SECTION 19

LIMITING AMPLIFIERS LIM/5 AND LIM/5A

Introduction

The Limiting Amplifier LIM/5 has been developed to supersede the Limiting amplifier LIM/2, certain components of which are now obsolescent. The design of the LIM/5 follows closely that of the LIM/2, the chief difference being that the LIM/5 is designed to work with zero volume input, and to deliver zero volume output ; the LIM/2 works with an input volume of -23 dB and delivers an output volume of -23dB, necessitating a separate amplifier to raise this volume to zero. The use of miniature valves and components has led to a considerable reduction of size in the LIM/5, which is constructed on a 4½-inch panel, for double-sided bay mounting. The incorporation of an amplifier to provide zero volume output eliminates the necessity for the separate output amplifier mentioned above.

The LIM/5 itself is intended for use on 22⅛ in. bays, the LIM/5A being used with 19-in. bays. Other differences between the two amplifiers are very slight, and are indicated in the footnotes to Fig. 46.

General Description

The LIM/5 comprises a variable-gain push-pull amplifier preceded by a variable attenuator, together with a side chain providing the bias voltage for reducing the amplifier gain at excessive peak volume, and an output amplifier.

Variable-mu pentodes are used in the variable-gain amplifier, because the mutual conductance of this type of valve decreases smoothly with increased bias, and vice versa ; the gain of the stage can thus be controlled by means of a d.c. potential. This potential is provided by the side chain, which is fed from the output of the variable-gain amplifier. No bias is applied until the peak output signal from the variable-gain amplifier exceeds the pre-determined value ; when however, this value is exceeded, control bias is applied to reduce the amplifier gain. The control bias increases very rapidly with increased amplifier output, so that, in practice, the output signal can only exceed the pre-determined value by a very small amount. The side chain is fed from the output of the amplifier to prevent any possibility of over-control (i.e. decreased output with increased input) which might occur if the side chain were fed from the input to the variable-gain amplifier.

The time constants associated with the control-bias supply circuits have been chosen with some care. The charge time constant is relatively short, and the discharge time constant (which can be varied to suit particular applications) is relatively long. Thus when the input signal peak amplitude exceeds the pre-determined value, the gain of the amplifier is reduced rapidly ; when the signal amplitude falls back below the limiting value, the gain of the amplifier returns slowly to its normal value. The charge time constant is, however, sufficiently long for very sharp peaks to be passed without the amplifier gain being appreciably reduced. These peaks will be of such a transient nature that the distortion produced will not be detected aurally, and by allowing this condition, mean modulation can be maintained at a higher level than if the charge time constant were very short.

The discharge time constant can be varied by means of the timing switch. If a very long discharge time is selected, the limiter will tend to behave as an automatic maximum-level-setting device. If, however, the discharge time constant is short, the limiter behaves as a compressor, cutting back peak levels, and restoring gain rapidly in the intervals between peaks. If it is required to use the limiter deliberately as a compressor the attenuator control at the input is adjusted to a higher setting ; the input signal amplitude at the input of the variable-gain amplifier is consequently increased, so that limiting commences at a lower volume of input signal, although maximum output volume remains substantially unaltered. The effect is to reduce the over-all dynamic range.

To facilitate removal and replacement of the unit, the power supply and programme connections are made through a single multi-way socket at the rear of the panel.

Circuit Description

The circuit of the LIM/5 comprises three sections, the variable-gain amplifier, the side chain and the output amplifier. A circuit diagram of the complete unit is shown in Fig. 46.

Variable-gain Amplifier (*Fig.*19.1)

This section of the LIM/5 comprises the push-pull valves V1 and V2, and their associated components. The input signal is applied to the primary winding of the transformer TR1 through the

12-db attenuator pad formed by R1-R4. The input impedance of the amplifier at the primary side of the transformer is approximately 600 ohms, and the attenuator has a transfer impedance of this value so that the same impedance is presented at the input of the attenuator. The centre-tapped transformer has an over-all ratio of 1 : 1, and its secondary winding feeds the variable stepped attenuator controlling the inputs to the grids of V1 and V2. The centre point of the attenuator is connected to the mid-point of the transformer secondary winding, and this point is connected to the control-bias source. The attenuator is variable in eight 2-dB steps, and is designated *Limiting dB*. Its total resistance is 528 ohms, which together with the resistance of the transformer secondary winding presents the required value of 600 ohms. In its position of maximum attenuation, the input at each valve grid is approximately 34 dB below input level. This figure comprises 28 dB from the fixed and variable attenuators, and 6 dB from the step-down ratio of the transformer.

