practice section 814001A

4001A Line Amplifier

contents

1. general description

1.01 The 4001A Line Amplifier (figure 1) provides two independent amplifier/amplitude-equalizer circuits, each with input and output impedance-matching transformers. The two independent circuits of the 4001A, referred to as "amp 1" and "amp 2", may be used in the transmit and receive channels of a 4wire voice frequency facility, or they may be used as unidirectional amplifiers in two separate circuits.

1.02 Either amplifier on the 4001A may be continuously adjusted to provide from −3 to +36dB of gain. Maximum output of either amplifier is +18dBm, with less than 1% distortion.

1.03 Option switches on the 4001A may be used to alter the gain range of either amplifier to −15 to +6dB. The overall range of either amp 1 or amp 2 in the 4001A module is, therefore, −15 to +36dB. Front-panel level adjustments may be accurately set to within ±0.1dB through the entire range of adjustment.

1.04 Three optional modes of amplitude equalization provided in each circuit compensate for the frequency response characteristics of loaded cable, nonloaded cable, or carrier transmission facilities. A variety of gain shapes may be effected through use of front-panel adjustments. See the equalization curves in section 2 for details.

1.05 Impedance-matching transformers facing the input and output of each amplifier may be switch-optioned for a balanced impedance match of 600 or 1200 ohms. Each transformer is center tapped to derive balanced simplex leads that provide for dx signaling, loopback, and other external functions requiring a dc path.

1.06 The 4001A Line Amplifier incorporates an internally regulated power supply that permits operation on −22 to −56Vdc input. Current requirements range from 20mA in the quiescent state to 60mA with both amplifiers' outputs at maximum.

1.07 Surge protection is provided for the input and output of both amplifiers.

1.08 Reverse battery protection and transient-limiting circuitry are provided in the amplifiers' internal power supply circuitry. RC filtering and de-

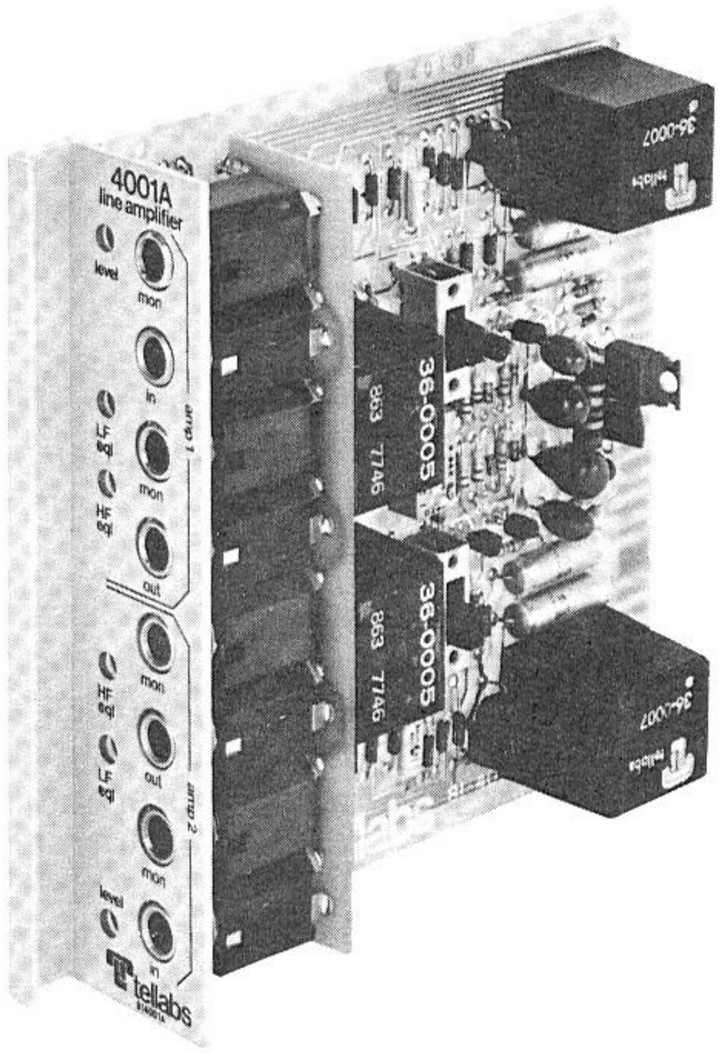


figure 1. 4001A Line Amplifier

coupling networks use tantalum capacitors to minimize crosstalk coupling and the effects of noise on the input power leads. Tantalum capacitors also reduce the amplifiers' susceptibility to RF interference.

1.09 The front panel of the 4001A is designed for accessibility to all adjustments while the module is mounted in place. Gain, high-frequency equalization, and low-frequency equalization controls are provided for each circuit, amp 1 and amp 2. The 4001A also features a full complement of eight front-panel test jacks to facilitate alignment and maintenance activities. Both bridging and opening jacks are provided at each 4wire port.

1.10 As a Type 10 module, the 4001A mounts in one position of a Tellabs Type 10 Mounting Shelf, versions of which are available for relay rack and KTU apparatus case installation. In relay rack applications, a maximum of 12 modules may be mounted across a 19 inch rack, and up to 14 modules may be mounted across a 23 inch rack. In either case, 6 inches of vertical rack space is utilized.

