INSTRUCTION MANUAL

Serial Number ____________

TYPE 3A9

DIFFERENTIAL AMPLIFIER

Tektronix, Inc.
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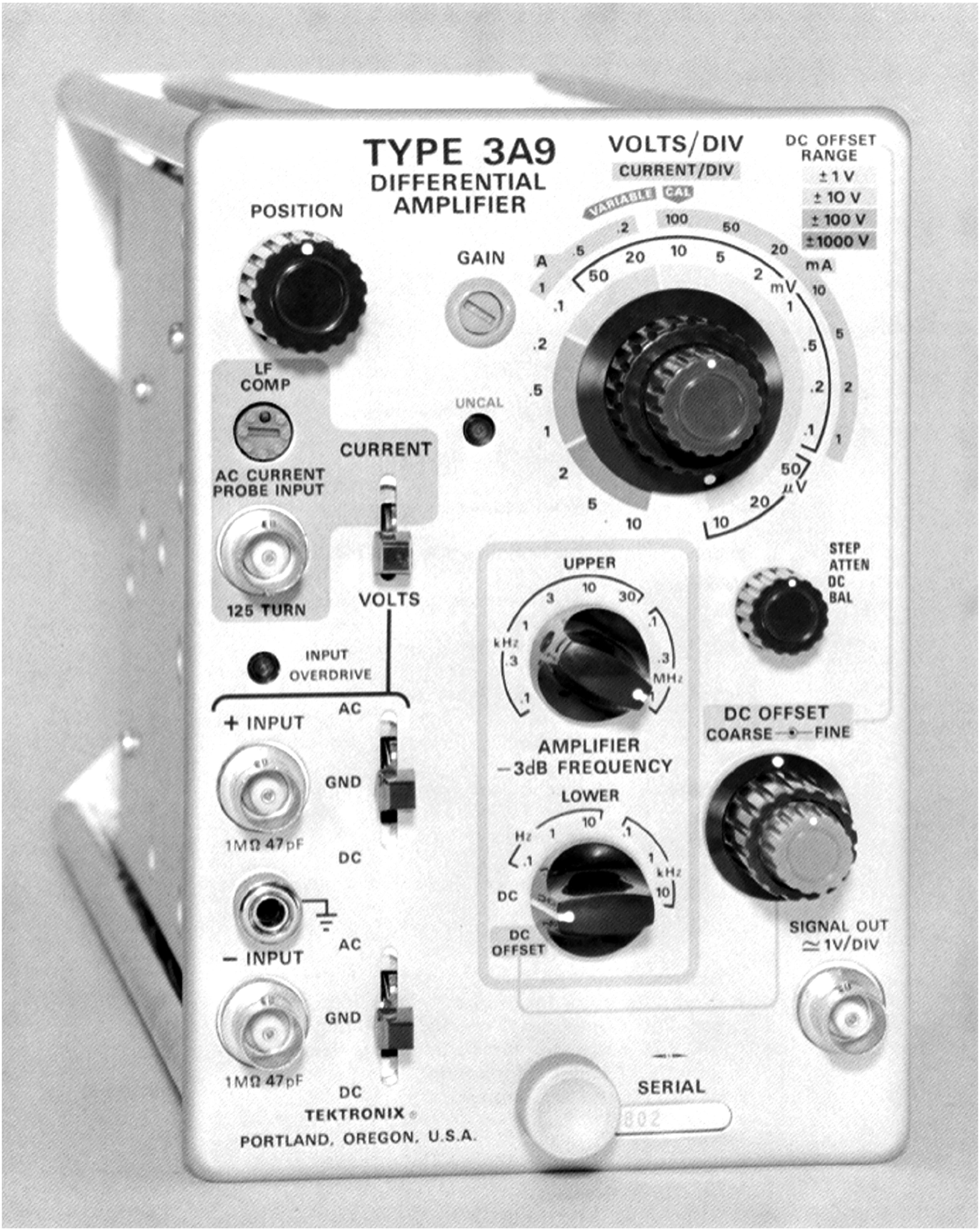
TYPE 3A9
DIFFERENTIAL AMPLIFIER
POSITION
VOLTS/DIV
CURRENT/DIV
VARIABLE
CAL
DC OFFSET RANGE
±1 V
± 10 V
± 100 V
±1000 V
GAIN
A
mA
mV
μV
UNCAL
LF COMP
CURRENT
AC CURRENT PROBE INPUT
125 TURN
VOLTS
STEP ATTEN DC BAL
UPPER
kHz
MHz
AMPLIFIER
−3dB FREQUENCY
LOWER
Hz
DC
DC OFFSET
INPUT OVERDRIVE
+ INPUT
AC
GND
1MΩ 47pF
– INPUT
DC OFFSET
COARSE FINE
SIGNAL OUT
≃1V/DIV
SERIAL
TEKTRONIX
PORTLAND, OREGON, U.S.A.

SECTION 1
SPECIFICATION

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

The Type 3A9 Vertical Plug-in is a DC coupled differential amplifier with excellent common-mode rejection and high gain characteristics for low level applications.

The DC Offset capability of the Type 3A9 allows the display of very small AC signals, containing a large DC component at deflection factors not possible with AC coupling. The vertical deflection factor of the Type 3A9 is variable from 10 μV/Div through 10 V/Div. The high and low —3 dB frequencies which can be selected at the front panel, set the bandwidth. Thus, for low frequency applications the signal-to-noise ratio can be improved by restricting the bandwidth of the Type 3A9.

The Type 3A9 is designed for use in Tektronix Types 561A, 561B, 564, 564B, 565, and without digital readout in the Type 567/6R1A and 568/230. Used with the Type 129 Power Supply, the Type 3A9 can drive recorders, X-Y Plotters, oscilloscopes and other indicators.

The instrument will perform as stated under the Performance heading, within an ambient temperature range of 0° C to +50° C (after a 1 minute warmup) provided that the instrument has been calibrated within an ambient temperature range of +20° C to +30° C. Warmup time for given accuracy is 5 minutes.

ELECTRICAL CHARACTERISTICS

Characteristic	Performance Requirement
Deflection Factor	
Calibrated Range	10 μV/DIV to 10 V/DIV; 19 steps in a 1-2-5 sequence, or 1 mA/DIV to 1 A/DIV
Accuracy	
Voltage	Within 2%
Current	Within 3%
Uncalibrated (Variable)	Continuously variable; extends deflection factor to at least 25 V/DIV.
Differential Dynamic Range	
10 μV/DIV to 10 mV/DIV	±1 V
20 mV/DIV to .1 V/DIV	±10 V
.2 V/DIV to 1 V/DIV	±100 V
2 V/DIV to 10 V/DIV	±1000 V (500 V maximum, each input)
Frequency Response (Full Graticule Reference with voltage input)	
Overall Response DC (Direct) Coupled Input	DC to 1 MHz, —0%, +30%
AC (Capacitive) Coupled Input, Lower Bandwidth Frequency	1.6 Hz within 5%
Bandwidth Limit (—3 dB points) Accuracy	
High	
1 MHz	0% to +30%
300 kHz to 100 Hz	Within 12% of value indicated by UPPER —3 dB FREQUENCY setting. 9 steps in a 10-3-1 sequence
Low	
0.1 Hz to 10 kHz	Within 12% of value indicated by LOWER —3 dB FREQUENCY setting. 6 steps in a 100-10-1 sequence
Current Probe Frequency Response	At least 10 Hz to 1 MHz (—0%, +30%)
Overdrive Recovery	10 μs or less to recover to within 0.5% of zero level after removal of a + or — test input applied for at least 1 second. Test signal not to exceed differential dynamic range.
Common Mode Dynamic Range	
10 μV/DIV to 10 mV/DIV	±10 V
20 mV/DIV to .1 V/DIV	±100 V
.2 V/DIV to 10 V/DIV	±500 V
Input Overdrive Light	Indicates that differential overdrive is being approached.
Common-Mode Rejection Ratio	
DC (Direct) Coupled	See Graph, Fig. 1-2
AC (Capacitive) Coupled	See Graph, Fig. 1-2
Maximum AC Current	10 A, peak to peak

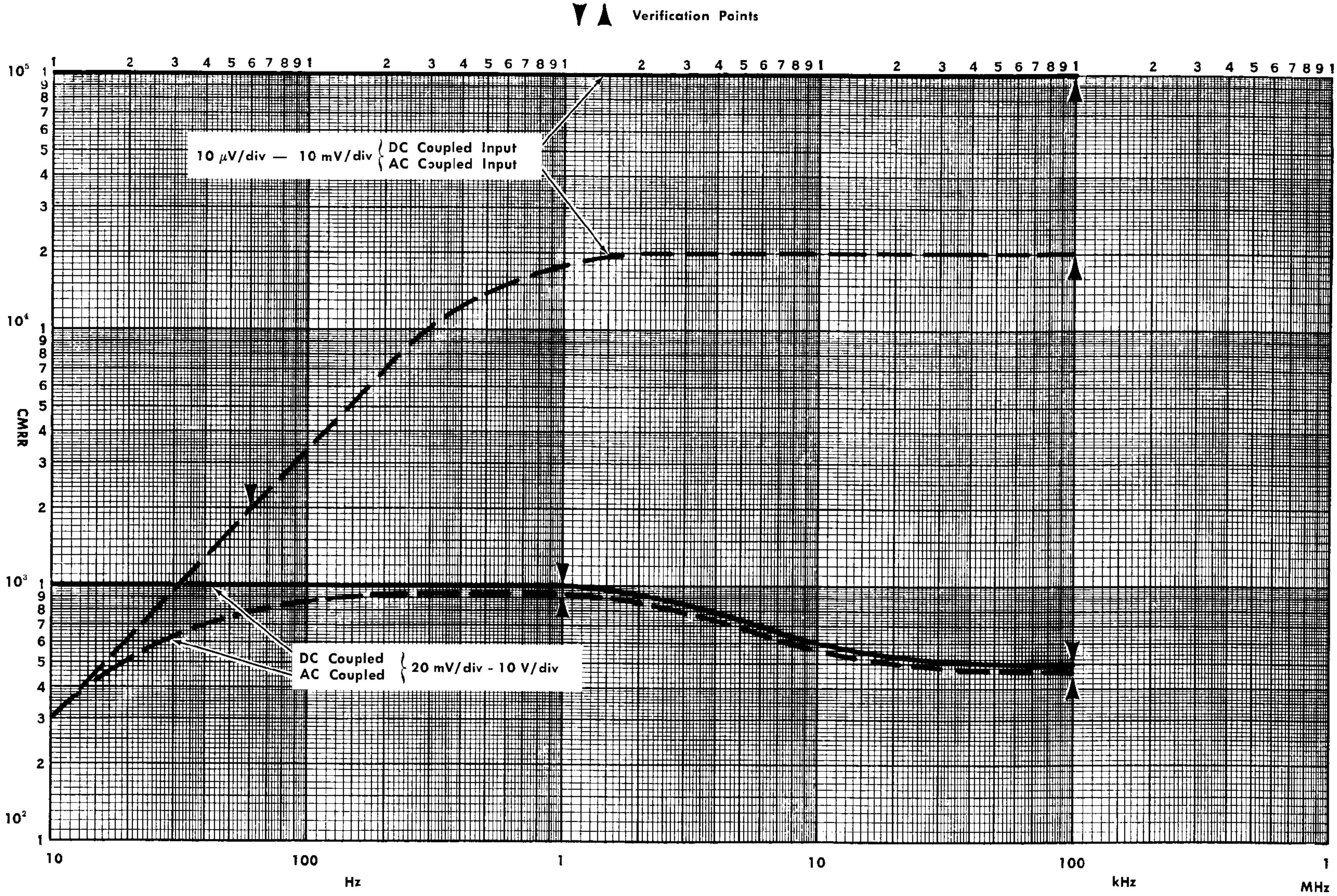

Fig. 1-2. CMRR vs Frequency, for Signals Not Exceeding Common-Mode Dynamic Range.

