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## TA-4650 Amplifier New Circuit Operation

### FET/BIPOLAR CASCADES

FETs and bipolar transistors are combined in several ways to produce stages with high-input impedance, high gain, or a combination of both.

The combination shown in Fig. 1a is an adaptation of the classic complementary feedback stage: it cascades two DC coupled amplifiers in a configuration that requires only a minimum of supply voltage, provides a stage voltage gain relatively independent of transistor characteristics, and has very-high input impedance. The gain in this circuit is determined by the ratio of two resistors, R207 and R208. The heavy negative feedback that is characteristic of this configuration produces a number of other benefits, such as reduced output impedance, increased bandwidth, lower distortion, etc. These characteristics of the feedback technique were discussed in the Technical Digest article on operational amplifiers. This circuit is in fact, a kind of simplified op amp that operates from a single supply.

The circuit in Fig. 1b is a sophisticated version of the feedback amplifier with a VFET used as the second stage. The reason for this is that this circuit is used in the low-level phono amplifier, an application where low-noise and high gain are important, and high input impedance is not.

The input transistor (Q101) is a new low-noise high-beta device. The high-beta and 1 megohm load resistor (R106) combine to yield an enormous voltage gain for the input stage of this circuit. A VFET is used for the next stage (Q102) because its high input impedance will not load Q101 and reduce the gain of the input stage. This circuit operates from a very high supply voltage (+98V), so it can handle the signal from high-output magnetic cartridges without distortion.

Two forms of negative feedback are used in this circuit. The base bias voltage for Q101 is derived from the source voltage of Q102, and the large capacitor (C107) across source resistor R112 bypasses signal voltage. This is the DC negative feedback. The bias voltage is therefore pure DC and the gain of transistor Q102 is not degraded by source degeneration. AC feedback from the output terminal (drain) of Q102 to the emitter of the input transistor accomplishes two things: gain stabilization and frequency shaping. The general gain reduction produced by the negative feedback makes the closed-loop stage gain less dependent on transistor characteristics; the frequency-selective network (R107 and R108, C104 and C105) used to accomplish this provides a gain characteristic that achieves RIAA equalization.

The circuit in Fig. 1c is extremely unusual in both configuration and performance, using both DC negative feedback and AC positive feedback. The DC negative feedback is achieved by using Q203's source resistor (R220) as the DC ground return for the collector of PNP transistor Q204. If the FET's drain current starts to decrease, its collector voltage rises and decreases the base-emitter bias of Q204. This reduces Q204's collector current, which decreases the voltage drop across R220. The reduced bias on the FET increases the FET's drain current, thus correcting the original shift that started the corrective procedure.

The AC positive feedback is called "Bootstrapping" in applications such as these. Its function is to make resistor R218 appear as a constant-current source to achieve extremely-high voltage gain for Q203. Since transistor Q204 is essentially an emitter follower, the signal voltage appearing at its emitter is nearly identical in amplitude to the signal at its base. Now if the signal voltage at each end of R218 is the same, and the signal current is determined by the

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transfer characteristics of the FET, Ohm's Law dictates that the equivalent value of R218 approaches infinity (as far as the signal current is concerned). In practice this turns out to be high enough to produce a stage gain of around 300X.

POWER AMPLIFIER

The input signal to the power amplifier (Fig. 2) is made to the non-inverting input of differential pair Q302/Q303. Transistor Q301 is a constant-current source for the differential pair. Signal developed across load resistor R305 is applied to com-

mon-emitter amplifier Q304. Note the RC network connected across R305. The purpose of R335 and C302 is to limit the high-frequency response of the circuitry so the open-loop gain drops below unity at frequencies where phase shift makes the feedback positive. If either component opens, the circuit may oscillate.

Diodes D301 and D302 in series with Q304's collector load resistor (R307) provide bias for transistors Q307 and Q309. Resistors R309, R310, R311 and trimmer RT301 provide precise adjustment of the bias point.