In addition to reducing greatly the magnitude of even-harmonic components of distortion, the use of a push-pull stage also lessens the magnitude of the plop which occurs in the output when the control bias is applied ; with a single valve, this plop would be audible. Resistor R5 is included in the cathode circuits of V1 and V2 to compensate for slight differences between the individual valves V1 and V2. By means of it, the grid bias applied to the valves may be varied differentially within narrow limits. The position of the slider is adjusted so that the mutual conductances of the two valves are equal ; the changes in the anode current in the two valves arising from the application of control bias will then be equal and, since they are applied to the output transformer TR2 in opposite phase, no output will appear across the secondary winding from this cause. In practice, perfect balance is not obtainable, but the degree of unbalance can be reduced to negligible proportions.

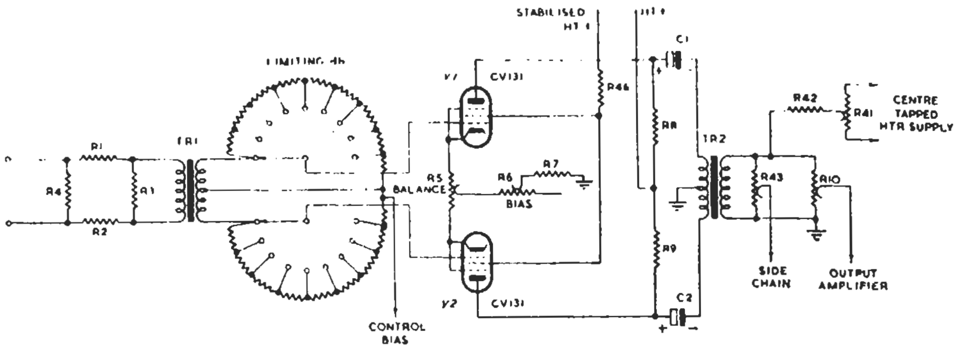

Fig. 19.1 Variable-gain Amplifier

Common bias for the two valves is provided by the variable resistor R6 ; R7 is a meter shunt by means of which the total feed for the two valves can be measured.

The output from V1 and V2 is fed to the primary winding of the shunt-fed transformer TR2, which has a primary/secondary impedance ratio of 1 : 8 overall. The gain controls R10 (output amplifier, labelled *Output Level*) and R43 (side chain, labelled *Limiting Level*) are connected across the secondary winding of the transformer. The non-earthy end of the transformer secondary is connected via R42 to the slider of the potentiometer R41 (*Hum Bal*) connected across the centre-tapped heater supply. The purpose of this is to reduce the hum produced by the heaters of V1 and V2 which appears in the output. By adjustment of R41 a hum voltage of anti-phase polarity and equal magnitude can be injected in parallel with the output from the amplifier, to reduce the hum level to negligible proportions. This arrangement has been adopted as the normal potentiometer technique is not satisfactory, since in general, the setting of the control for minimum hum from one valve would not be the same as that required for the other.

Side Chain (*Fig.* 19.2)

The input signal to the side chain is derived from the pre-set potentiometer R43, connected across the output of the variable-gain amplifier. The signal is applied to the grid of the amplifying stage V3b, the output of which is fed to the primary winding of the shunt-fed transformer TR4. The transformer has an impedance ratio of 1 : 8 overall, and its secondary winding feeds the full-wave rectifier unit comprising MR1, MR2 and R24. No capacitance is connected across R24, so that the signal applied to the grid of V5a is a copy of the input signal, with the negative-going portions of the signal reversed in polarity.

The additional resister R26 in the anode circuit of V5a and the associated capacitor C14 are used to correct a tendancy to instability in certain unbalanced conditions.

From the anode circuit of V5a, the negative-going pulses are fed via R34 and C8 to R35. In parallel with R35 is connected the diode V7 and the capacitor C9; C9 is charged negatively when the cathode of V7 is negative with respect to its anode. The charging time constant is determined by the values of R34, R35, C8 and C9 and the forward resistance of V7; it is such that on transient pulses C9 does not charge appreciably, and the gain of V1 and V2 is thus not materially reduced when isolated transient peaks are applied to the input.