ELECTRICAL CHARACTERISTICS *(Cont)*

Characteristic	Performance Requirement
Maximum Input Voltage DC ((Direct) Coupled, DC plus peak AC	
10 μV/DIV to 10 mV/DIV	±15 V
20 mV/DIV to 10 V/DIV	±500 V
AC (Capacitive) Coupled Input DC Voltage	±500 V, each input
AC (Capacitive) Coupled Input DC Rejection	At least 4 x 10^5:1
Input R and C	
Resistance	1 MΩ, within 1%
Capacitance	47 pF, within 2.5 pF
Time Constant	47 μs, within 4%
Maximum Input Gate Current	+25°C +50°C
10 μV/DIV to 10 mV/DIV	each input ±20 pA ±100 pA both inputs ±40 pA ±200 pA
20 mV/DIV to 10 V/DIV	each input ±10 pA ±10 pA
Display Shift at 10 μV/DIV	
AC Coupled	each input ±2 cm ±10 cm
Variable Balance	0.2 divisions or less shift as VARIABLE control is turned from fully clockwise to fully counterclockwise position
Step Atten DC Balance	Adjustable for no position change while switching VOLTS/DIV-CURRENT/DIV
Displayed Voltage Noise Tangentially Measured	12 μV or 0.1 div (whichever is greater) 1 MHz bandwidth, source resistance 25 Ω or less. See Section 5 for method of measurement.
DC Drift	
Drift with Time (Ambient Temperature and Line Voltage Constant)	
Short Term	5 μV/min (peak to peak) or 0.1 div (whichever is greater) after 1 hour warmup.
Long Term	10 μV/hour (peak to peak) or 0.1 div (whichever is greater) after 1 hour warmup.
Drift with Ambient Temperature (Line Voltage Constant)	50 μV/°C
Isolation between + and — Inputs (+INPUT to an Open — INPUT, —INPUT to an Open + INPUT)	
10 μV/DIV to 10 V/DIV	At least 200:1, DC to 1 MHz.
Signal Output	
Dynamic Range	At least +5 V to —5 V
Amplitude	1 V/Displayed Division, within 20%
Amplitudle Change Over Dynamic Range	Within 2%
Bandwidth	DC to at least 500 kHz
Output Resistance	100 Ω or less
DC Offset	
Coarse Range from Electrical Zero	
10 μV/DIV to 10 mV/DIV	+1 V to —1 V (within 10%)
20 mV/DIV to .1 V/DIV	+10 V to —10 V (within 10%)
.2 V/DIV to 1 V/DIV	+100 V to —100 V (within 10%)
2 V/DIV to 10 V/DIV	+1000 V to —1000 V (within 10%)

ENVIRONMENTAL

Characteristic	Performance Requirement
Temperature	
Non-operating	—40°C to +65°C
Operating	0°C to +50°C
Altitude	
Non-operating	To 50,000 feet
Operating	To 15,000 feet
Transportation	Qualifies under National Safe Transit Committee test procedure 1A, Category II (24 inch drop)

SECTION 3
CIRCUIT DESCRIPTION

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

A block diagram description covering the general configuration of each circuit in the Type 3A9 is included in this section. Following the block diagram description is a detailed description of each circuit and the functions of specific components.

Simplified drawings are provided where necessary for easier circuit understanding. Complete schematic diagrams are included in the Diagrams sections. These should be referred to throughout the detailed circuit description.

The values of resistors on the schematics are in ohms unless otherwise specified. Capacitor values are indicated in the following manner unless otherwise specified; whole numbers indicate the value in pF, decimal numbers indicate the value in μF. For example, 33 is pF and 0.1 is μF.

BLOCK DIAGRAM DESCRIPTION (see Block Diagram Pullout preceding schematics)

Input Coupling

A signal applied to the + Input connector passes through the input coupling selector switch to the input attenuator circuit. The signals can be AC coupled, DC coupled or disconnected internally. When the Input coupling switch (see Input Amplifier diagram) is in the DC position, the input signal is coupled directly to the input attenuator. In the AC position, the AC signal is coupled through the coupling capacitor, blocking any DC component. The GND position disconnects the signal from the amplifier, connects the signal to ground through 1 MΩ and grounds the input amplifier gate. This switching arrangement provides a ground reference for the amplifier without removing the input leads or otherwise disconnecting the input signal. The 1 MΩ resistor allows the input capacitor to be precharged in the GND position. With the input capacitor charged to the DC level of the signal, there will be no charging current surge into the amplifier input when switching to the AC position.

The —INPUT function in the same manner as the +INPUT.

Current Probe Input

Signal from the current probe is fed into the ×16 preamp through two paths (1) directly from the AC CURRENT-VOLTS switch to the +INPUT, and (2) via the PROBE COMP control, through the compensating feedback amplifier (integrator), through the AC CURRENT-VOLTS switch to the —INPUT.

When the AC CURRENT-VOLTS switch is in the VOLTS position, the probe signal is grounded.

The amplifier, Q370-Q375, an integrating feedback configuration, provides compensation for the probe characteristics to give essentially flat response to less than 10 Hz (dependent upon current probe type). Fig. 3-1 gives a straight-line approximation of probe and compensation characteristics and the resultant response.

Fig. 3-2 shows a simplified diagram of the amplifier.

Input Attenuators

The input attenuators for the + and — Inputs are of the conventional RC type and, with one exception, are identical. The exception is that the resistive elements of the — input attenuator are adjustable to facilitate matching the — and + inputs to obtain optimum DC common-mode signal rejection.

The attenuators (schematic diagram number 2) are frequency-compensated voltage dividers which provide constant attenuation at all frequencies within the passband of the instrument, while maintaining a constant input time constant (47 μs) for all positions of the VOLTS/DIV switch.

Each attenuator contains an adjustable capacitor to provide correct attenuation at high frequencies and adjustable shunt capacitance to provide correct input capacitance. The attenuators, in conjunction with gain switching in the output amplifier, are used in only the 20 mV/DIV through 10 V/DIV. From 10 μV/DIV through 10 mV/DIV, only the output amplifier gain switching is used to set the deflection factor.

Preamp

From the input attenuators, the signal is coupled to the preamp. The preamp consists of two identical feedback amplifiers connected in a differential configuration. The overall differential gain is approximately 16.3.

The supply voltages for the two amplifiers are obtained from a common power supply which is bootstrapped to the input to improve the common-mode rejection ration of the preamp.

Each input is equipped with an overdrive protection circuit consisting of fuses and clamping diodes. For deflection factors from 10 μV/DIV through 10 mV/DIV the fuse will open if the current exceed 1/16 A (approximately 15 V at the input), preventing damage to the input circuitry.

An overdrive detector circuit is provided to indicate when the preamp is approaching the limits of its differential dynamic range. A front-panel indicating lamp lights when overdrive occurs.

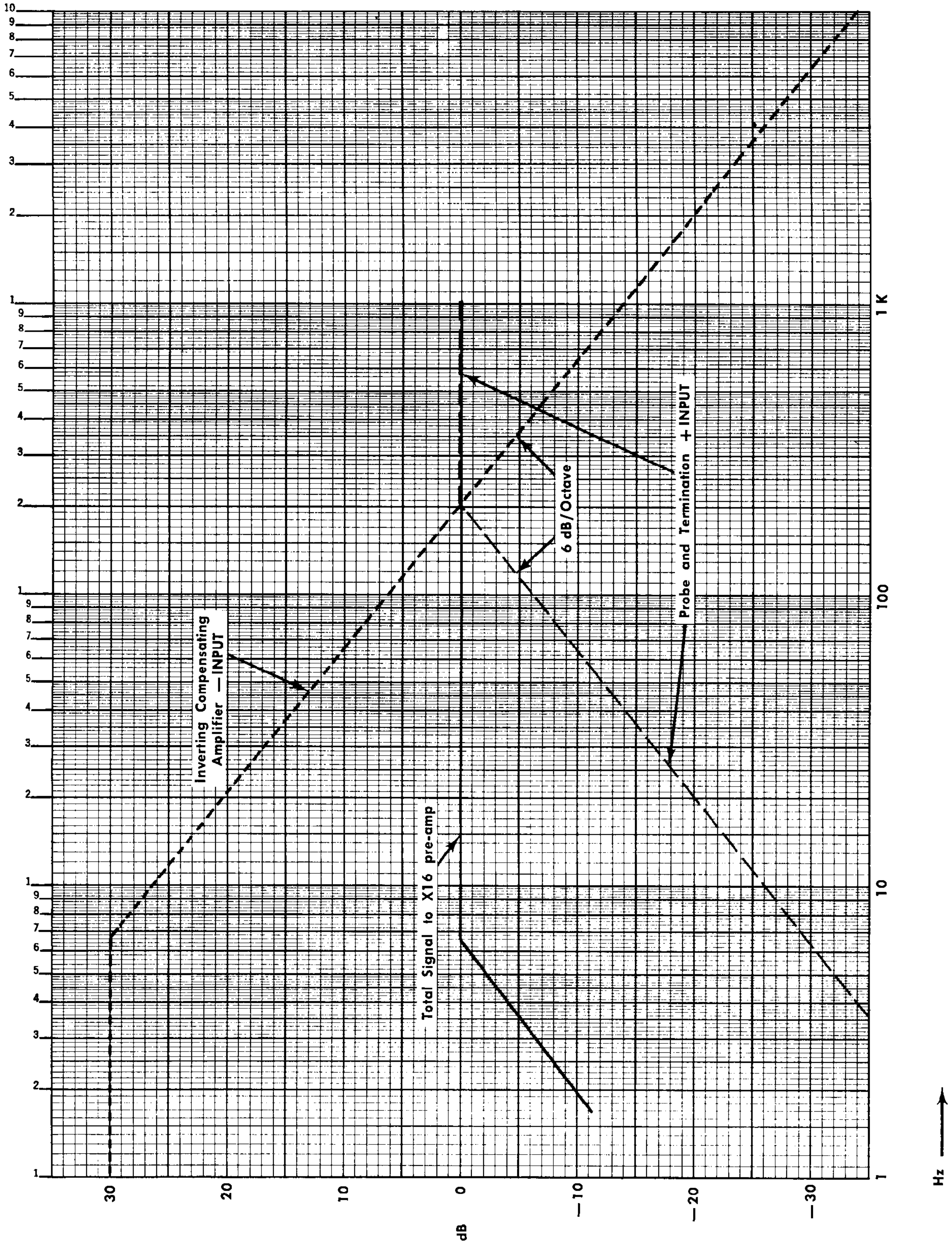

Fig. 3-1. Straight line approximation of probe and compensation characteristics.