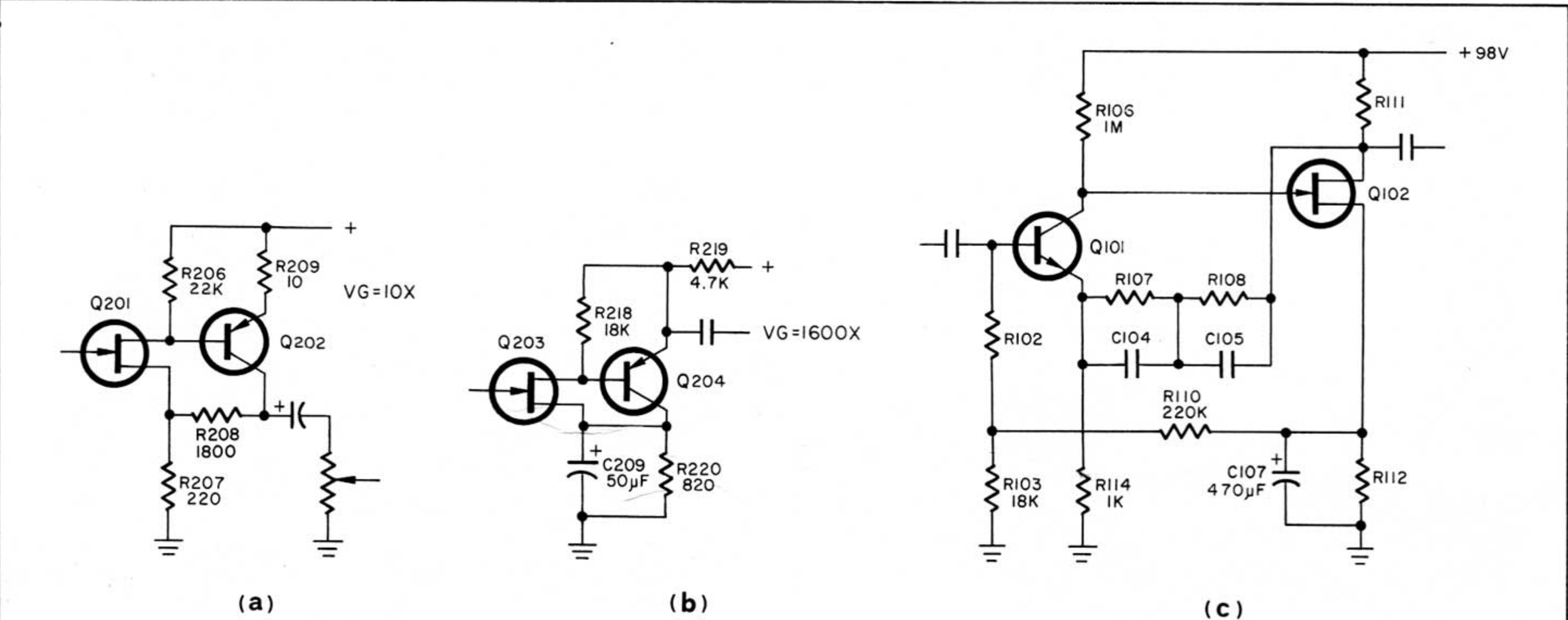