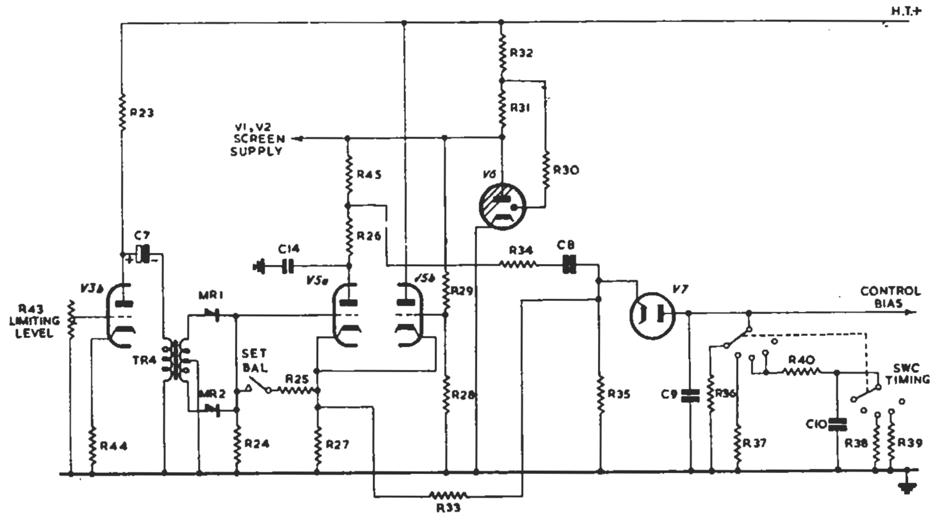

Fig. 19.2 Side Chain

Valve V5a is normally held non-conducting by the positive bias applied to its cathode by current flowing through R27. This current is supplied by valve V5b, the grid of which is held at a positive potential relative to earth by the voltage drop across R28, which forms part of a potential divider R29, R28, connected across a source of stabilised voltage, V6. The grid bias applied to V5a in this manner is about —20 volts, approximately 15 volts beyond cut-off.

When a signal is applied to the input of the side chain, positive-going signals will be applied to the grid of V5a, and if the signal amplitude is sufficiently great, the valve will conduct. The resultant current flowing through the anode load resistor R45 will produce negative-going pulses, which are utilised to provide the control bias for valves V1 and V2 of the variable-gain amplifier as described later.

The cathode of V7 is returned via R33 to the common cathode circuit of V5a and V5b, and by the potentiometer action of R33 and R35, the cathode of V7 has a positive bias applied. The purpose of this bias is twofold. Firstly, if no bias were applied, a voltage would appear across V7 in the absence of a signal due to the random arrival of electrons at the anode. This voltage, which would make the anode of V7 negative with respect to its cathode, would be shared between R35 and the resistor in parallel with C9, selected by the *Timing* switch, and there would consequently be a control bias applied to V1 and V2 in the absence of an input signal. Further, this voltage, of the order of 1 volt, would be liable to wide changes with variations of filament voltage. The application of positive bias to the cathode of V7 (about 2 volts) eliminates this standing bias, since random electrons will no longer arrive at the anode.

Secondly, the cut-off voltage of V5a varies with individual valves, and the commencement of limiting action, if determined by the voltage at which V5a begins to conduct, would be subject to variation. Since, however, V7 does not begin to conduct until the voltage applied to its cathode exceeds 1 volt approximately, the commencement of limiting action is not so dependent upon the exact value of grid bias at which V5a begins to conduct.

The recovery time constant of the control bias is determined by the magnitude of C9 and the discharge resistor selected by means of the *Timing* switch. The switch has four positions. In the first position, where R36 is selected, the recovery time constant is approximately 0·5 seconds. In this position recovery after overload is rapid, and is suitable therefore where the limiter is used for compression. In the second position, where R37 is selected, the recovery time constant is 2·5 seconds.

In the third position, the first of two more complex discharge circuits is introduced. If an overload of short duration occurs, C9 charges, but C10 does not, since its charge time constant is about 2 seconds. At the end of the overload period, the charge on C9 is shared with C10, and since C10 is much larger than C9, the control bias falls fairly rapidly as C10 charges, to a value of approximately 1/9th of its initial value. The time constant of this charge is approximately 0·1 seconds, determined to a first degree of approximation by the magnitude of C9, C10 and R40. The control bias then returns slowly to zero value as C9 and C10 discharge through R38, the time constant being approximately 40 seconds. If, however, a sustained overload, or a series of short duration overloads in quick succession, occurs, C9 will charge rapidly as before, and C10 will also be charged, but more slowly. When the overload period ends, C9 and C10 will be at approximately the same potential, and consequently C9 will not discharge into C10. The control bias will then die away slowly, the recovery time constant being approximately 40 seconds. In this position, therefore, the limiter differentiates between short isolated overload periods, and sustained overload periods. In both instances, gain is reduced during the overload period, but in the first instance recovery is rapid, whilst in the second, recovery is prolonged.