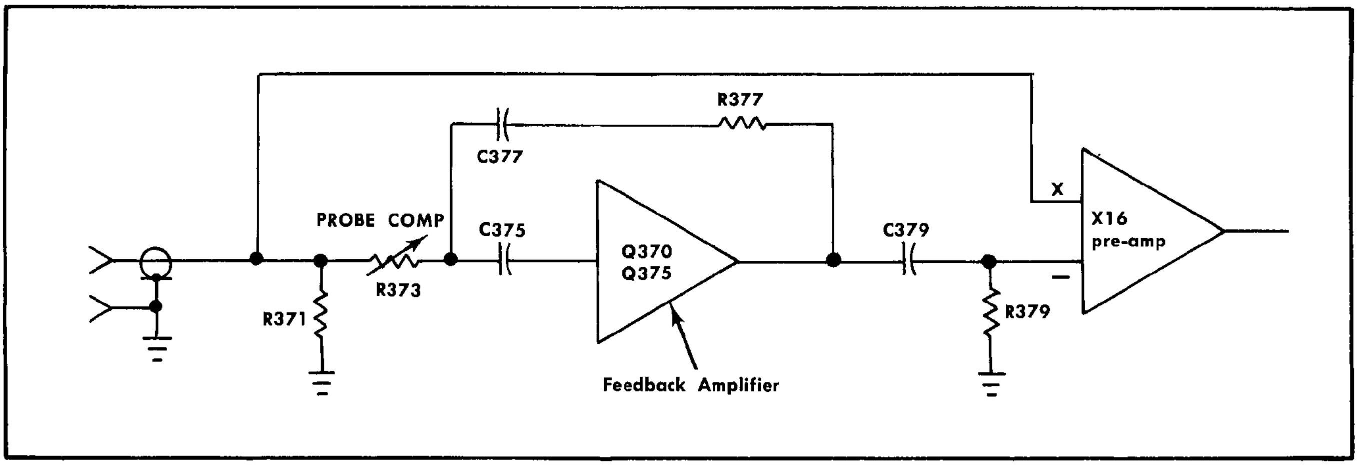

Fig. 3-2. Simplified diagram of the current probe amplifier.

When the LOWER —3dB FREQUENCY selector is in any position other than DC or DC OFFSET and the Input Coupling switch is in DC, there is no on-screen indication of the DC condition in the preamp. If the differential dynamic range of the amplifier is exceeded and the amplifier is driven into non-linearity or overdrive, an erroneous display is likely.

An offset generator is provided to balance out any currents in the preamp resulting from signals containing differential components. Offset (variable) allows the varying component to be amplified, and at the same time maintains the amplifier differential capabilities.

Low Frequency —3 dB Point

The push-pull output of the preamp is coupled through a LOWER —3 dB FREQUENCY selector. The selector switches the components of the coupling network in each half of the preamp to select the low frequency cutoff points (.1 Hz, 1 Hz, 10 Hz, 100 Hz, 1 kHz and 10 kHz). The DC position of the selector bypasses the low frequency selection circuitry and direct-couples the preamp to the Output Amplifier.

Output Amplifier

The signal from the LOWER —3 dB FREQUENCY selector is coupled to the gain-switching section of the Output Amplifier. This section of the Output Amplifier is a feedback amplifier similar to that of the preamp. The VOLTS/DIV switch changes the value of the common source resistor of the amplifier, thereby changing the gain.

The UPPER —3 dB FREQUENCY selector switches capacitance across the output of the Gain Switching Amplifier to set the high frequency —3 dB point through 9 frequencies; 100 Hz, 300 Hz, 1 kHz, 3 kHz, 10 kHz, 30 kHz, 100 kHz, 300 kHz and 1 MHz.

Positioning of the trace, and variable VOLTS/DIV, are provided in the stage following the UPPER —3dB FREQUENCY selector. A CALibrate switch and indicator lamp are provided to show the CAL switch out of the CALibrated position.

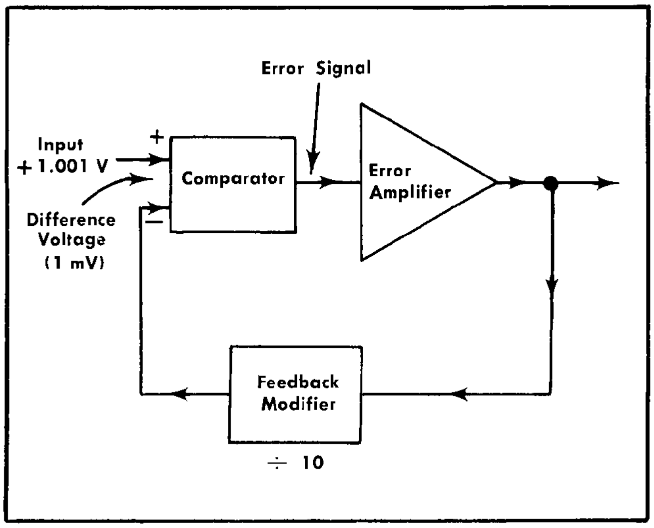

Fig. 3-3. Block representation of generalized feedback system.

Overall amplifier gain is adjusted in the feedback loop of the deflection amplifier.

A signal out (approximately 1.0 volt per displayed division, depending on the sensitivity of the main frame) jack is provided on the front panel with an internal adjustment to set the DC level.

BASIC FEEDBACK AMPLIFIERS

Since the 3A9 utilizes several multi-stage feedback amplifiers, a review of feedback systems is given.

Fig. 3-3 represents a generalized feedback system in which it is desired to produce an output signal accurately and stably related to the input.

The arrangement of Fig. 3-3 causes the modified output to be nearly equal to the input. Any difference between these is detected by the comparator, which produces an error signal equal to the difference and applies this difference to the error amplifier, which in turn amplifies the error and feeds back a correction to reduce the original error.

The input to the modifier (the system output) is also accurately related to the system input, provided that the modifier is made up of stable components.

Assume an amplifier gain of 10,000 and a feedback modifier which is a 10:1 divider. If the amplifier output is 10 volts, the modifier output is 1 volt and the error signal (output divided by gain) is 1 mV. In this case, the difference between the desired output (10 times the 1.001 volt input) of 10.01 volts and the actual output of 10.00 volts is only 10 mV, or 1 part in 1000.

In practice the comparator and error amplifier are often combined in a differential amplifier.

A single-ended version of the basic configuration used in the Type 3A9 is illustrated in Fig. 3-4 with the basic blocks of Fig. 3-3 identified.

The comparator is FET Q1. Any departure in the gate-to-source bias voltage will cause a change in drain current, the change being applied as an error signal to the input of the error amplifier.

The error amplifier consists of grounded emitter stage Q_2, driving emitter follower Q_3. The internal output appears at the emitter of Q3 and is fed back to the comparator input by way of modifier (voltage divider) R_1, R_2.

For this amplifier, $V_0 = (1 + \frac{R_2}{R_1}) V_{om}$, and since $V_{om} \cong V_i$, then the gain, $\frac{V_o}{V_i} \cong 1 + \frac{R_2}{R_1}$.

The useful output of the amplifier is the collector signal current i_o'. This current is nearly equal to the emitter current, i_o'', which is flowing through R_1 (in addition to the relatively small error current from Q_1).

$V_{om} = i_o''R_1$, and since $V_{om} \cong V_i$ and $i_o'' \cong i_o'$, then $i_o' \cong \frac{V_i}{R_1}$.

Thus, the output current vs. input voltage depends primarily on the gain setting resistor R_1.

A voltage output can also be obtained by passing i_o' through load resistor R_3. The overall voltage gain is, then, $\frac{V_o'}{V_i} \cong \frac{R_3}{R_1}$.

If the lower end (grounded end in Fig. 3-3) of R_1, instead of being returned to ground, is connected to the same point in another identical circuit, a differential feedback amplifier with push-pull output is the result (see Fig. 3-5).

DETAILED CIRCUIT DESCRIPTION

Input Coupling

Signals applied to the + and — input connectors may be AC coupled, direct (DC) coupled or internally disconnected (see Fig. 3-6).

When the +AC-GND-DC input coupling switch, SW201, in in the DC position, the + input signal is coupled directly to the + input attenuators.

When the input switch is set to AC capacitor C202 is placed in the circuit to couple signals of approximately 1.6 Hz and higher to the attenuators. C202 blocks any DC component of the signal.

When the input switch is in the GND position, R201 and C201 present a load to the circuit under test that is similar to the load presented when the input switch is set to AC. The GND position also provides a ground reference to the input of the amplifier without the need to remove the applied signal from the input connector.

NOTE

When DC levels are to be blocked by AC coupling, the input switch should be set to GND while input connections are made or broken. This will permit the coupling capacitor to charge without damaging the input circuitry or overdriving the amplifier.

When the CURRENT-VOLTS switch is in the VOLTS position, the + and — inputs are connected to the input attenuators and the current signal is connected to ground. When in the CURRENT position, the current probe signal is connected to the input attenuators.

Input Attenuators

The input attenuators are conventional frequency-compensated voltage dividers. At DC and for low-frequency signals, the dividers are essentially resistive (attenuation ratio determined by the resistance ratio). At high frequencies, at which the capacitive reactance becomes effective, the attenuation ratio is determined by the impedance ratio.

In addition to providing constant attenuation at all frequencies within the bandwidth capabilities of the instrument, the input attenuators maintain a constant input RC characteristic (one megohm paralleled by 47 pF) for all settings of the VOLTS/DIV switch.

Input Protection

Input protection consists of fuses F131, F231 and diodes D132, D133, D232 and D233. If the signal should reach a level sufficient to forward-bias one of the protection diodes (greater than ±15.6 V), current will be drawn through that diode, protecting the input FET's. If that current should exceed 1/16 A, the protective fuse(s) will open. If the circuit under test is not able to supply enough current to open the fuse, damage to the circuit under test could result.

Gate Current Compensation

The leakage current associated with the gates of the input FET's may be as high as 100 pA. This 100 pA of leakage current (through 1 megohm to ground, R113 or R213) will produce an offset of 100 μV, which at high input sensitivities of not acceptable. To compensate this effect, the gates of the input FET's may be adjusted to zero volts by returning R113, R213 through variable controls R115 and R215 to a slightly negative supply voltage (see Fig. 3-7).