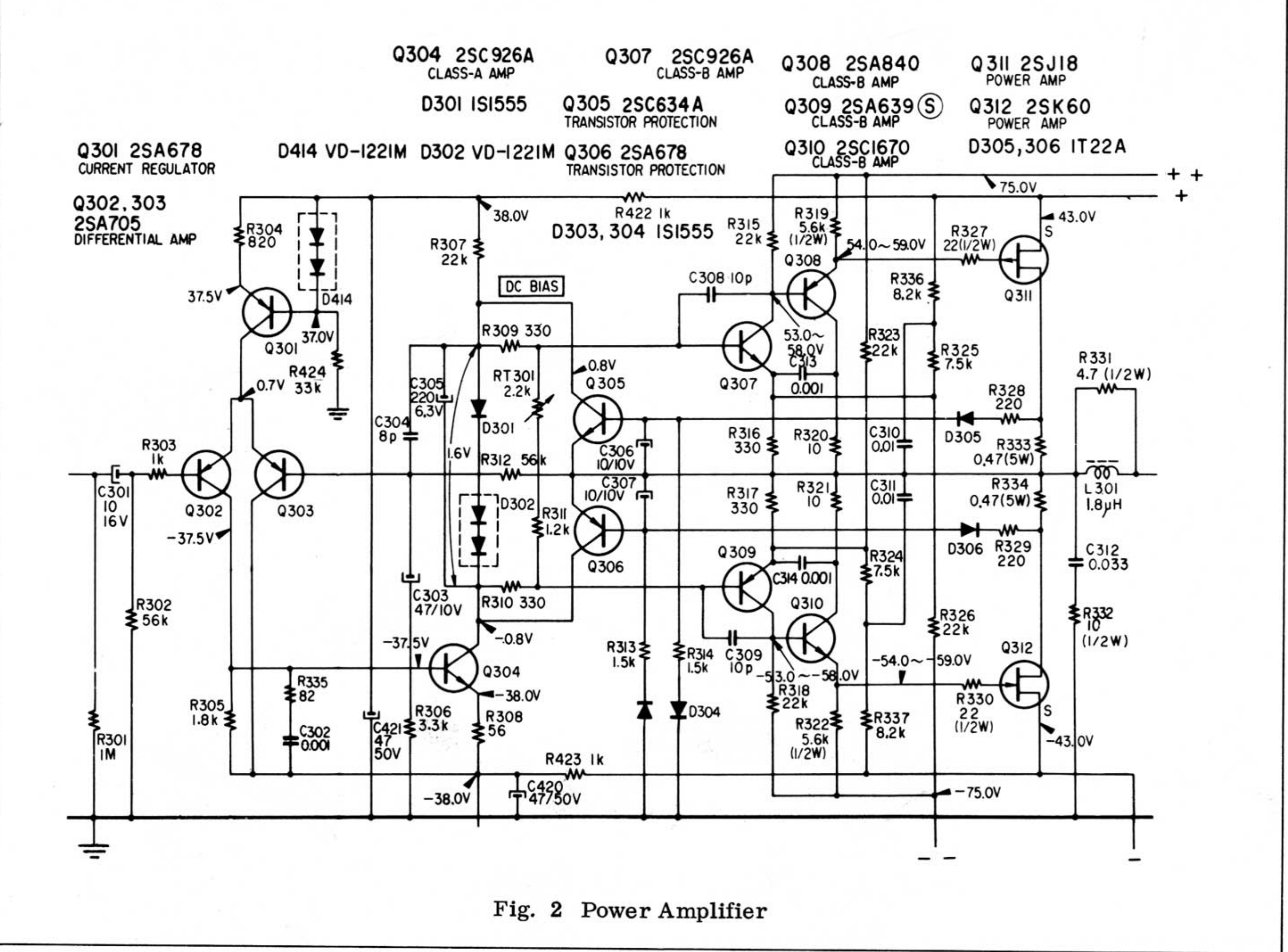