2. application

2.01 The 4001A Line Amplifier module is designed to provide bidirectional (transmit and receive) level control and amplitude equalization to a 4wire voice frequency transmission facility; or it may provide unidirectional level control and amplitude equalization in two separate, one-way voice frequency channels (see figure 2). The module also contributes input and output impedance matching,

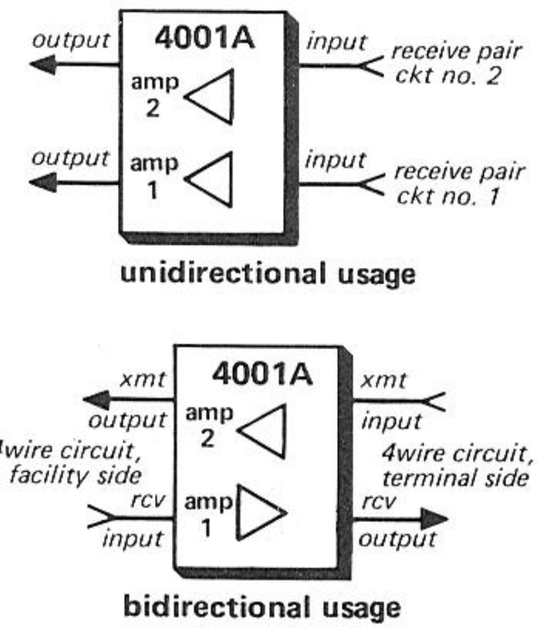


figure 2. Bidirectional and unidirectional applications

longitudinal isolation, and surge protection to the facility served by each of its two amplifier/equalizer circuits.

2.02 In itself, the 4001A may be compared to a 44V4 4-wire repeater. When paired with a Tellabs 4wire-to-2wire Terminating Set — 4942 or 420X Series (or equivalent) — a type 24V4 repeater results. The 4001A may be used as a terminal or intermediate repeater (see figure 3).

levels

2.03 Gain levels in both channels are continuously adjustable from approximately −3 to +36dB. The maximum output level of either channel is +18dBm. Amp 1 and amp 2 gain adjustments are independent of each other. An alternate gain range of −15 to +6dB may be switched into either channel to accommodate those applications (some data sets, for example) where output levels are too high and must therefore be attenuated. The −15 to +36dB overall loss/gain range of the 4001A allows the module to be used in any 4wire application, consistent with good transmission practices, where preamplification and/or postamplification is required. The module's alternate gain range, when optioned in, will not affect equalization, gain stability, or gain setability.

impedance matching

2.04 Balanced impedance-matching transformers with 600 and 1200 ohm options at both input and output of each of its two channels allow the 4001A to interface either loaded cable (1200 ohms) or nonloaded cable, carrier, sf signaling units, terminating sets or station apparatus (600 ohms). The 600/1200 ohm option is independently switch-selectable for each of the Line Amplifier's four ports. Metallic isolation is also provided by the 4001A's transformers.

2.05 The four impedance-matching transformers on the 4001A Line Amplifier are center-tapped to derive simplex leads, allowing the module to be used in circuits employing dx, loopback and other dc signaling techniques.

equalization

2.06 Amplitude equalization is provided in both channels of the 4001A. Because equalizing at the receive end of the circuit (post-equalization) is generally preferable to equalizing at the transmit end (pre-equalization)*, the use of the 4001A's equalizers in one or both channels is generally dependent upon the module's position in the circuit. In some applications, pre-equalization may be necessary. For example, use of the 4001A as a bidirectional amplifier at an intermediate point in a 4wire circuit often requires the use of the transmit channel equalizer as well as the receive channel equalizer.

**Pre-equalization tends to amplify high-frequency signals to a level that is conducive to crosstalk. Post-equalization not only eliminates this problem, but also expedites the equalization procedure because the circuit is easier to equalize at the receive end.*

2.07 Each channel provides two optional modes of amplitude equalization and a bypass (non-equalizing) mode. Each mode is independent of the module's gain and impedance settings. Each of the 4001A's two channels utilizes a three-position switch to select the desired mode of equalization. The three positions are labeled *BYP* (bypass, flat, no equalization), *EQL* (high-low equalization for loaded cable or carrier) and *NL* (equalization for nonloaded cable).

2.08 The *BYP* mode is selected if only flat gain is desired in an application. In this mode, all equalization is removed, and the transmission response through the channel is flat (within ±1dB of the 1000Hz level) from 100Hz to above 10,000Hz.

2.09 The *EQL* (equalization for loaded cable) mode provides a variety of low-frequency and high-frequency gain shapes to compensate for loss in loaded cable and other transmission facilities with a similar frequency response. Amplitude "bumps" may be independently adjusted at the high and the low ends of each channel's frequency range, equalizing the frequency response of the associated transmission facility between approximately 300Hz and 3400Hz. Additionally, both low-end and high-end roll-off are provided to attenuate out-of-band noise at both ends of the normal voice frequency spectrum and to improve stability when used with a 4wire-to-2wire term set in 24V4 applications.