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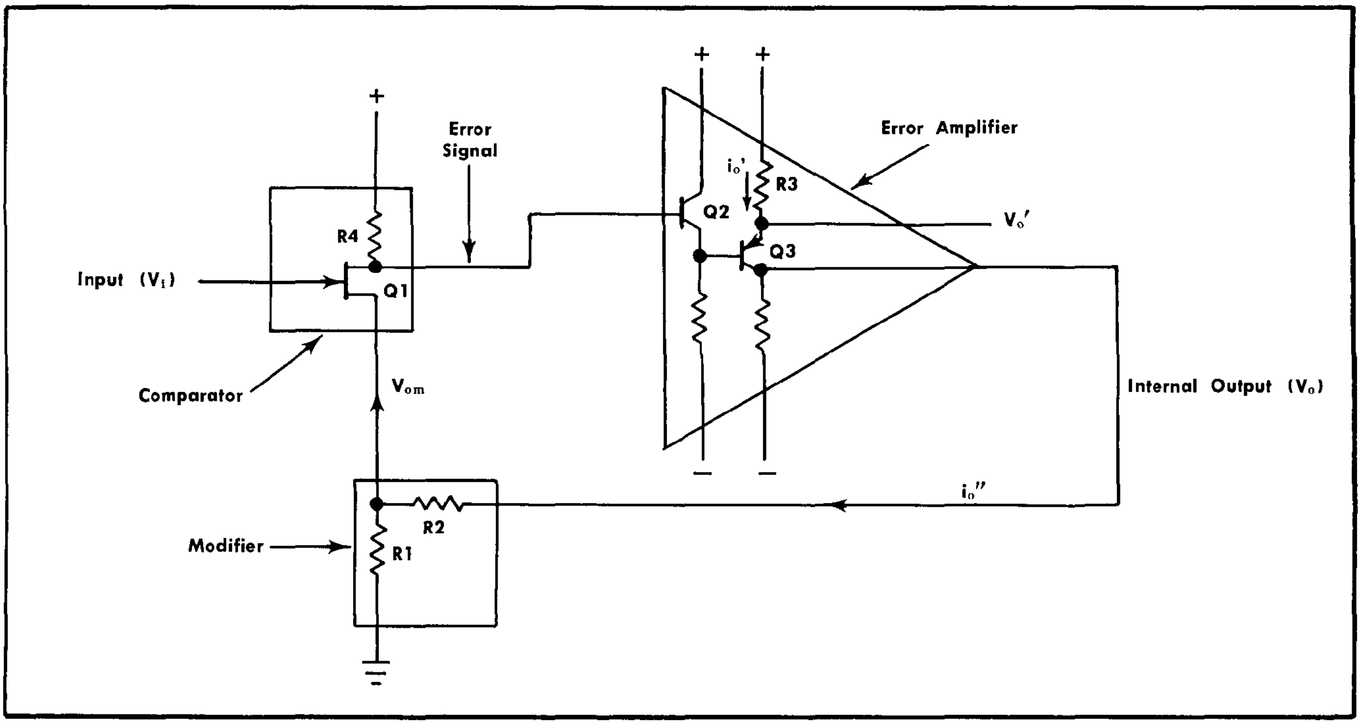

Fig. 3-4. Single-ended version of the basic configuration used in the Type 3A9.

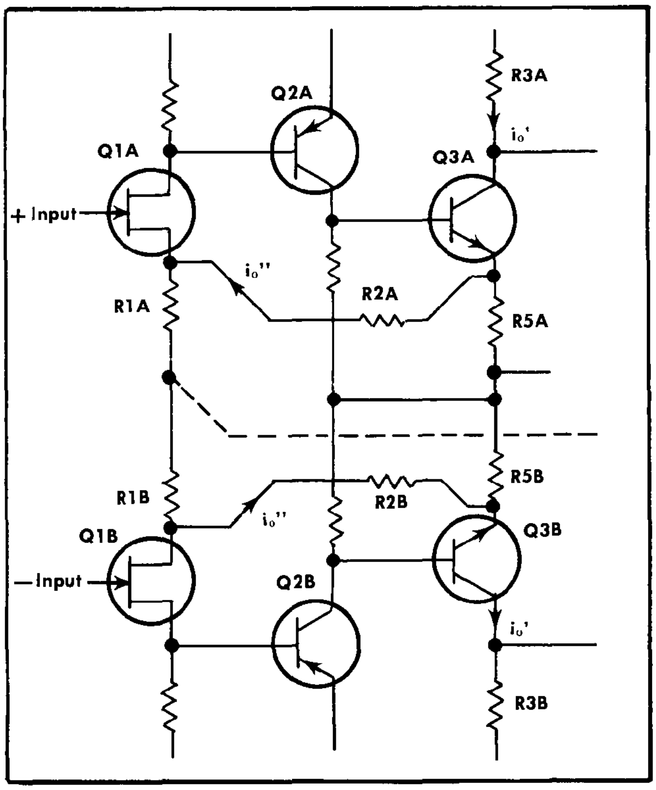

Fig. 3-5. Basic differential feedback amplifier.

Leakage current associated with the gates of the input FET's and the overload protection diodes increase rapidly with temperature, approximately doubling for every 10°C. To compensate this increase, a temperature-sensitive input current balancing network is included, using thermistors as the sensing elements.

As the voltage across R113 and R213 increases due to increase in temperature of the active devices, an equal voltage change is produced in the thermistor compensating circuit, maintaining the FET gate level at zero volts.

The gate current compensation becomes inoperative if the straps are removed for high input impedance operation.

Preamp

The feedback amplifiers in the + and — inputs are identical except for circuit numbers. Except where needed for clarification, only the amplifier in the +input will be described in detail.

Fig. 3-8 is a partial diagram of the input amplifier illustrating the current paths.

The feedback amplifier in the +input consists of Q133A, Q144A and Q254. The feedback path is from the source of Q254, through the divider (modifier) consisting of R253, R251. R251 is the gain setting resistor and since approximately the same signal current flows through both R251 and R257, the gain may be caluculated by the ratio of these resistances, R257/R251 (V_o/V_1).

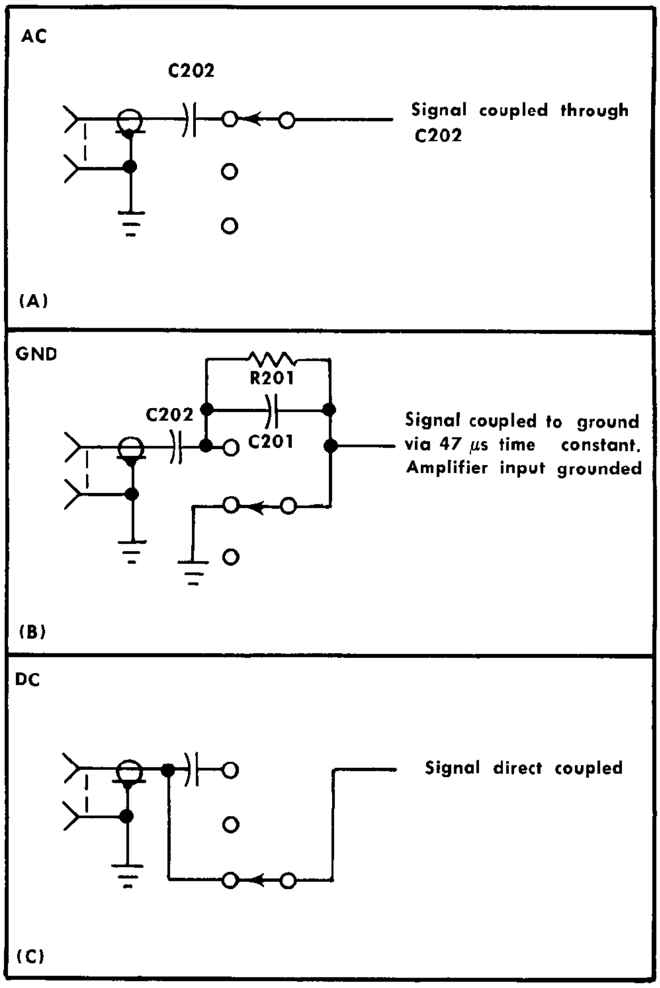

Fig. 3-6. Signal path for 3 positions of the input coupling switch.

Common-Mode Rejection

One of the primary functions of the preamp is to reject any common-mode component of the input signal and amplify only the difference.

Assume that the inputs are tied together and a voltage is applied to the common input. The amplifier differential output is ideally zero, and would actually be zero provided that the characteristics of all corresponding elements on the two sides of the amplifier were exactly matched (e.g., Q133A & B tansconductuance and μ, Q144A & B beta, current sources, etc.). In practice, any mismatch will cause a differential output.

Even with perfect matching there is still a common-mode output current, due to common-mode gain, which results in an undesirable common-mode signal applied to the subsequent stages of the amplifier.

A floating power supply minimizes these common-mode difficulties and therefore improves the common-mode rejection. (Fig. 3-9).

The input to the bootstrap (×1 gain) amplifier is connected to the junction of R151, R251. The bootstrap amplifier consists of an emitter follower, Q283, and its +8, +17 and —13 V supplies are generated by a chain of Zener diode shunt regulators, D275, D285, and D295. Current for the ×16 preamp and the Zener diodes is supplied by two current sources, Q284 and Q294. The collector impedance or these current sources presents minimum loading to Q283 output and maintains the gain of the ×1 amplifier (bootstrap efficiency) very close to 1.

The entire power supply and amplifier move an amount equal to the common-mode voltage, and no changes occur in voltage or current level as a result of common-mode voltage except at Q154, Q254 drains.

Zeners D355, D352 and D347 provide regulated —15 and —30 volts.

Q295 diverts current away from Q326, the Offset generator current source, in the event of failure of the +125 volt supply. Without this protection, if the +125 volt supply is slow in rising, (or fails) current could be forced to flow out the FET gate circuit, through the Type 3A9 input. To prevent this condition, if the +125 volts supply fails, Q295 base goes negative to the point at which Q295 saturates, providing a low impedance path to divert current from Q326.

D297 protects Q295 from reverse breakdown.

High Frequency Common-Mode Rejection

At higher frequencies stray capacitance to ground at various points in the ×16 preamp begins to inject significant current into the amplifier as a result of common-mode signals. Differential capacitor C162, connected from the floating power supply to the output lines, injects adjustable current into the output to equalize the net output current resulting from high frequency common-mode signals, and extends the frequency range over which good CMRR can be obtained to approximately 100 kHz.

Input Cross-Neutralization

The use of a common bootstrap supply results in an undesirable capacitive coupling between the two inputs. Consider the effect of applying +1 volt to the +input while keeping the —input at 0 volts (grounded). See Fig. 3-10.

The results are: (a) an output current, as shown in Fig. 3-10 and (b) a shift of all floating supply voltages (and several other voltage levels) by 0.5 volt, due to the divider action of R151, R251. The drain of Q133B also rises and injects a current, i_b, through the drain-to-gate capacitance of $Q133_b$ and into the —input. If there is any impedance between the —input and ground, i_b will develop a voltage which will be applied to the —input. This voltage subtracts from the original +input and causes an erroneous output.

The —amplifier signal output current i_o flows through R153, and causes its lower end to go negative. An adjustable capacitor, C131, connected from Q154 source to the —input can be adjusted to divert current, i_b away from the input and so neutralize the effect of C_{dg}.

C231 and R231 perform a similar function for the +input.