In the fourth position, the behaviour of the circuit is similar to that in position 3, except that the recovery time constant is nominally 16 minutes; in this condition the limiter behaves as an automatic maximum-level-setting amplifier.

To assist in the operation of equalising the mutual conductances of V1 and V2, a " set-balance " key is fitted in the grid circuit of V5a. When the key is pressed, the grid of V5a is connected to cathode, so that the valve condition changes rapidly from non-conducting to fully conducting, simulating the application of a severe transient overload. The control bias then changes rapidly from zero to maximum value, producing an audible " plop " at the output. This " plop " can then be reduced to a minimum value by adjustment of R5.

Output Amplifier (Fig. 19.3)

The output amplifier comprises V3a driving valves V4a and V4b, a cathode-coupled push-pull output pair. The overall gain is 18 dB; negative voltage feedback (15 dB) is applied from a tertiary winding of the output transformer TR3 to the cathode of V3a; capacitor C4 is included in parallel with the anode load of V3a to ensure that the amplifier remains stable at high frequencies. Resistor R21 is connected in series with the secondary winding of the transformer TR3, so that together with the secondary winding resistance and amplifier output impedance, the output impedance is equal to 600 ohms.

The push-pull stage is noteworthy for the cathode coupling arrangement adopted. The two cathode-load resistors are connected by means of the capacitor C5, and by virtue of the low impedance of the capacitor at all frequencies in the working range, the circuit behaves as if V4a and V4b shared a common cathode-load resistor, equal to the value of R17 and R15 in parallel. The grid of V4b is decoupled to earth by C6, and the stage therefore functions as a normal cathode-coupled pair to applied a.f. signals.

The grid leak of each valve is not, however, returned to a tapping point on its own cathode load, but to the corresponding point on the cathode load of the other. The purpose of this is to ensure that the currents through both valves are as nearly equal as possible, so that polarisation of the core of the output transformer is reduced to a minimum.

The action of the circuit is as follows. If the current through valve V4a increases for any reason, the cathode potential of V4a increases, and the grid potential of V4b also increases. Consequently the cathode potential of V4b will also rise by cathode-follower action, and as its cathode load is very large, the rise in potential will be almost equal to the rise in grid potential. To produce this increased potential, the V4b anode current must therefore have increased by a value almost equal to the rise in V4a. The rise in potential of the cathode of V4b will also be communicated to the

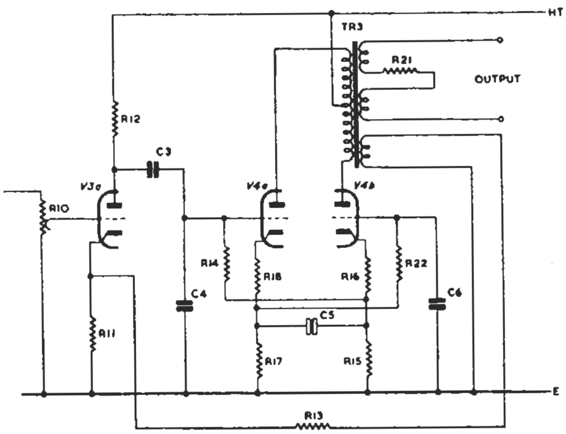

Fig. 19.3 Output Amplifier

grid of V4a, and since this rise is less than the rise in cathode potential of V4a, the grid-cathode voltage of V4a will have increased negatively, tending to reduce the anode current of V4a. The system therefore also stabilises both valves against individual anode-current changes, as well as ensuring equality of anode currents. For successful operation, the cathode resistors must be closely matched.

Operating Instructions

1. *Feeds*

Switch on mains unit and allow at least five minutes warming-up period to elapse. Check with feed meter that the anode currents of valves V4a and V4b are equal within 0·3 mA. If this equality does not occur, a faulty valve or other component is indicated.

Adjust the *Bias* control to give a reading of 8 mA for the total cathode current of valves V1 and V2.

2. *Hum*

Set the *Output Level* control to maximum and with an amplifier detector at high gain connected to the limiter output, adjust the *Hum Bal.* control to give minimum hum output, which should be not greater than −40 **dB** into 600 ohms. A rare specimen of CV 131 may not allow this, in which case the valve must be rejected. This adjustment is necessary only at long intervals or when a CV 131 valve is replaced.