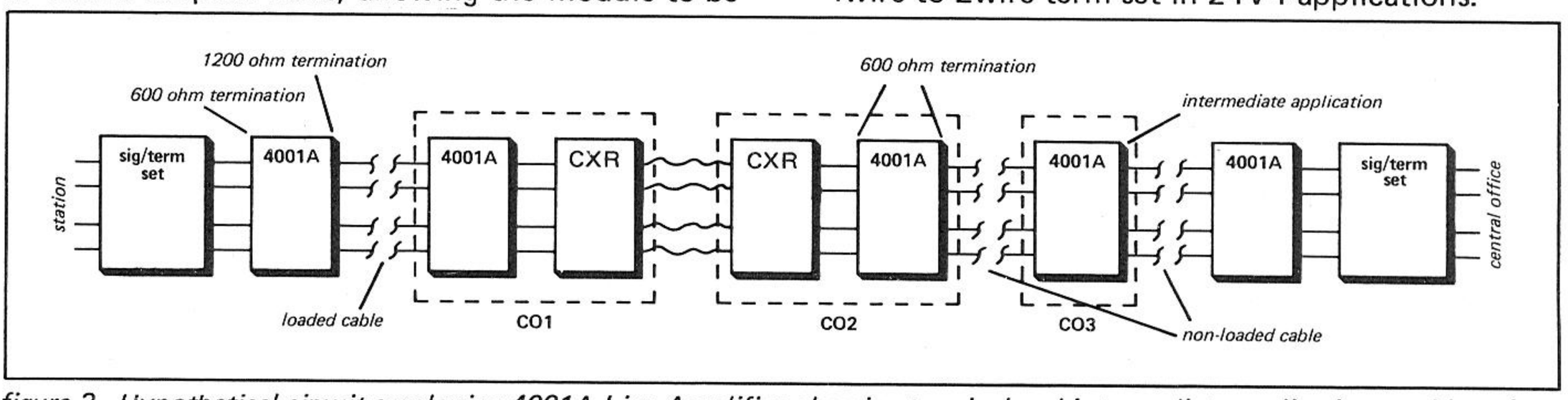


figure 3. Hypothetical circuit employing 4001A Line Amplifier, showing terminal and intermediate applications and interfaces

2.10 High-frequency and low-frequency front-panel-accessible controls (potentiometers) are used to adjust the module for the desired equalization characteristics in the *EQL* mode.

2.11 With the high-frequency and low-frequency controls adjusted to minimum settings, low-end roll-off begins at approximately 600Hz and high-end response is depressed about 6dB at 3000Hz, with 12dB per octave roll-off above that frequency. At moderate settings of the *LF* and *HF* controls, bumps begin to occur at approximately 300 Hz and 3400Hz. High and low-frequency adjustments do not interact. Figure 4 shows typical response curves for combined high and low frequency equalizer settings in the *EQL* mode. (Use of only the low-frequency control in the *EQL* mode would produce a response similar to the curves shown in figure 5, and use of only the high-frequency control would produce response curves similar to figure 6.)