DC OFFSET

The purpose of the DC Offset system is to buck out small DC components of the input signal, allowing the amplifier to

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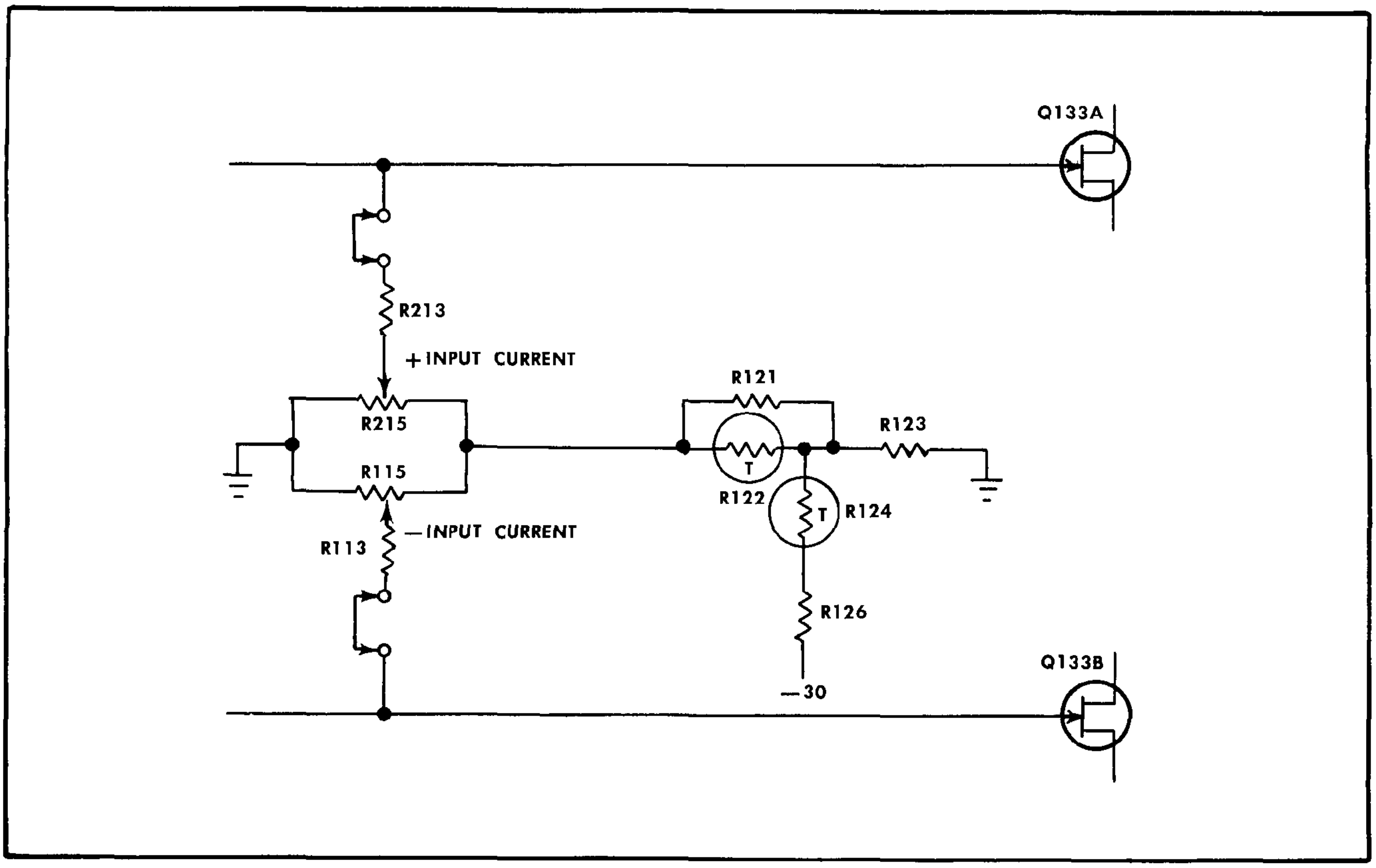


Fig. 3-7. Gate current compensating circuit.

amplify only the varying components while maintaining the differential capabilities.

When a DC signal is applied across the inputs, the resultant output currents are balanced out as described below (see Fig. 3-11). Fig. 3-11A shows the currents for zero input. If a DC signal is applied to the +input, a current will flow in R251, R257, producing an output. If this current can be supplied by the offset generator as shown in Fig. 3-11B, the current in Q254, Q154 does not change and no output is produced. In this manner the DC component of the signal may be offset (up to ±1 volt) and the full differential capabilities of the amplifier realized.

The offset generator produces a balanced offset current for use in the ×16 preamp. Due to the wide range of the offset system (200,000 cm at 10 μV/DIV) stable components are used, and circuit techniques are employed which minimize drift and noise.

In the reference voltage generator the DC OFFSET COARSE and FINE potentiometers tap an adjustable portion of the voltage across the reference Zener, D352. Voltage divider R341, R347 and R345 supplies a fixed 50% of the differential signal applied to the current generator. The voltage is adjustable over —4 V to +4 V (approx). See Fig. 3-12.

This adjustable reference voltage is applied to the input of a pair of coupled feedback amplifiers (similar in concept to the ×16 preamp).

The feedback amplifiers A and B are composed of Q314A, Q334 and Q314B, Q324, respectively, with the

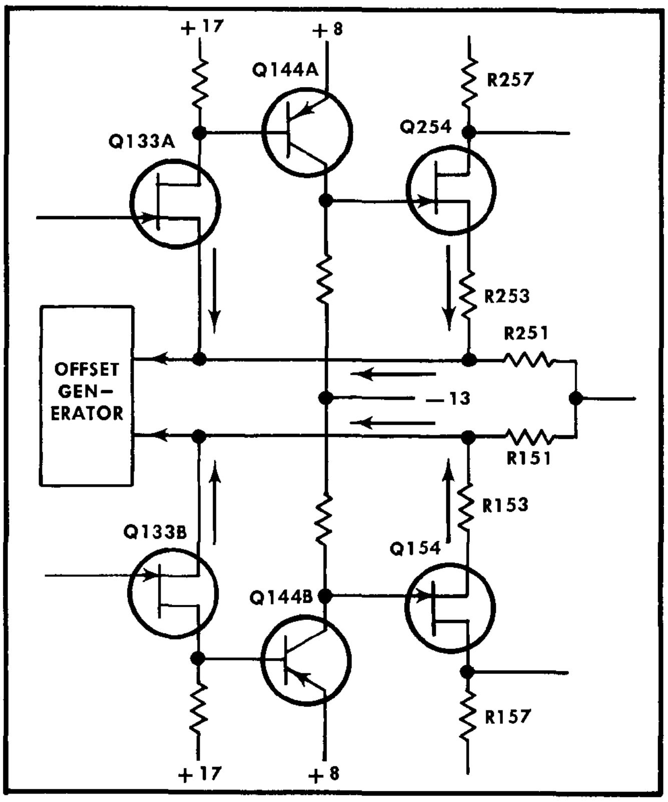


Fig. 3-8. Partial schematic of the input amplifier showing current paths.

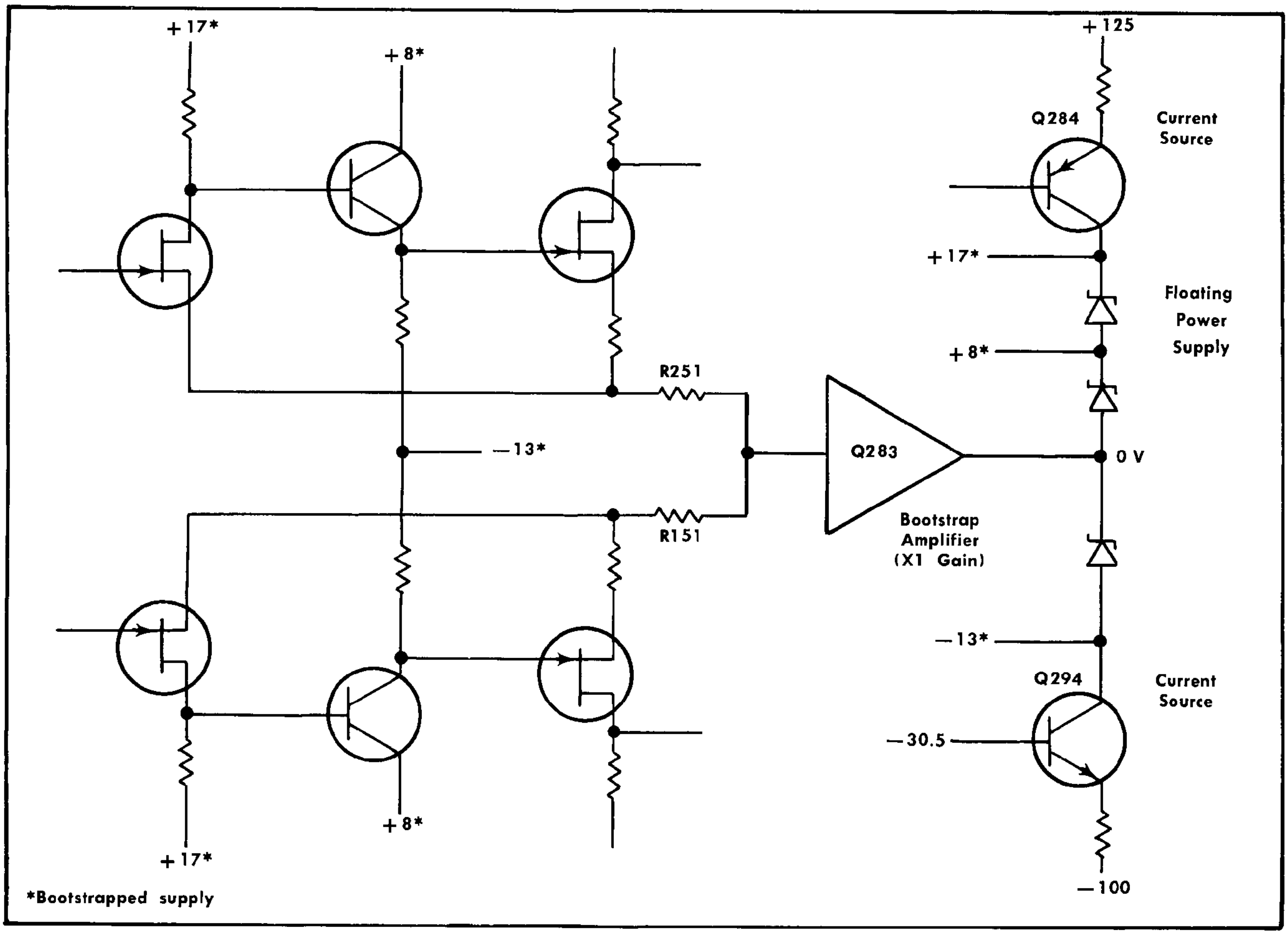


Fig. 3-9. Input amplifier with bootstrapped power supply.

reference input applied to the emitters of dual transistor Q314 and the feedback to its bases. Current source Q326 supplies operating current for the amplifiers. See the preamp schematic at the back of the manual. In amplifier A (Fig. 3-12) the feedback action forces the —input voltage (also the output voltage) V_{2a}, to follow the +input, V_{1a}, and similarly V_{2b} follows V_{1b}. The differential input, (V_{1b} —V_{1a}) is therefore reproduced across resistors R331, R321 as (V_{2b} — V_{2a}) and the resultant current ,i_{offset}, $\frac{V_{2b} - V_{2a}}{R_{321} + R_{331}}$, flows through the FET output stages of amplifiers Q324 and Q334, and out the FET drains to the ×16 preamp.

When the offset is not in use, V_{1b} is switched to the fixed divider.

V_{1a} is adjustable over a small range with respect to V_{1b} by the COARSE DC BAL control, to adjust out any initial DC unbalance in the ×16 preamp to bring its output to zero with zero input.

The FINE offset control moves the voltage at both ends of the COARSE control via divider R351, R352, R353, R354 by varying the voltage at the junction of R352 and R353.

Capacitor C336 filters Zener noise from the reference voltage.

LOWER —3 dB FREQUENCY SELECTOR

This switch selects the lower —3 dB Frequency of the amplifier and has a range of 0.1 Hz to 10 kHz in decade steps. Selection is accomplished by switching the resistor and capacitor of a pair of AC couplings, one in each side of the amplifier, between the ×16 preamp and the gain-switched amplifier. See Fig. 3-13. For 100 Hz to 10 kHz, C258 is used, and resistors R276, R277 and R279 are switched to the output in the following combination:

—3 dB Freq	100 Hz	1 kHz	10 kHz
Resistors	R279	R276-R279	R277-R279

Whenever R276 or R277 is not on the output side of C258 the resistance (R276 or R277) is placed across the input, to keep the high frequency load resistance seen by i_{in} constant.

C276 is switched across C258 for the lower three ranges, 0.1 Hz, 1 Hz and 10 Hz. C258 is shorted out for DC coupling.