Fig. 1 FET/Bipolar Cascades





Transistors Q307 and Q309 serve two purposes; they amplify the signal to provide the large signal swings required by the VFET output stage, and also provide automatic bias compensation for the VFETs in conjunction with resistors R325, R326, R336, and R323, R324, R337. Bias correction is required because the gate-source bias on the VFET is dependent on the relative magnitudes of the main supply voltages (connected to the sources) and the high supply voltages (powering circuitry that controls the gate voltage). The large changes in the main supply voltages that result from signal level variations would unfavorably alter the VFET's bias (and hence operating point) without corrective circuitry. Also, ripple on the supply-voltage buses would appear in the drain current of the output transistors, since VFETs have a triode-like output characteristic. The resistor strings across the supply buses provide samples of the ripple voltages to the emitter of Q307 and Q309 that are processed in a manner that results in cancellation of the ripple.

Source followers Q308 and Q310 present a low driving impedance to the gates of the VFETs. Although the gates consume no power, their rather high input capacitance would otherwise load resistors R315 and R318 at high frequencies, thereby severely limiting the frequency response.

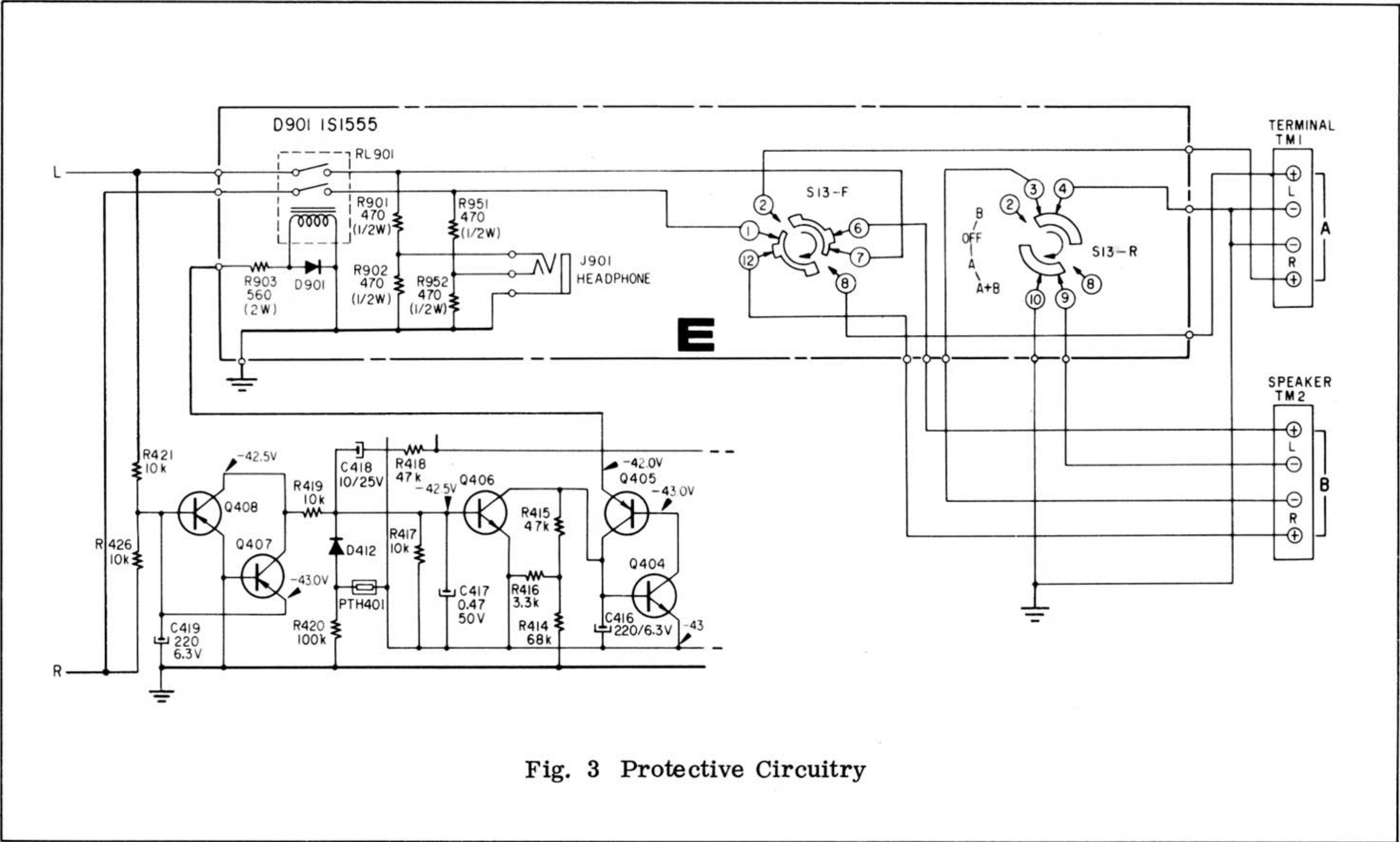
**Overdrive Protection.** Transistors Q305 and Q306 are the heart of a protective circuit that prevents excessive AC output current due to too much drive, or excessively-low load impedance. AC output currents that exceed a predetermined level produce AC voltage across sensing resistors R333 and R334 that is high enough to exceed the barrier potential of diode D305 (D306) and the base-emitter junction of transistor Q305 (Q306). This action

turns on transistors Q305 and Q306, changing their collector-emitter impedance from an open circuit to a low value. This low impedance shunts the bias diodes (D301 and D302) for transistors Q307 and Q309. These transistors move towards cutoff because of the "semi" base-emitter short, their collector voltages move towards the supply voltage level, and the gate bias of the VFETs move towards cutoff. This action reduces the AC current flow in the VFET source circuit until it drops to a safe level.