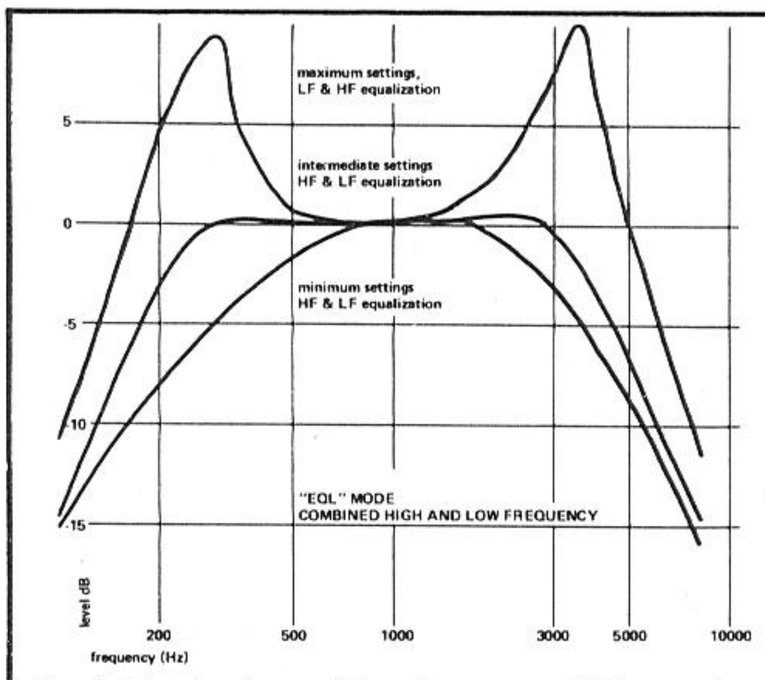


fig 4. Typical combined curves, EQL mode

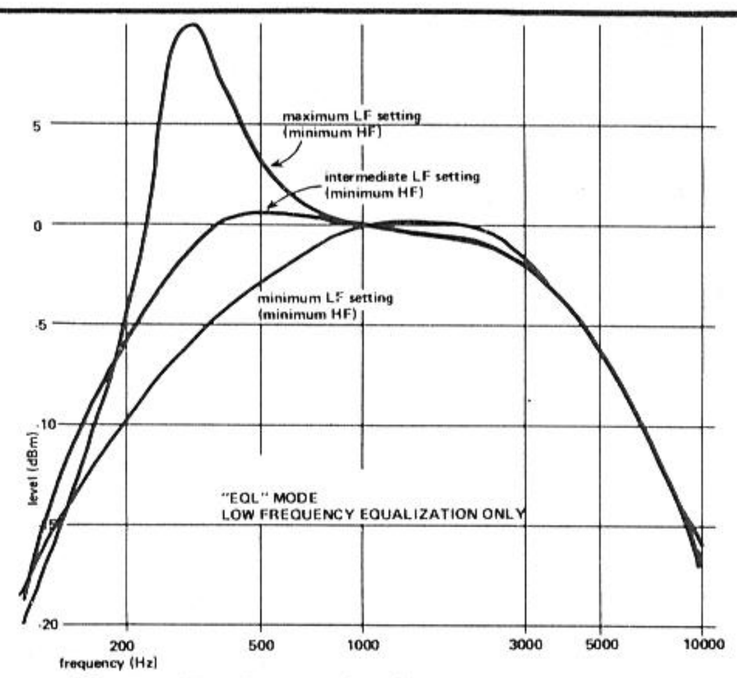


figure 5. Typical LF curves, EQL mode

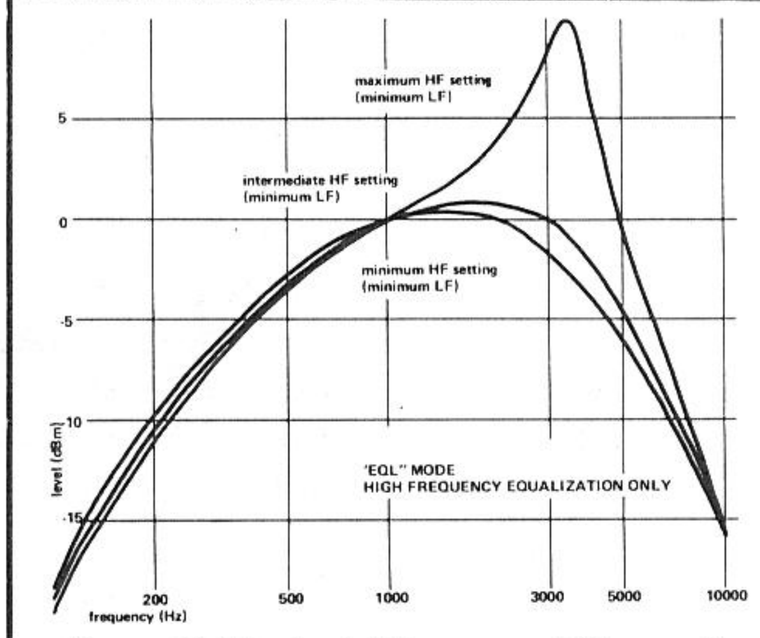


figure 6. Typical HF curves, EQL mode

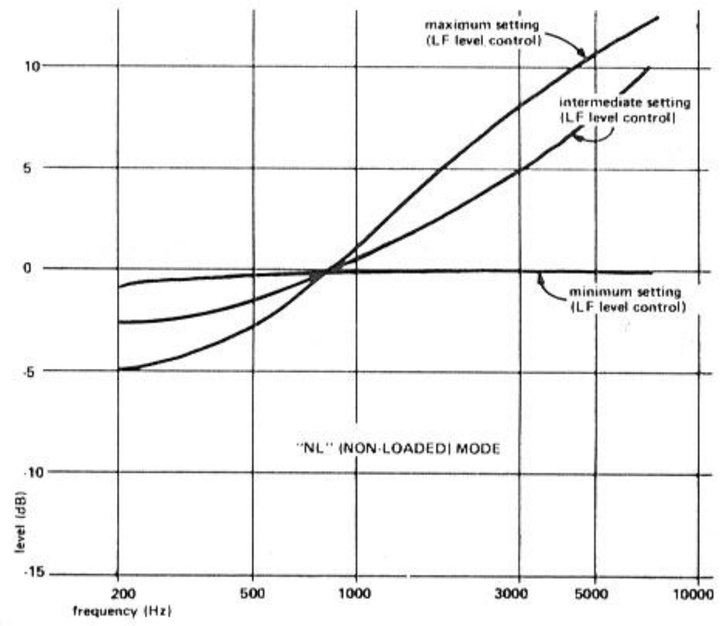


figure 7. Typical curves, NL mode

2.12 In each channel's *NL* (nonloaded cable) equalization mode, the high-frequency equalizer section is bypassed and, via the low-frequency control, the channel's frequency response is adjusted to complement that of various lengths and gauges of nonloaded cable. The equalization is, again, independent of gain setting and impedance matching options. Figure 7 shows typical response curves for this mode.

front panel

2.13 The 4001A's front panel provides access to gain, high-frequency equalization, and low-frequency equalization adjustments for amp 1 and amp 2 channels. In addition, the front panel contains four pairs of jacks for use during alignment and maintenance procedures. Both bridging (*MON*) and opening (*IN* and *OUT*) jacks are provided at each 4wire port.