Resistor R256 adds a small increment in gain, when C258 is used to compensate for the loss of gain through the capacitive divider formed by C258 and stray capacitance C_s.

Ⓐ

Gain Switching Amplifier

The gain switching amplifier is a balanced differential configuration very similar to the ×16 preamp, with a fixed power supply.

Gain is changed by switching values of R408.

Diode D422 prevents reverse breakdown in Q424 under overdrive conditions. D420 limits the voltage at the base of Q434 and prevents base-emitter breakdown in the following stage.

R405, AC Atten Bal, in series with the source of Q404A develops a small adjustable voltage which is used to set the voltage across the gain-setting resistors, R407 and R408, to zero when the gate-to-gate voltage of Q404 is zero.

Zener D415 provides a stable emitter supply voltage for Q414, and C415 filters out Zener noise. R421 maintains proper Zener current.

C414 and C514 prevent high frequency oscillations.

The Var Bal control, R425, sets the voltage across the VAR control to zero, with zero input signal, to prevent trace deflection as the VAR control is rotated throughout its range.

UPPER —3 dB FREQUENCY Selector

Switch 175B, UPPER —3 dB FREQUENCY Selector, switches capacitors across the output of Q424, Q524 to set the high frequency response characteristics.

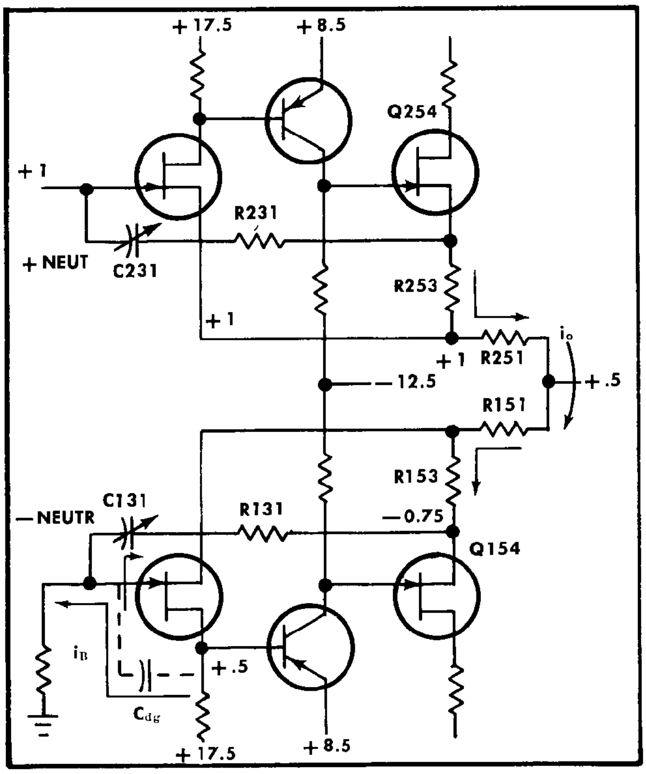


Fig. 3-10. Input amplifier showing effects of capacitive coupling through C_{dg} and resulting current, i_o.

Position and Variable Stage

Position control R440 feeds adjustable current into the emitters of Q434, Q534 by way of R437, R537. This current mixes with signal current developed in the emitter resistors, R431-R433, R531-R533 and R535 and flows out of the collectors to provide vertical beam deflection.

Variable control (VAR) R535 provides emitter degeneration, the gain being determined by the total emitter feedback resistance. Gain is adjustable over a 2.5:1 ratio, and provides a fine control to interpolate between the steps of the VOLTS/DIV switch.

An indicator lamp (UNCAL) lights whenever the VAR switch is out of the CAL position.

Output Stage

The output amplifier, Q444-Q544, Q454-Q554, is a feedback amplifier with the feedback path from Q454 collector through R445-R545 and the adjustable feedback divider R443, R447, R543, R547 and R450, to the bases of Q444-Q544.

D444, D445 prevent the base-to-base signal to Q444-Q544 from exceeding 0.6 volts, ensuring a fast overdrive recovery of the output amplifier.

Overall gain of the Type 3A9 can be adjusted to match the main frame in which it is used by adjusting GAIN control R450. R450 provides a variable current diverting path in the feedback.

Diodes D563, D565 and D567 provide operating voltages, +15 V, +35 V and +50 V to various points throughout the Type 3A9. The capacitors in this Zener-regulated supply provide filtering.

Trigger and Signal Out Amplifiers

A signal is picked off at Q454 collector and fed to a FET source follower. The FET source provides a low impedance point from which trigger signal is fed to the time base. The trigger signal amplitude at Q464 source is approximately 3.75 volts per division of display.

Signal is also fed to the base of an emitter follower, Q474, to provide signal access at the front-panel SIG OUT jack.

R471 and R473 divide the signal to give approximately 1.0 volt per division of display at the front-panel SIG OUT jack.

R467, Sig Out DC Level, sets the DC level at the SIG OUT jack to zero volts.

C461, Sig Out HF Comp, compensates the voltage divider, R461, R465, R467, to provide good frequency response at the SIG OUT jack.

Input Overdrive Indicator

When the LOWER —3 dB FREQUENCY selector is in any position other than DC or DC OFFSET and the input coupling switch is in DC, there is no on-screen indication of the DC conditions in the ×16 preamp. The amplifier may be driven into non-linearity or overload by a DC component which could result in an erroneous display.

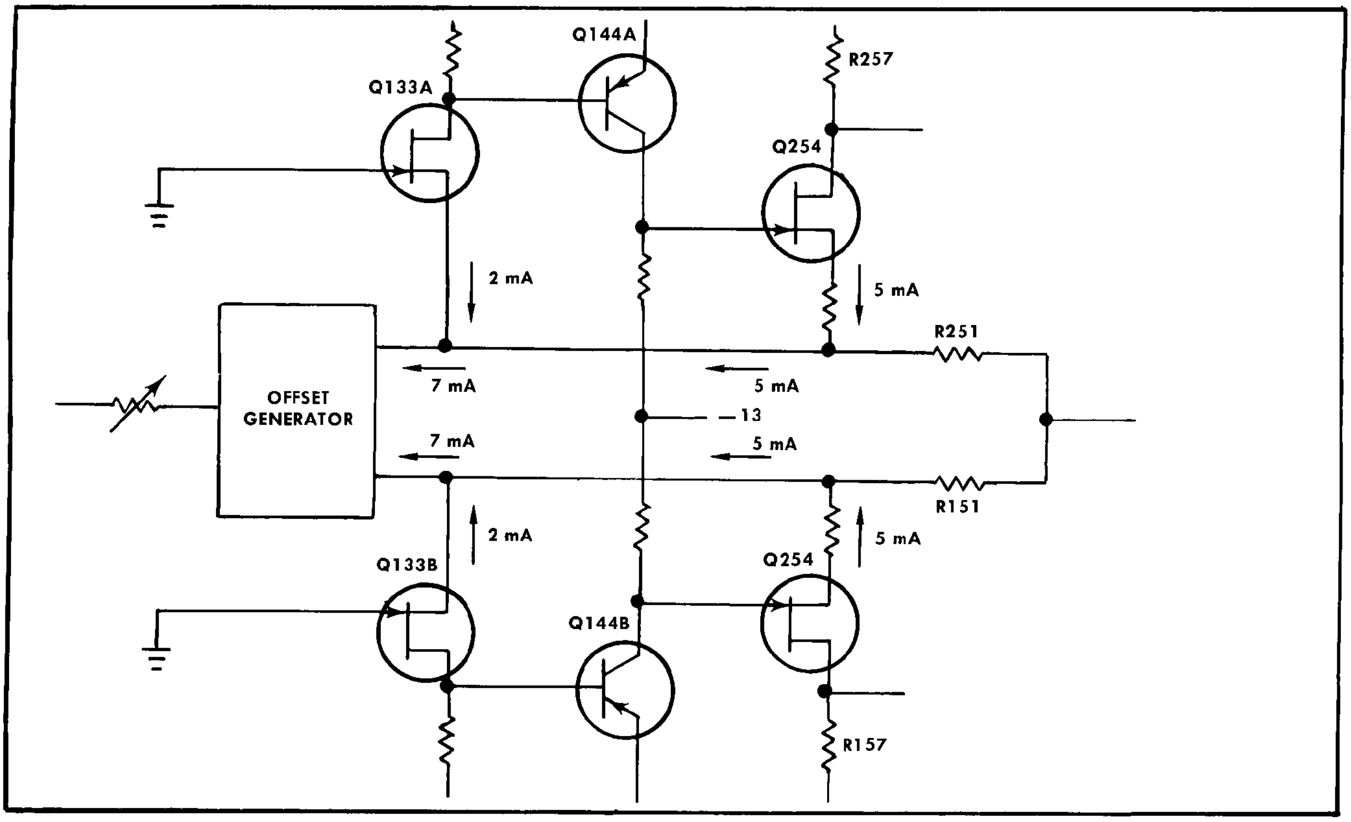


Fig. 3-11A. Conditions with zero offset voltage, showing balanced currents.

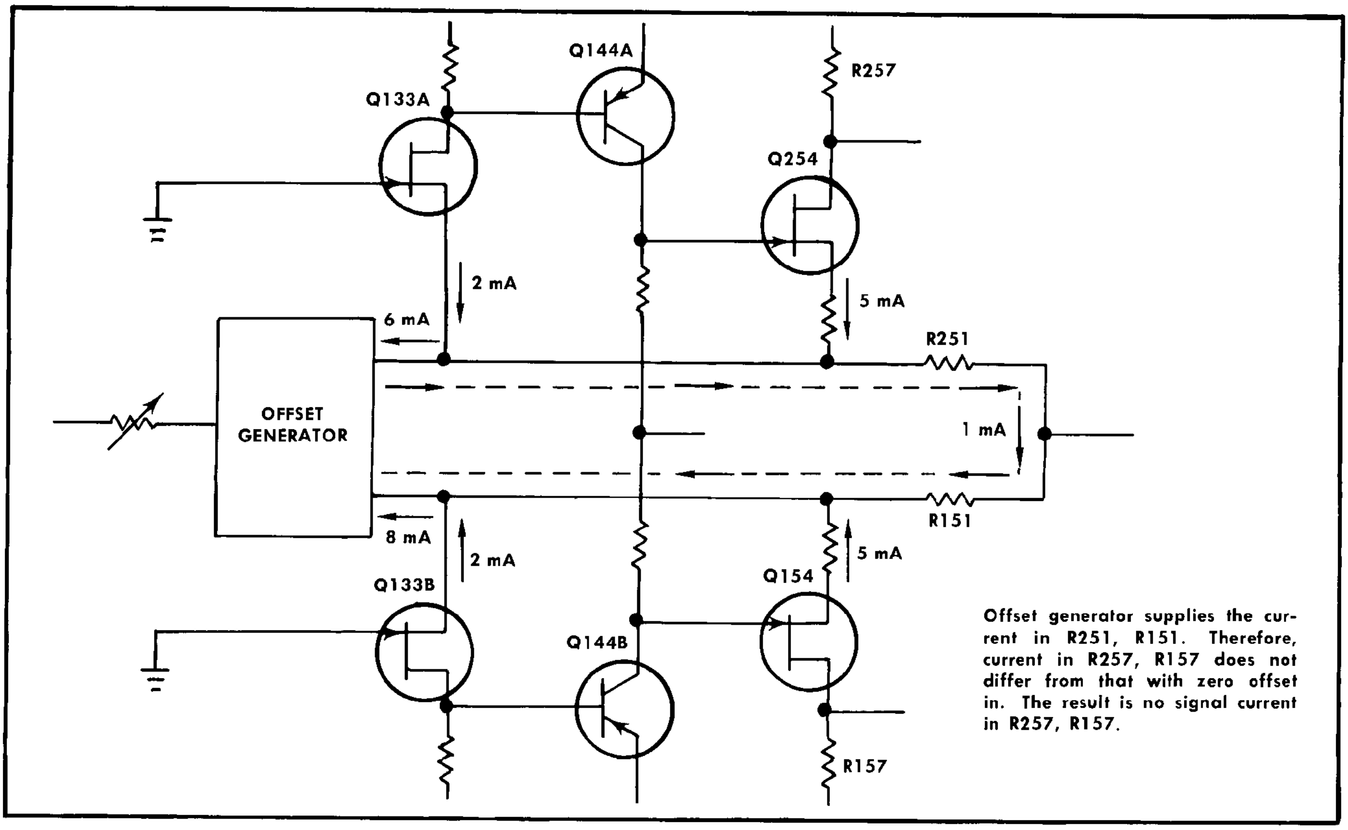


Fig. 3-11B. Conditions with offset to produce 1 mA through R251, R151.