PROTECTIVE CIRCUITRY

**Speaker Protection.** This model introduces a new and extremely effective speaker protection circuit (Fig. 3). Resistor R421 and R426 couple any DC or extremely low-frequency audio voltage on either speaker line to transistors Q408 and Q407. Capacitor C419 acts as a low-pass filter (in conjunction with R421 and 426), so normal audio signals won't operate the protection circuit. If the fault voltage is positive, transistor Q407 will conduct; if the voltage is negative, Q408 will conduct. Their conduction closes the base current path (R419) for Q406, causing it to conduct and short the base-emitter junction of Q404. This opens the latched-up transistor combination Q404/Q405 that controls the current flow thru relay RL901. With no relay current, RL901 releases and the speaker lines open, thereby protecting the speaker.

The circuit also protects the speakers from the transients that occur when the power switch is turned on. Any "popping" noise that occurs cannot be heard because the time constant of capacitor C416 and resistor R415 prevents relay RL901 from being energized immediately. Capacitor C416 shunts current around the base-emitter junction of transistor Q404





until the capacitor has charged sufficiently for its voltage to exceed the barrier voltage of Q404. About 6 - 8 seconds after power is turned on, the voltage on C416 rises high enough for Q404 to conduct and energize RL901, and thereby connect the speakers. Similarly, the circuit protects the speakers from turn-off transients. When the power switch is turned off, the highly-negative supply begins to move towards zero. Since capacitor C418 and resistor R418 are connected from the highly-negative supply bus to the base of transistor Q406, Q406's base becomes more positive than its emitter, forward biasing Q406 into conduction and opening relay RL901 as previously described.

**Overheating Alarm.** The speaker protection circuit also serves as an "alarm" circuit to warn of overheating. Thermistor PTH401 is attached to the output transistors' heat sink. When the heat sink (and PTH401) is at an acceptably-low temperature, the resistance of PTH401 is relatively low, so the voltage across it is below the barrier (conduction) voltage of diode D412 and transistor Q406. If the output transistor overheats (presumably from operating at too high a power-output level), the heat sink temperature will rise, and the resistance of PTH401 will increase. Since PTH401 and resistor R420 form a voltage divider, the amount of voltage dropped across PTH401 increases. When this voltage drop exceeds about 1.2, diode D412 and Q406's BE junction becomes forward biased. This causes Q406 to conduct and opens relay RL901 as previously described.

POWER SUPPLY

**Rectifiers.** The VFET output stage requires driver

stages whose supply voltage is much higher than the supply voltage for the VFETs. This is accomplished by using voltage-multiplier circuits that add voltage to the main outputs to produce auxiliary outputs that are nearly twice the voltage of the main outputs. How this is done is best seen by examining the simplified schematic of the rectifier circuit (Fig. 4).

A bridge rectifier (D401, D402, D408, D409) and center tapped transformer produce the positive and negative main outputs that supply the VFET output stages. The main outputs are each around 43 volts under no-signal conditions. Since they use a capacitive input filter (C401 and C412), this voltage drops significantly with maximum signal.

The high-voltage outputs (two positive, one negative) are produced by voltage-multiplier circuits. Positive 130V for the high-voltage regulator is obtained by charging capacitor C405 in the following manner: when (A) is - and (B) is +, diode D410 conducts and charges capacitor C402 to the peak transformer voltage (measured from (A) to (B)). When (A) is + and (B) is -, D410 opens and diodes D404 and D401 conduct. This allows capacitor C402 to charge capacitor C405. The conduction of D401 also charges capacitor C401 to about 1/2 the peak transformer voltage. Since the voltages on capacitors C401 and C405 are in series-aiding, the total DC voltage available to the HV regulator is about triple the (no load) main output voltage.

Capacitors C403 (C413) and C404 (C414) and diodes D405 (D411) and D403 perform the same functions for the positive (and negative) driver supply. Resistor R401 (R413) and capacitor C406 (C415) provide additional filtering.