3. installation

inspection

3.01 The 4001A Line Amplifier module should be visually inspected upon arrival in order to find possible damage incurred during shipment. If damage is noted, a claim should immediately be filed with the carrier. If stored, the Line Amplifier module should be visually inspected again prior to installation.

mounting

3.02 The 4001A Line Amplifier mounts in one position of the Tellabs Type 10 Mounting Shelf, which is available in configurations for both relay rack and apparatus case installation. The module plugs physically and electrically into a 56-pin connector at the rear of the Type 10 Shelf.

installer connections

3.03 Before making any connections to the mounting shelf, ensure that power is **off** and modules are **removed**. The 4001A module should be put into place only **after** wiring has been completed and **after** properly optioned.

connect:	**to pin:**
AMP 1 TIP IN.	55
AMP 1 RING IN	49
AMP 1 SIMPLEX IN	53 and 51
AMP 1 TIP OUT	41
AMP 1 RING OUT	47
AMP 1 SIMPLEX OUT.	43 and 45
AMP 2 TIP IN.	7
AMP 2 RING IN	13
AMP 2 SIMPLEX IN	9 and 11
AMP 2 TIP OUT	5
AMP 2 RING OUT	15
AMP 2 SIMPLEX OUT.	1 and 3
BATT (–22 to –56 Vdc battery in)	35
GND (ground)	17

table 1. External connections to 4001A

3.04 Table 1 lists connections to the 4001A Line Amplifier. All connections are made via wire-wrap

at the 56-pin connector at the rear of each module's mounting shelf position. Pin numbers are found on the body of the connector.

options

3.05 Three option switches must be set before the 4001A can be placed in service. Locations of these switches are shown in figure 8. Option switch *S1*, a six-position DIP switch, is used to condition the input and output impedances of the amp 1 and amp 2 circuits. Normally, the 600 ohm option is selected for interfacing carrier, station apparatus, sf signaling units, and nonloaded cable, while the 1200 ohm option is selected for interfacing loaded cable. Switch *S1* also determines whether the alternate gain range is introduced into either circuit (amp 1 or amp 2). Select the level range most compatible with the level requirements of the application. Table 2 specifies the switch conditioning for each application.

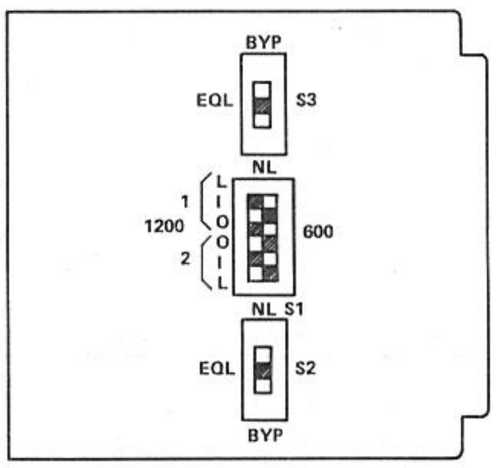


figure 8. Switch locations

switch S1 position	channel	on	off
1 (L)	amp 1	insert alternate gain range (–15 to +6dB)	normal gain range (–3 to +36dB)
2 (I)	amp 1	600 ohm input	1200 ohm input
3 (O)	amp 1	600 ohm output	1200 ohm output
4 (O)	amp 2	600 ohm output	1200 ohm output
5 (I)	amp 2	600 ohm input	1200 ohm input
6 (L)	amp 2	insert alternate gain range (–15 to +6dB)	normal gain range (–3 to +36dB)

table 2. Switch S1 option chart

3.06 Switches *S2* and *S3* determine the equalization mode for the amp 2 and amp 1 circuits, respecitvely. Set each switch to the *BYP* position if no equalization is desired, to the *EQL* position to provide high-low equalization for loaded cable or carrier, or to the *NL* position to provide equalization for nonloaded cable.

alignment

3.07 Because the two channels (amp 1 and amp 2) of the 4001A are identical, the following alignment procedure applies to either or both channels. Measurements are made via the module's own jacks. If the module's simplex leads are used, test equipment must be balanced to ensure proper readings.

3.08 After all option switches have been set, adjust all front-panel controls fully counterclockwise. Insert the module into its mounting, apply power, apply a signal to the channel's input port via test oscillator at the level and impedance as specified on the circuit level record (CLR), and adjust the gain control to achieve the desired level at 1000Hz, as measured via a transmission measuring set (TMS) at the channel's output port. Repeat this procedure for the other channel. If no equalization is required, no other adjustments need be made.

3.09 If equalization is to be provided (whether for loaded or nonloaded cable or carrier interfacing), the following procedure should be followed (end-to-end facility measurements should be made while adjusting the equalizers):

A. Remove the oscillator from the input port while leaving the TMS on the output port.

B. Request that the distant end of the facility send tone.

C. Adjust the *HF* and *LF* receive-channel equalizers (*LF* only if in *NL* mode) to provide the desired frequency response. Be sure to trim the *LF* adjustment after setting the *HF* section, and vice versa.

D. In the *EQL* (high-low equalization) mode for loaded cable or carrier, measurements are suggested at 400, 600 and 800Hz for low-end equalizer adjustment. For high-end equalization, measurements at 2000, 3000 and 4000Hz are recommended. In the *NL* (nonloaded cable) equalization mode, measurements should be made at several frequencies within the voice band.

E. If a flat response with high-end and low-end roll-off is desired, set switch *S2* or *S3* to the *EQL* position, as previously noted, and, using a suitably terminated VF oscillator and voltmeter, carefully adjust the *LF* and *HF* equalization controls to achieve levels at 400Hz and 3200Hz, respectively, that are equal to the level at 1000Hz. Roll-off is then automatically provided below 400Hz and above 3500Hz.