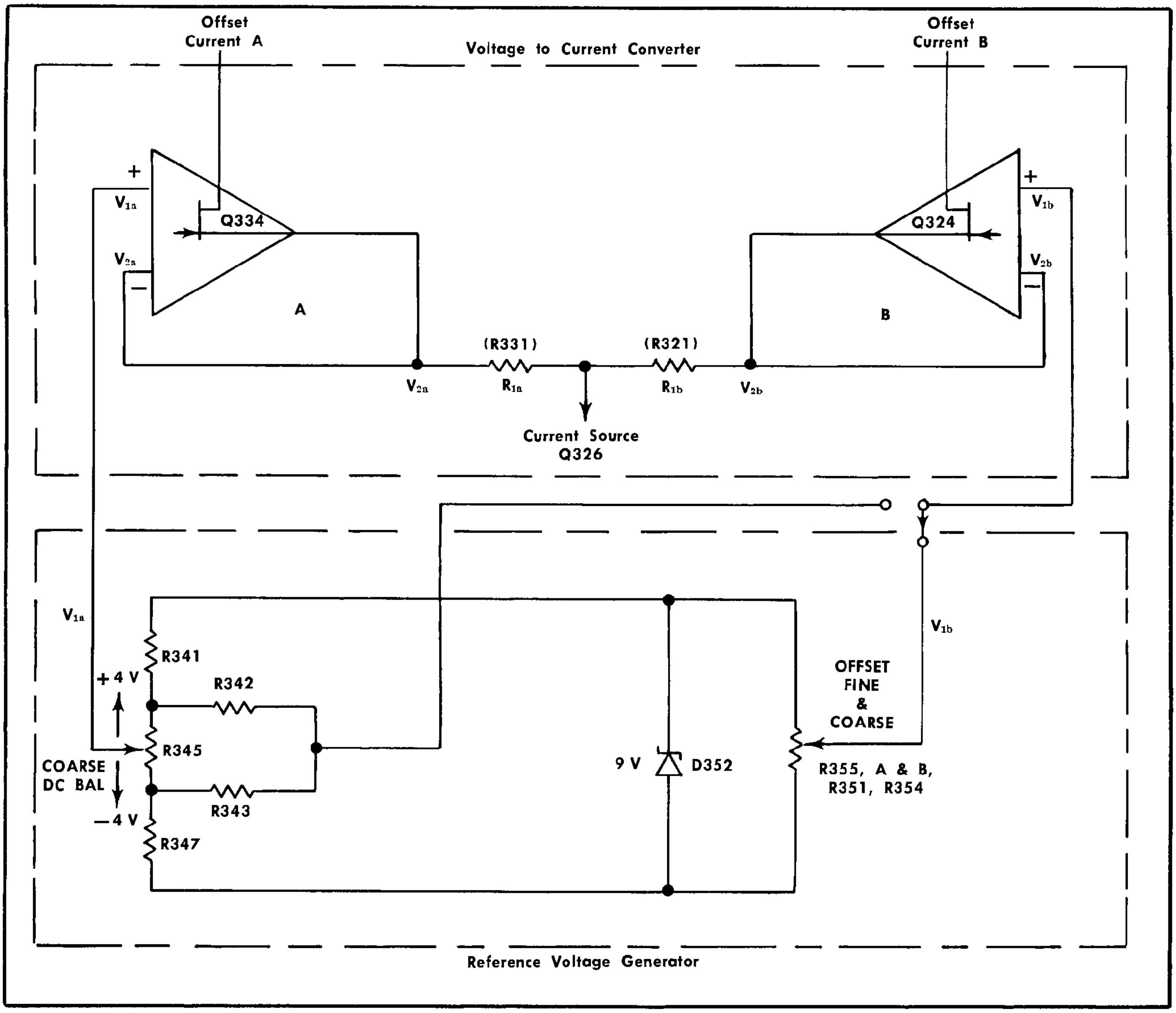


Fig. 3-12. Simplified offset voltage generator.

The input overdrive lamp indicates that the ×16 preamp is approaching the limits of its differential dynamic range.

The indicator circuit functions as follows: When the amplifier is operating normally (no overdrive condition), D162 and D262 are reverse biased, Q163 is biased off and Q164 is saturated. Current in R172 (with Q164 saturated) sets the voltage across B174 below the firing potential and B174 is extinguished.

If the voltage on either of the output lines (anodes of D162 or D262) exceeds the voltage at the emitter of Q163 by approximately 1 volt, D162 or D262 turns on, biasing Q163 into conduction, turning off Q164, allowing the voltage across B174 to reach the firing point.

C164 and R164 allow the lamp to indicate on overdrive pulses of short duty cycle. C164 charges through Q163, R171 and R172. When Q163 turns off, C164 discharges slowly through R164, holding B174 on long enough to be seen, or until the next pulse.

R171 and R174 equalize the firing transients on the two leads of the neon, B174, reducing radiation into the physically close input circuitry.

Current Probe Amplifier

Probe signal is fed directly into the preamp +input when CURRENT-VOLTS selector switch is in the CURRENT position. The input signal is also fed to the integrating feedback amplifier which compensates for the undesirable low frequency probe characteristics. This compensated signal is then fed to the preamp —input.

R373, PROBE COMP, provides adjustable compensation for the various current probe types and for variations in probe inductance for any given type.

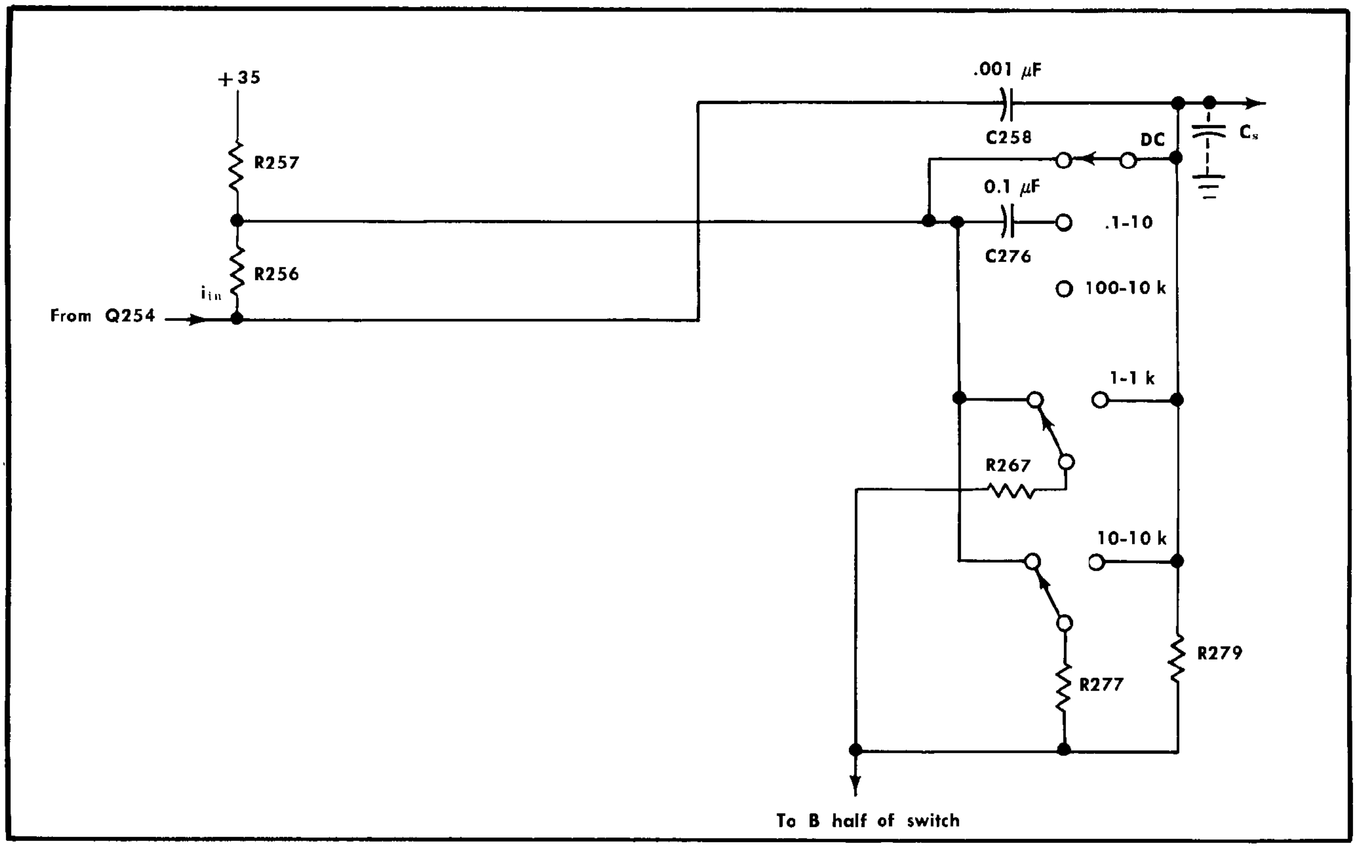


Fig. 3-13. Simplified LOWER —3 dB FREQUENCY selector.

R377, in series with the feedback capacitor C377, compensates for the variations of input resistance as R373 is adjusted, and keeps the high-frequency deflection factor correct.