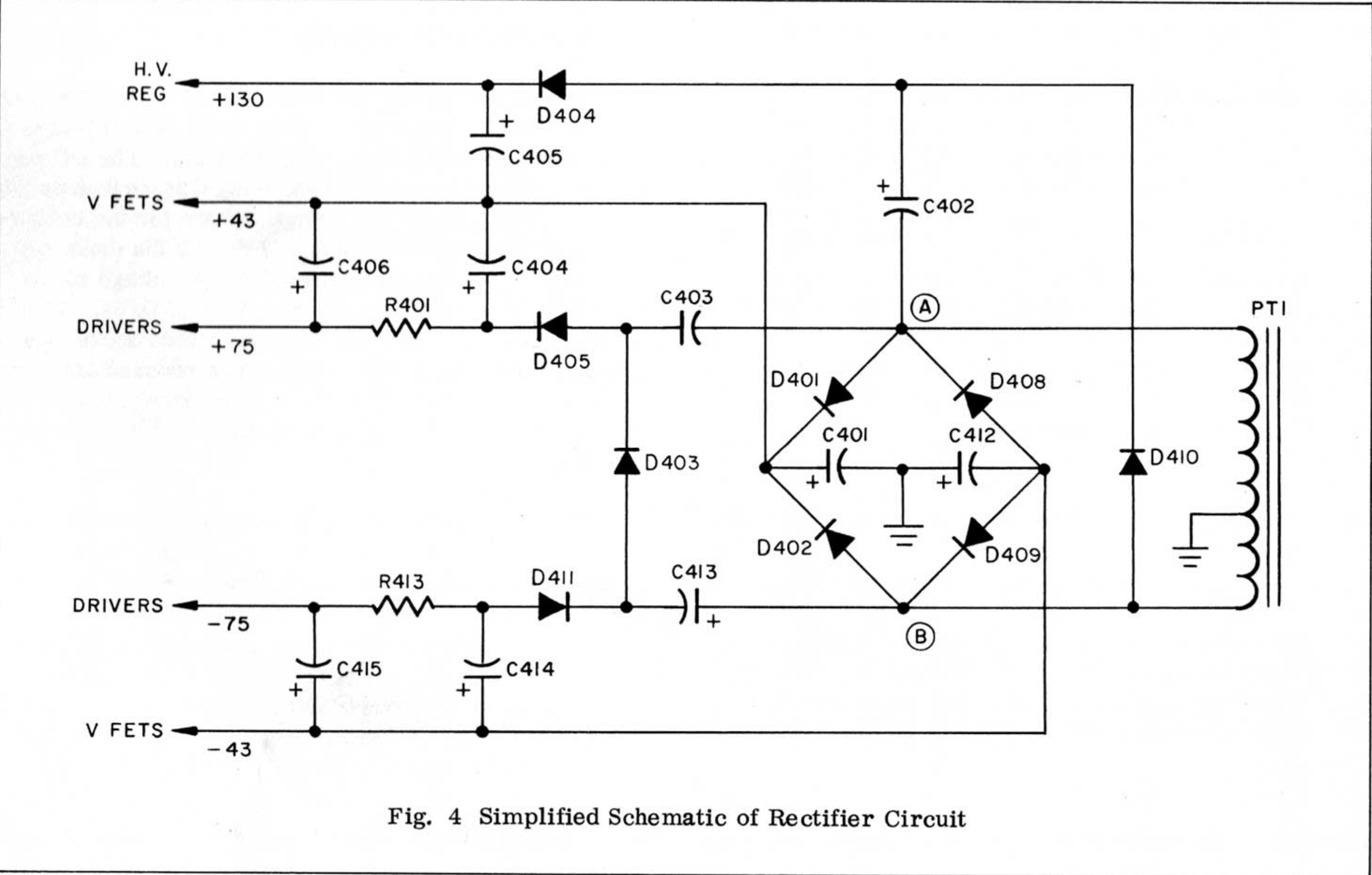


Fig. 4 Simplified Schematic of Rectifier Circuit



**Regulators.** The LV (low-voltage) regulator operates from the main (+ 43V) positive supply (See Fig. 5) The circuit is fairly standard: transistor Q403 is the series pass element, transistor Q401 is the error detector and control amplifier, and zener diode D406 is the reference voltage source (temperature stabilized by diode D407). However, Q401's load resistor (R411) is returned to the HV (high-voltage) regulator output. This yields improved line regulation for the LV regulator, and ensures that the HV regulator transistors will not be reverse biased (and thereby damaged) by the LV regulator coming up its full output voltage (+20V) before the HV regulator exceeds this level.