3.10 After the desired equalization has been achieved, readjust the gain potentiometers to provide the desired 1000Hz gain. (Gain adjustment will not affect the equalizer response.)

3.11 Repeat this procedure for the other channel, if required. This completes the alignment procedure.

4. circuit description

4.01 This circuit description is designed to familiarize you with the 4001A Line Amplifier for engineering and application purposes only. Attempts to troubleshoot the 4001A internally are not recommended. Please refer to the associated functional Block Diagram (section 5) as an aid in understanding this circuit description.

4.02 The 4001A power supply is a simple series voltage regulator that uses a zener diode as a reference source. A series diode in the negative input lead protects the circuit against reversed input power connections, and a high-voltage zener diode between input battery and ground limits high-level supply transients to a safe level. Tantalum filter capacitors are used to provide filtering and decoupling between amp 1 and amp 2 channel supplies.

4.03 Each channel (amp 1 and amp 2) of the 4001A uses input and output transformers to interface external circuits and to derive simplex leads at both ports. Lightning protection is provided on the secondaries of both transformers through use of a multi-junction varistor on the input transformer and an avalanche diode on the output transformer. Precision resistors are used to establish the input and output impedances.

4.04 In each channel, a quad operational amplifier integrated circuit is used to provide gain for the active filters, isolation between the equalizer and amplifier sections, and channel voltage gain. The voltage gain stage makes use of both negative and positive feedback, with gain controlled by varying the negative feedback. This approach to gain control provides, in addition to optimum gain stability and setability, optimum output signal-to-noise performance.

4.05 Low-frequency equalization in each channel is provided by an active two-pole high-pass filter. The natural frequency of the filter is set at 260Hz, and the damping factor of the filter is varied to derive low-frequency equalization. With the *LF* potentiometer in the full counterclockwise position, filter loop gain is unity and the filter shape is overdamped. As the *LF* potentiometer is rotated approximately ¼ turn clockwise, the response becomes critically damped (damping factor of 0.707). Full clockwise rotation produces a damping factor of about 0.2, which yields an underdamped response with about a 12dB gain peak at 400Hz.

4.06 With switches *S2* (amp 1 circuit) and *S3* (amp 2 circuit) in the *NL* position, the loop gain of each channel's high-pass active filter is fixed at unity, producing the overdamped response, and an additional RC high-pass section is introduced, producing a monotonically-increasing output frequency characteristic complementary to that of nonloaded telephone cable.

4.07 High-frequency equalization in each channel is provided by an active two-pole low-pass filter whose natural frequency is 3400Hz. Amplitude equalization is again provided by varying the damping factor of the filter. The damping factor, and thus high-frequency equalization, is controlled by the *HF* potentiometer. With the *HF* potentiometer at full counterclockwise rotation, the damping factor of the low-pass filter is about 0.8, which is near critical damping and maximum flat response. As the *HF* potentiometer is adjusted in the clockwise direction, high-frequency gain is enhanced relative to that at 1000Hz, and at full clockwise rotation, the gain at 3400Hz is approximately 12dB greater than the gain at 1000Hz. The filter provides a 12dB per octave roll-off above the natural frequency.

4.08 Following each channel's high-frequency equalizer is a unity-gain buffer amplifier that isolates the impedance variations of the filters from the voltage gain stage. An emitter-coupled output amplifier provides power gain and establishes the output impedance for each channel. In the bypass mode, the two equalizer stages are bypassed and the input to the voltage follower is provided directly from the input transformer.

6. specifications

gain range
approximately –3 to +36dB, or –15 to +6dB (switched) (either amp 1 or amp 2)

distortion
less than 1% at +10dBm output level

maximum output level (overload point)
no visible clipping at output level of +18dBm

equalization, bypass (BYP) mode
±1dB re 1000Hz from 100Hz to 10,000Hz

equalization, nonloaded cable (NL) mode
nominal 6dB/octave slope (see figure 7 for typical curves)

equalization, loaded cable or carrier (EQL) mode
maximum HF equalization provides a minimum of 10dB at 3400Hz ±100Hz, reference 1000Hz level
minimum HF equalization provides –2.5dB at 3400Hz ±100Hz, reference 1000Hz level
maximum LF equalization provides a minimum of 10dB at 320Hz ±40Hz, reference 1000Hz level
minimum LF equalization provides –6dB at 320Hz ±40Hz, reference 1000Hz level
(see figures 4, 5, and 6 for typical curves)

frequency response
(bypass position) ±1dB re 1000Hz level, 100 to 10,000Hz

noise
20dBrnC maximum at 36dB gain

longitudinal balance
60dB minimum

delay distortion
less than 100μs from 300 to 10,000Hz; less than 50μs from 500 to 10,000Hz

input impedance
600 or 1200 ohms ±5%, balanced

output impedance
600 or 1200 ohms ±5%, balanced

simplex current
120mA maximum, with 5mA maximum unbalanced

input power
–22 to –56Vdc, 60mA maximum (both amp 1 and amp 2 output levels at +18dBm), 20mA quiescent

