

On the negative side, the pre-driver Q316 feeds the negative push-pull drivers Q318, Q319 which drive the four negative main output MOSFETs Q325, Q329, Q334, Q337 and their current-sharing resistors R367, R375, R389, R392. The bias voltage for Q318 and Q319 is provided by R357 and D322, D323 and they also act to clamp the MOSFET gate drive to limit the negative peak current output to a safe level.

The distortion correction transistor Q315 senses the difference between the output signal (via D314, C326, R345, C323) and the signal on Q316's emitter, amplifies the error and feeds it back by driving a correction current through R340 and R342. Q307 and Q312 prevent excessive currents being drawn when the amplifier is driven into negative clipping. This configuration is covered by NAD patents.

The main outputs are fed from the low voltage supply rails $\pm V_L$ via the commutation diodes D326, D327. Above the commutation level, the current for the main outputs is drawn via the EDP MOSFETs from the $\pm V_H$ supplies. V_L is typically 75V in 4 Ω mode and 87V in 8 Ω mode. V_H is typically 108V in 4 Ω mode and 120V in 8 Ω mode.

The drive for the EDP MOSFETs is taken from the collector of Q308 and buffered by Q317 and Q320. A positive offset voltage is applied by D319 biased through R353 to drive the positive EDP MOSFETs Q326, Q330, Q333 with their current sharing resistors R369, R377, R385. The arrangement acts as a voltage follower so that, above commutation, the voltage on Q335's drain follows the signal on Q317's base (and hence the output signal) but displaced about 20 volts above the latter. D324 prevents reverse bias of the MOSFET gates and D325 limits the maximum drain current.

The negative EDP circuit achieves the same end, but in a different way to suit the quasi-complementary N-channel design. The signal on the emitter of Q320 is further buffered by Q313 and fed via the offset zener diode D316 and D318, C325, R355, R356 to the base of Q324. D323, Q323, Q324 and the MOSFETs Q328, Q332, Q336 act in the same way as a conventional complementary feedback pair. The result is that the voltage on the drain of Q336 etc. follows accurately that on the base of Q324 (plus an offset voltage). Q324's emitter is biased up 15 volts by Q323 and D323 in order to ensure that the MOSFETs can be driven into saturation on negative peaks. D318 prevents reverse bias of Q324's base-emitter junction and D323 limits the maximum drain current.

On the positive side, all the high-level, low-current stages (i.e. everything apart from the output MOSFETs) are fed from an extra +V_{HH} supply which is about 6 volts higher than +V_H. This extra voltage is necessary to ensure that the output and EDP MOSFETs can all be driven into positive saturation.

Some AC feedback is taken direct from the output MOSFETs via R327 to the feedback point on R326. The major part, however, is taken after the output relay RLY301 via R325. Both of these feedback resistors are 5 watt rated precision metal film types. The value of resistor R324 is set on production test to fix the total amplifier gain at precisely 29dB. A DC feedback servo ensures a very low output offset voltage and this comprises IC301, R314, R315, R318, R328, R329, C312, C313, C317. IC301 is fed from the $\pm 18V$ supplies via R302 and R308 (decoupled by C304, C308) which drop the voltage to typically $\pm 13.5V$ to be safely within the op-amp's rating.

Protection against short circuits and load faults is provided using a sophisticated analogue computer which calculates the junction temperature of the output MOSFETs with separate detectors for the positive and negative sides.

On the positive side, D402, R404, Q403 sense the voltage across Q338 and convert this to a current through R405 and hence D407. D401, R401, Q401, R402 sense the voltage across (and hence the current through) R394 and convert this to a smaller current through D403 and R406. These current signals feed into the transconductance amplifier IC401a which is configured as an analogue multiplier. The output current from IC401a, proportional to the instantaneous power dissipated in the positive output MOSFETs, flows through the R-C network C401, R420, C403, R422, C405, R424 to

ground. This network mimics the thermal time constants between the output MOSFET's case temperature and junction temperature. The voltage developed across the network is sensed by Q406 which switches on when excessive power is dissipated. By thermally coupling Q406 to the case of one of the MOSFETs (Q327), and applying an offset bias current through R418, the switching threshold of Q406 can be made to track quite accurately just inside the maximum rated junction temperature for the MOSFETs.