The HV regulator is also fairly standard; transistor Q409 is a Darlington driver for pass transistor Q402, and transistor Q410 is the error-detector and control amplifier. However, the reference-voltage source is the LV regulator. This makes the HV regulator stability (and other performance characteristics) dependent on the LV regulator. Also, since the load resistor for Q401 is connected to the HV regulator output (as previously described), the LV regulator is dependent on the operation of the HV regulator. What this interaction means is that a fault in either regulator will affect both regulators.

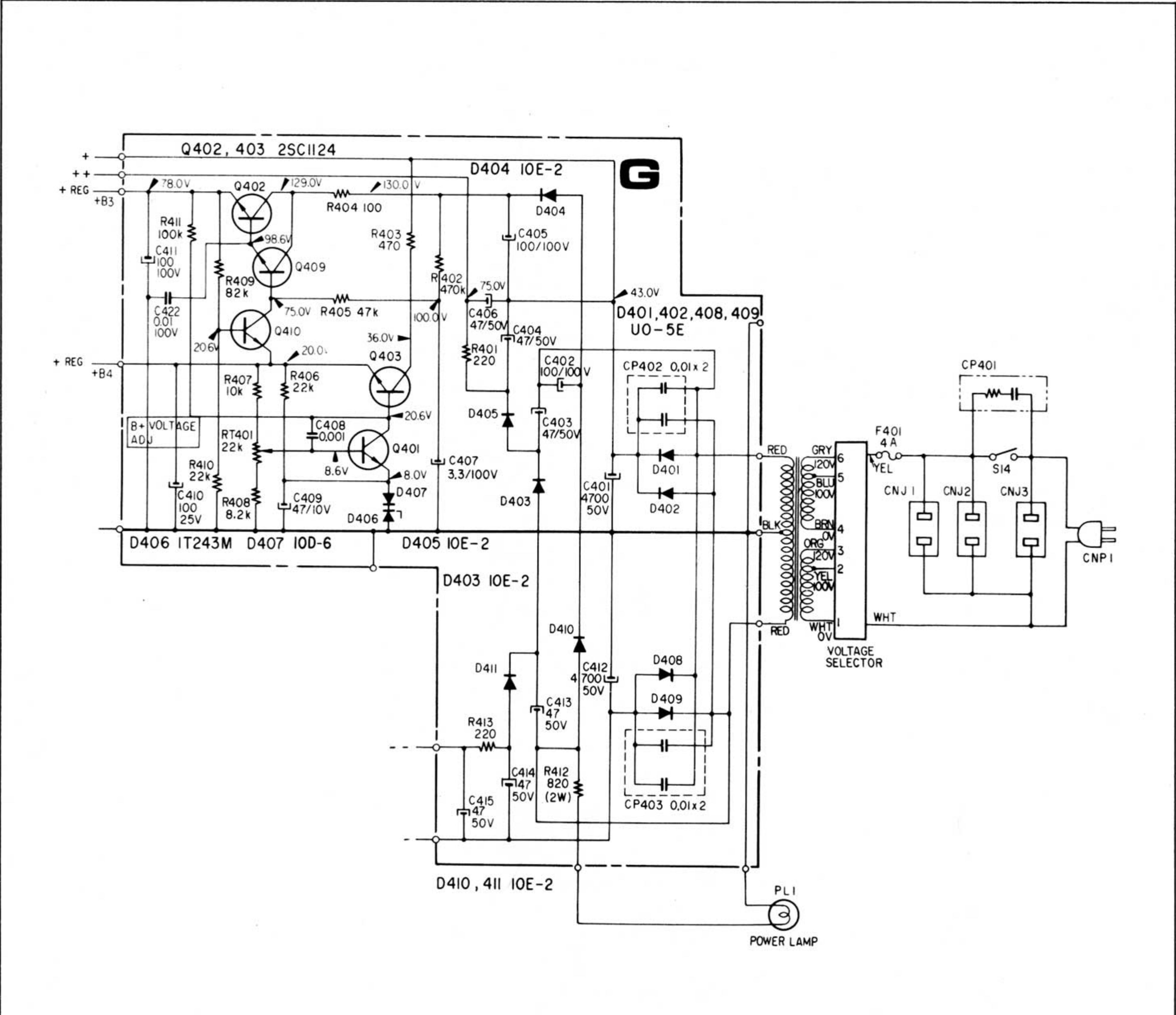


Fig. 5 Power Supply Schematic



# NOTES

[illegible]