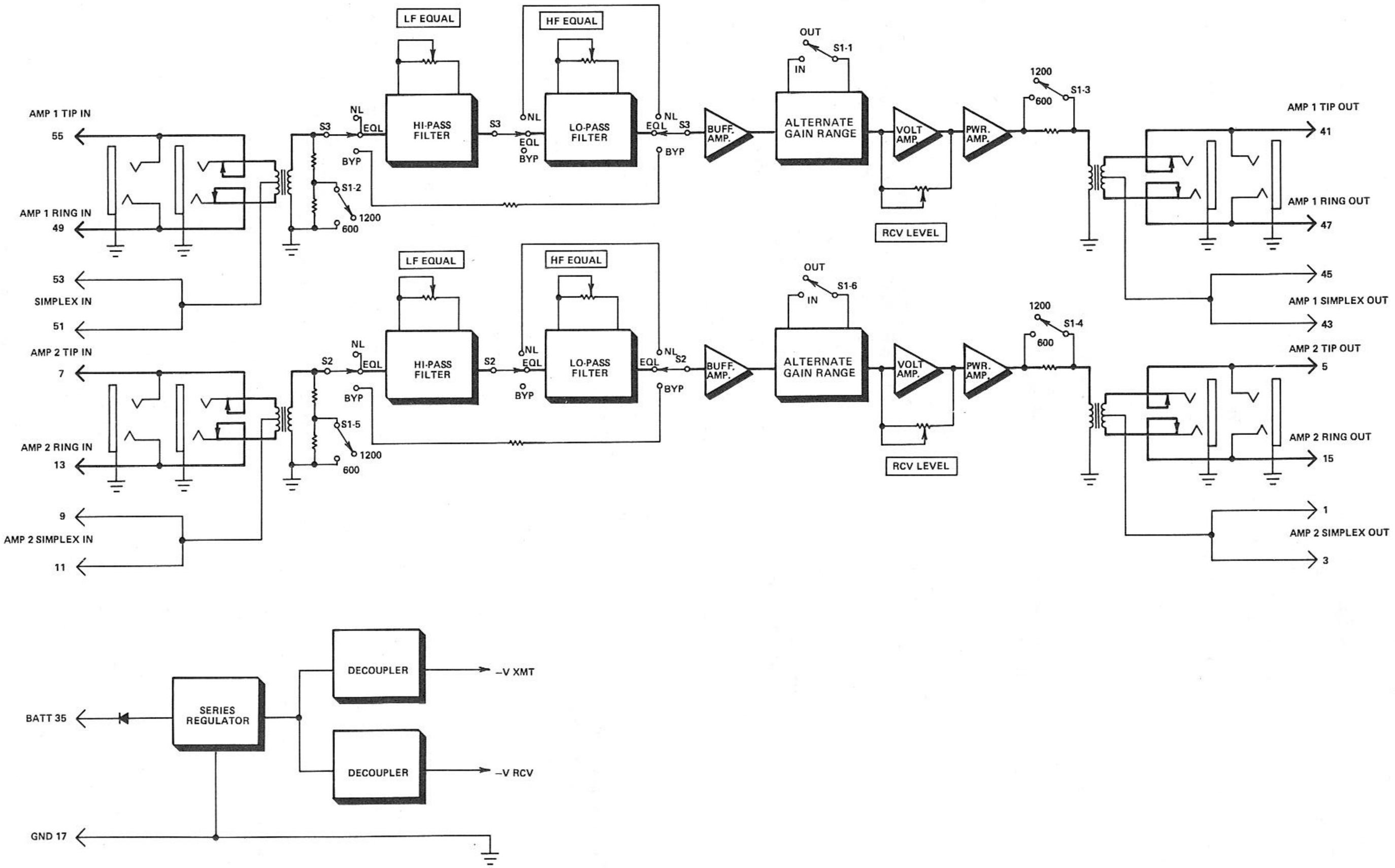
crosstalk coupling
greater than 90dB equal-level coupling loss, either amplifier, 300 to 4000Hz

operating environment
20° to 130°F (–7° to 54°C) humidity to 95% (no condensation)

dimensions
5.58 inches (14.17cm) high
1.42 inches (3.61cm) wide
5.96 inches (15.14cm) deep

weight
15 ounces (425 grams)

mounting
relay rack or apparatus case via one position of Tellabs Type 10 (or Wescom Type 400) Mounting Shelf



4001A Line Amplifier 814001A

5. block diagram

7. testing and troubleshooting

7.01 This Testing Guide may be used to assist in the installation, testing, or troubleshooting of the 4001A Line Amplifier module. The Guide is intended as an aid in the localization of trouble to a specific module. If a module is suspected of being defective, a new module should be substituted and the test conducted again. If the substitute module operates correctly, the original module should be considered defective and returned to Tellabs for repair or replacement. It is strongly recommended that no internal (component level) testing or repairs be attempted on the 4001A module. Unauthorized testing or repairs may void the module's warranty.

7.02 If a situation arises that is not covered in the Testing Guide, contact Tellabs Customer Service at (312) 969-8800 for further assistance.