The negative side sensing is slightly different because the MOSFET current is sensed across R389, R393. This is done by D405, Q404, R410, with a bias current applied via R407. The collector current is fed from Q404's collector via R409 and current mirror D406, R408, Q405, R411 to produce a current into IC101b pin 16. The resistor values are arranged so that the scaling factor is the same as for the positive side. Voltage sensing is carried out by Q402, R403 and the resulting current fed to IC101b via D404. The output from IC101b is configured exactly as IC101a to drive the thermal sense transistor Q407, coupled to output MOSFET Q325. The two sense transistors Q406, Q407 have their collectors connected together and drive the protection relay driver IC601 via R604, R603, Q601, R607. These last devices are all mounted on the power supply PCB.

The last circuit on the power amplifier PCB is the voltage and current detector for the CPP (Continuous Power Protection) system. Q408, Q409, R427, R428, R431, Q410 sense the voltage across (and hence the current through) R389, R393 and convert this to a smaller current at Q410's collector. Q408, Q409 are biased from the current source Q412, Q413, R438, R439, R426. Q410's output current is fed via R430 to the current mirror D408, R429, Q411, R433 which is powered from +18V and generates a voltage across R434 which is proportional to the amplifier's output current. Similarly, R432, D409 generate a voltage across R437 which is proportional to the amplifier's output voltage. These two voltages are summed by R435, R436 and then averaged by C608 which is mounted on the power supply PCB.

Moving on to the power supply PCB we find Q610 which senses the voltage across C608 and starts to conduct if this exceeds approximately 600mV. Q611 and C609 serve the same function for the right hand channel. The collectors of Q610 and Q611 are connected together so that either or both channels can control the following SC² (Soft Clipping Control) system. The SC² circuit comprises Q604-Q608 and their associated bias components. Q606 buffers the DC control signal from Q610, Q611. The signal is further buffered by R626, R625 and Q604 to produce the positive soft clip voltage. The same signal is inverted by R628, D604, D605, Q608, R629, R630, Q607 and buffered again by R627, R624 and Q605 to produce the negative soft clip voltage. These two control voltages are fed to both power amplifier PCBs to drive the soft-clip diodes D301, D302 already mentioned. The action of this circuit is such that, if the amplifier's output exceeds a certain threshold level, the soft-clip control voltages are reduced to prevent any further increase in output. The averaging time constant of C608, C609 (≈ 2.3 seconds) ensures that the circuit ignores all music signals, but responds quite quickly to continuous test signals such as sine-waves. The various component values are chosen to set the amplifier's 1kHz clipping level for continuous sine-waves with both channels driven to approximately 280-290 watts into 8 Ω and the same into 4 Ω .

The SC² circuit is also used for two other functions. The normal Soft Clip function can be engaged using SW202. This connects R633 from Q606's base to ground and, at the same time removes the short circuit across the Soft Clip LED D801 allowing it to light with current from R635. D608, R636, R634, R632 produce the correct soft clip level in conjunction with R633. They are fed from +VHH which ensures that the soft clip level tracks changes in supply voltage caused by line or load variations.

The last function of the SC² circuit is to implement the first stage of TCP (Thermally Controlled Protection). If the temperature of either heatsink exceeds 80°C then one of the two thermal switches SW301 will open causing Q612 to switch off and Q614 to switch on. When Q614 switches on it connects R646 to ground and brings the soft clip control voltages down to a much lower level than with SW202/R633. This level is set so that the amplifier's output cannot swing far enough positive or

negative for the EDP circuits to turn on and connect the outputs to the high voltage supplies. Thus all the output current is constrained to be drawn from $\pm V_L$ which reduces the stress on the transformer and output devices. At the same time, Q615 and Q617 are also switched on, which engages the input attenuators (Q301, R304) on each power amplifier PCB to reduce the output level by about 4dB. This prevents any gross clipping being introduced, even if the amplifier was already being over-driven. When the thermal trips open and Q612 switches off, it allows current to pass through the red half of D802, the POWER/protection LED, which then glows amber to indicate that this first mode of protection has been engaged. CPP, SC² and TCP are all covered by NAD patents or pending patents.