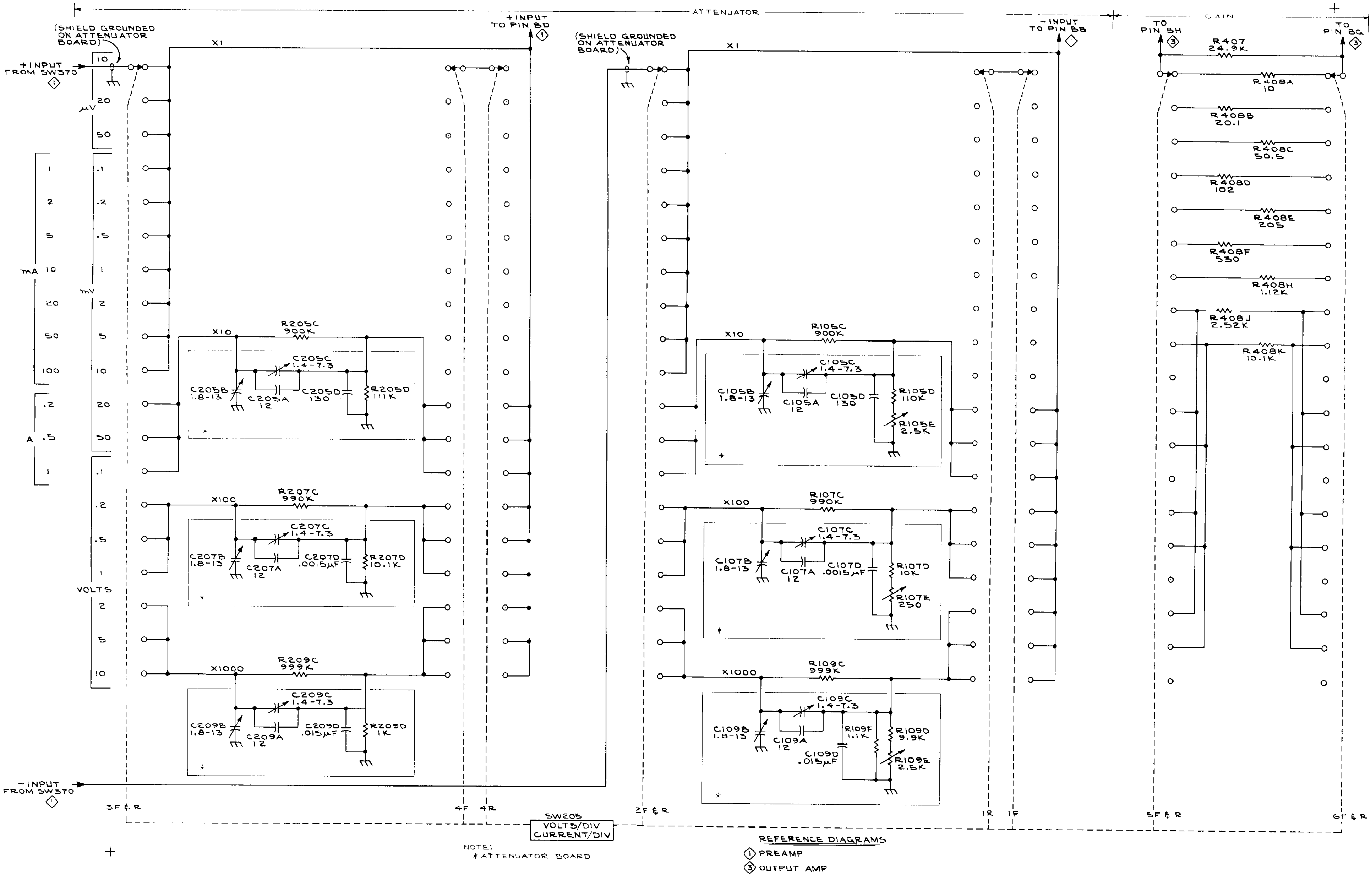
C379, R379 is an AC coupling which blocks the DC level (at the output of the feedback amplifier) from the ×16 preamp.

R371 provides the proper load for the probe.

R383, R385, R387, R391 set the operating parameters of the amplifier.

R389, C383 are high frequency parasitic oscillation suppressors.

C375 is a DC blocking capacitor.



TYPE 3A9

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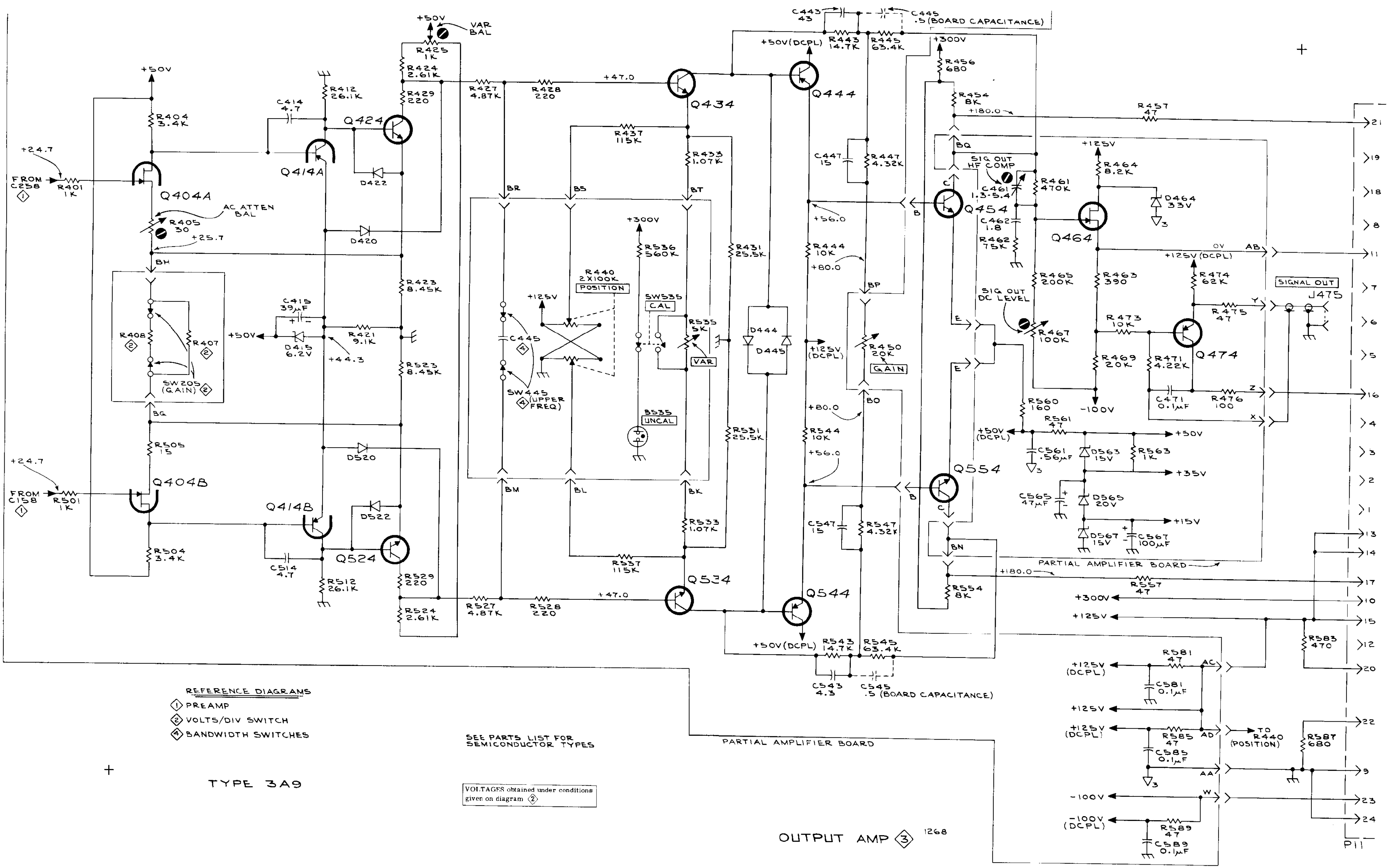
1268

VOLTS/DIV SWITCH ②



REFERENCE DIAGRAMS
1 PREAMP
2 VOLTS/DIV SWITCH
4 BANDWIDTH SWITCHES

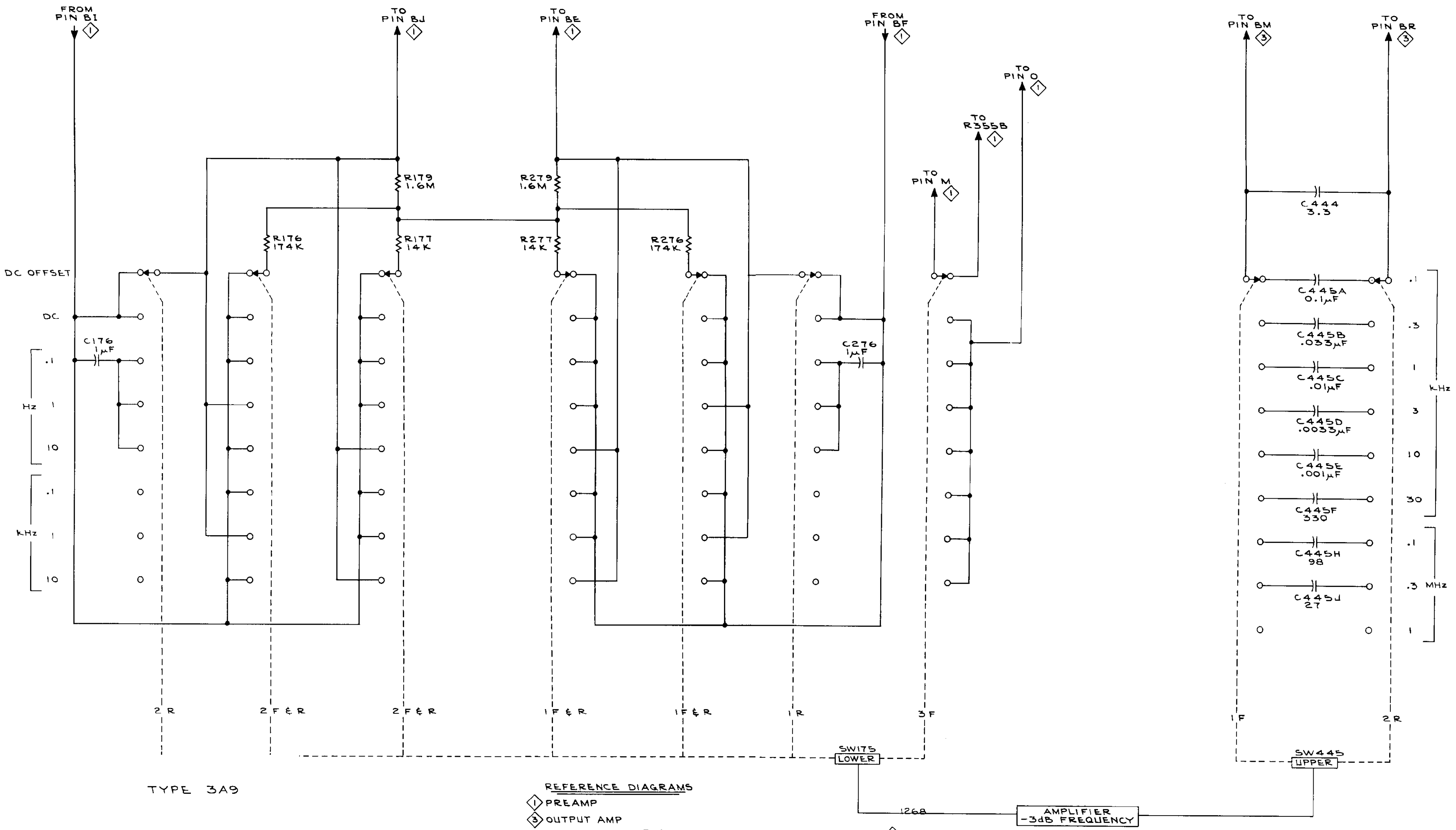
SEE PARTS LIST FOR SEMICONDUCTOR TYPES

VOLTAGES obtained under conditions given on diagram 2

TYPE 3A9

OUTPUT AMP 3

1268



TYPE 3A9

REFERENCE DIAGRAMS
1 PREAMP
3 OUTPUT AMP

BANDWIDTH SWITCHES 4