7.03 If a 4001A is diagnosed as defective, the situation may be remedied by either *replacement* or *repair and return*. Because it is the more expedient method, the *replacement* procedure should be followed whenever time is a critical factor (e.g., service outages, etc.).

replacement

7.04 If a defective 4001A is encountered, notify Tellabs via telephone, letter or twx. Notification should include all relevant information, including the 8X4001A part number (from which we can determine the issue of the module in question). Upon notification, we shall ship a replacement module to you. If the warranty period of the defective module has not elapsed, the replacement module will be shipped at no charge. Package the defective module in the replacement module's carton; sign the packing list included with the replacement module and enclose it with the defective module (this is your return authorization); affix the preaddressed label provided with the replacement module to the carton being returned; and ship the equipment prepaid to Tellabs.

repair and return

7.05 Return the defective 4001A module, shipment prepaid, to:

Tellabs Incorporated
4951 Indiana Avenue
Lisle, Illinois 60532
Attn: repair and return dept.

Enclose an explanation of the module's malfunction. Follow your company's standard procedure with respect to administrative paperwork. Tellabs will repair the module and ship it back to you. If the module is in warranty, no invoice will be issued.

4001A testing guide checklist

Note: *Because the two circuits (amp 1 and amp 2) of the 4001A are identical, this checklist will apply equally to either circuit. Differences in option switch assignments and input and output pin assignments are noted where applicable.*

test	test procedure	normal result	if normal conditions are not met verify
normal gain range	Connect test signal to amplifier input via pins 55 and 49 (amp 1) or 7 and 13 (amp 2) or via appropriate *IN* jack. Measure amplifier output at pins 41 and 47 (amp 1) or 5 and 15 (amp 2) or at appropriate *OUT* jack.	With appropriate *level* control fully counterclockwise (CCW), switch *S3* (amp 1) or *S2* (amp 2) in *BYP* position, and *S1-1* or *S1-6 off*, output level approximately 3dB lower than input ☐. At full clockwise (CW), output level about 36dB higher than input ☐.	Power applied to module ☐. Wiring ☐. Proper impedance terminations (check for double terminations) ☐. Impedance switches correctly set ☐. Switch *S3* or *S2* in *BYP* position ☐. Switch *S1-1* or *S1-6* in *off* position ☐.
alternate gain range	Connect test signal to amplifier input and measure amplifier output as instructed for gain test above.	With appropriate *level* control fully CCW, switch *S3* (amp 1) or *S2* (amp 2) in *BYP* position, and *S1-1* or *S1-6 on*, output level approx. 15dB lower than input ☐. At full CW, output level approx. 6dB higher than input ☐.	Power ☐. Wiring ☐. Proper impedance terminations (check for double terminations) ☐. Impedance switches correctly set ☐. Switch *S3* or *S2* in *BYP* position ☐. Switch *S1-1* or *S1-6* in *on* position ☐. Output level not exceeding +18dBm overload point ☐.
loaded cable or carrier amplitude equalization (EQL)	Set switch *S3* (amp 1) or *S2* (amp 2) to *EQL* position and connect test signal to amplifier input as described above. Vary frequency of signal from 200 to 6000Hz and observe output level at appropriate pins or jack.	With appropriate *LF* and *HF eql* controls fully CCW and with *S3* or *S2* in *EQL* position, 1000Hz gain approx. 3dB lower than when *S3* or *S2* in *BYP* position ☐. As *LF* and *HF* eql controls adjusted CW, 1000Hz gain increases a few dB, and, at full CW, gain peaks of 10dB minimum (relative to 1000Hz level) occur at about 300 and 4000Hz ☐. Levels at 200 and 6000Hz about 5dB below 1000Hz level ☐.	Power ☐. Wiring ☐. Terminating impedances correct ☐. Slide *S3* or *S2* to alternate position and back to clean contacts ☐. If "singing" is observed, adjust either *HF* or *LF* control CCW until oscillations disappear (over-equalized condition) ☐. Impedance options correctly set ☐. Input signal level approximately constant over test range ☐. Levels not exceeding maximum +18dBm output ☐.
nonloaded cable amplitude equalization (NL)	Set *S3* (amp 1) or *S2* (amp 2) to *NL* position and connect test signal as described above. Vary signal frequency over voice band and observe output level at appropriate pins or jack.	With appropriate *LF eql* control fully CCW, level at 1000Hz approximately 2dB lower than when *S3* or *S2* in *BYP* position ☐. As *LF eql* control adjusted CW, 1000Hz level decreased ☐. At full CW, levels compared to those at full CCW are as follows: 400Hz down approx. 23dB ☐; 1000Hz down approx. 14dB ☐; 4000Hz down approx. 3.5dB ☐.	Power ☐. Wiring ☐. Impedance options correctly set ☐. Slide *S3* or *S2* to alternate position and back to clean contacts ☐. Input signal level approximately constant over test range ☐. Levels not exceeding maximum +18dBm output ☐.
noise	Insert shorting plug into appropriate *IN* jack or connect shorting strap between pins 55 and 49 (amp 1) or 7 and 13 (amp 2). Measure output noise level, either at appropriate *OUT* jack (terminated measurement) or between pins 41 and 47 (amp 1) or 5 and 15 (amp 2) (monitor measurement).	Measured noise less than 20dBrnC for all gain settings and all three equalizer positions ☐. Noise level follows amplifier *level* setting ☐.	Input to amplifier shorted ☐. Noise Test Set at proper terminating impedance ☐. High RF environment affecting Test Set ☐.