The ultimate protection, both for the amplifier and loudspeakers, is provided by the speaker output relays. These are controlled by IC601. Apart from opening the relays on signals from the V-I protection circuit as already explained, IC601 has two other "fault" sources. First it senses the DC level on the output of each power amplifier via R601, R602, R605, R606, C602, C603 and opens the relays if the average DC becomes excessive. Secondly it provides muting at switch-on / switch-off. The "ON" condition is sensed via D602, which rectifies the low voltage AC and charges C606 negatively. At switch-on, the relays remain open until the voltage across C606 has gone sufficiently negative to pull down IC601 pin 1. At switch-off, C606 discharges rapidly through R619, D607 and causes the relays to open very quickly. The second stage of TCP is effected by the two 100° C thermal trips SW302 which are connected in series with the output relays. If either heatsink exceeds this temperature, then the relays open. At the same time, Q602 is turned on via R615, R616, thus turning on Q603 which in turn switches on the mute transistors on each power amplifier PCB (Q302). As these transistors switch much faster than the relay's contacts, they will remove the output signal a millisecond or two before the relay contacts open. This prevents arcing and erosion of the relay contacts which can lead to increased contact resistance and ultimate failure. When Q603 switches on it also turns on Q609 which shorts out the green half of D802, the POWER/protection LED. Q609 also pulls down D606 which switches off Q612 allowing current to flow through the red half of D802. Thus, whenever the output relays open, the POWER LED will glow red - whatever the condition of the other protection systems.

The supplies for the main power amplifiers are located in the centre of the power supply PCB. The low voltage (56/65Vac) transformer taps are fed via 10A anti-surge fuses F501, F503 to the bridge rectifier BR502. This feeds two banks of four 4,700 μ F/100V reservoir capacitors C501, C502, C503, C504, C508, C509, C513, C514 providing the $\pm V_L$ supplies. The high voltage (80.5/89.5Vac) transformer taps are fed via 10A anti-surge fuses F502, F504 to the bridge rectifier BR501. This feeds two banks of three 10,000 μ F/50V reservoir capacitors C505, C506, C510, C511, C515, C516 providing the $\pm V_H$ supplies. Finally, the highest voltage tap (101/110Vac) is taken via a 250mA anti-surge fuse F505, R501 and rectifier D504 to 4,700 μ F/16V reservoir capacitors C507, C512 providing the +VHH supply. F505 is also taken via D505, R502 to the -VH supply in order to balance the current drawn from this transformer tap. D501, D502, D503 prevent excessive forward or reverse voltages from appearing across the VH or VHH reservoir capacitors under fault conditions.

A separate 21-0-21 volt winding is used to power the $\pm 18V$ regulators. This winding is fed via BR901 to the reservoir capacitors C905, C906. The positive unregulated voltage is used to power the speaker output and switch-on delay relays RLY301 \times 2 and RLY601. IC901 and IC 902, together with their associated components R901-904, C901-904 produce the low noise regulated $\pm 18V$ supplies.

The primary side of the transformer has two windings, one 0-120V and one 0-110-120V. These are taken to the power supply PCB where the mains voltage can be set for 120V, 230V or 240V by means of wire jumpers. The incoming mains voltage is connected via a detachable mains cord to an IEC standard 3-pin inlet, which has a primary fuseholder built in on the live side. This contains the primary fuse F701 (6.3AT for 230 or 240V, 10AT for 120V) and also a spare fuse in its own compartment. This connector is wired to the two-pole power switch SW701 which is fitted with arc-suppression capacitors C701, C702.