the voltage swing capability of the driver circuit. A 20–50% higher dissipation is considered normal.

In order to illustrate the DC current

and quiescent power dissipation requirements, we will calculate these for a 20W/8Ω amp. The RMS output voltage is:

$$V_{RMS} = \sqrt{P \times R} = \sqrt{20 \times 8} = 12.65V\ RMS$$

This is equivalent to 17.84V peak. Disregarding all losses in the amplifier, you would need a 2 × 17.84V supply for this amp. The RMS load current is:

$$I_{RMS} = \sqrt{\frac{P}{R}} = \sqrt{\frac{20}{8}} = 1.58A$$

Class A push-pull amps have an advantage in that they will leave the Class A at approximately twice the DC current in the output. As the current flow increases in the N-channel (NPN), it decreases in the P-channel (PNP) and vice versa, which is like doubling the quiescent current in the output stage before it reverts to Class B operation. The relationship between the RMS load current and the DC current in the output stage is:

$$I_{RMS} = 2 \times I_{DC} \times 0.707$$

The necessary DC current for our 20W amplifier will therefore be:

$$I_{DC} = \frac{I_{RMS}}{2 \times 0.707} = \frac{1.58}{1.41} = 1.12A$$

Theoretically, you would then have a quiescent power dissipation of 2 × 17.84V × 1.12A = 40W in your amp.

For practical amplifiers, you need to consider the losses in the output stage and operate them at a higher supply voltage. You would probably use a ±20V supply and select a higher quiescent current so your amp is well into Class A continuously (a minimum of 1.3A is indicated). This will raise the quiescent power dissipation to 52W, which is 30% higher than the theoretical value. You might go even higher for linearity reasons, but don't forget that the necessary heatsinking also increases with the power dissipation. If you consider running your amp at 50W Class A, the minimum requirements are: I_{DC} = 1.77A, and supply voltage of ±28V, for a theoretical dissipation of 100W. In a practical situation, you would run the amp close to 2A DC current with a minimum supply voltage of ±35–40V, for a quiescent power dissipation of more than 140W. You would need a very large heatsink, or you might consider using a fan. You can actually buy very low-noise fans and use a three-speed fan control. For high-power Class A applications, a forced-convection cooler with fan is almost mandatory. □