Note: For the *Hum Bal.* control (R41) to function correctly, it is essential that an earthed centre-tap be connected across the heater supply; if this arrangement is not provided on the type of mains unit in use, one of the following measures should be adopted:

(a) If the heater supply is floating, two 47-ohm resistors should be connected across it in series, and their junction taken to earth.
(b) If the heater supply is already earthed on one side, this earth should be removed and replaced by the arrangement described under (a), unless the existing earth is essential for other equipment taking a heater supply from the same mains unit.
(c) If it is not permissible to disconnect an earth already existing on one side of the heater supply, the hum-suppression circuit may possibly still function for a particular pair of valves V1 and V2, but if it does not it can be made to do so if the heater-supply leads from the mains unit are interchanged.

3. *Balance*

This operation should only be necessary when
(i) the equipment is first installed,
(ii) either V1 or V2 is changed, or
(iii) it is suspected that the characteristics of the valves have changed through ageing or other causes.

To obtain correct balance conditions proceed as follows:

(a) adjust the total cathode current of V1 and V2 to 8 mA as indicated in (1).

(b) set the *Output Level* control at maximum, *Limiting dB* control fully anti-clockwise and *Timing* control at position 1.

(c) Connect output of limiter to loudspeaker at normal gain, or use headphones if necessary.

(d) Depress and release the *Set Bal.* push-button repeatedly, at intervals of at least one second to allow time for gain recovery, meanwhile adjusting the *Balance* control until the plops produced by the operation of the *Set Bal.* push-button are reduced to minimum loudness. When carrying out this operation, attention should be concentrated on the low-frequency component of the plop, the residual high-frequency click being relatively unimportant.

4. *Lining Up*

Although the output is normally zero volume, it can be increased to +8 dB.

Since the circuits with which the limiter is associated vary considerably at different centres, it is not desirable that a standard line-up instruction should be given here. Detailed information is issued in the Station Instructions at those centres where limiters are employed.

Valve Data

Valve	*Type*	I_a,*mA*	I_s,*mA*	*Remarks*
V1, 2	CV 131	3·5	0·5	
V3 V3a V3b	CV 455			 Voltage across R11, 0·75 V* Voltage across R44, 1·1 V*
V4	CV 455	7·2		Each section (*see Feeds, above*)
V5 V5a V5b	CV 455	 0 4·5		 No signal No signal. Voltage across R27 25 V**
V6	CV 287			Voltage across R31, 43V**
V7	CV 140			

* Measured with AVO Model 40, 12 V range.
** Measured with AVO Model 40, 120 V range.

Total feed 42 mA at h.t. supply of 275 volts. l.t. supply 6·3 volts a.c., 1·6 A.

General Data

Impedances
- Input: 600 ohms
- Output: 600 ohms
- Normal load: 600 ohms

Normal working volume
- Input 0 dB
- Output 0 dB

Maximum output +8 dB

Normal limiting output 0 dB

Maximum gain between 600-ohm terminations with no limiting 13 ±1 dB.

Frequency Response

Test Conditions. Measured with 600-ohm source, working into 600 ohms. *Timing* switch set to position 1.

1. *No limiting (See table below)*
   Input level 0 dB.
   Limiting db control set at " 0."
   Limiting level control set fully anti-clockwise.
   Output level control set to give 0 dB gain at 1 kc/s.

2. *Limiting* 10 *dB (See table below)*

The limiter should first be set to limit at a level of +8 dB, as indicated below:

(a) Set *Limiting dB* control to " 0."
(b) Set *Limiting level* control fully anti-clockwise.
(c) Adjust *Output level* control to give 0dB gain at 1 kc/s.
(d) Inject 1-kc/s tone at +8 dB level and increase *Limiting level* control setting until output is reduced by 0·2 dB.

With limiter adjusted as set out above inject 1-kc/s input tone at +8 dB level, and adjust *Limiting dB* control to " +10 "; the output should not increase by more than 0·5 dB.

The figures given in the table below are relative to the output at 1 kc/s.

Frequency c/s	*No Limiting* dB	*Limiting* 10 *dB* dB
40—100	+0 −1·5	
100—1,000	+0 −0·5	
1,000—10,000	±0·5	
40—10,000		±1·5

Noise

Test Conditions. Input terminated in 600 ohms. Output connected to 600-ohm input of amplifier detector, *Output level* control set for 0 dB gain at 1 kc/s.

Noise level less than −48 dB.

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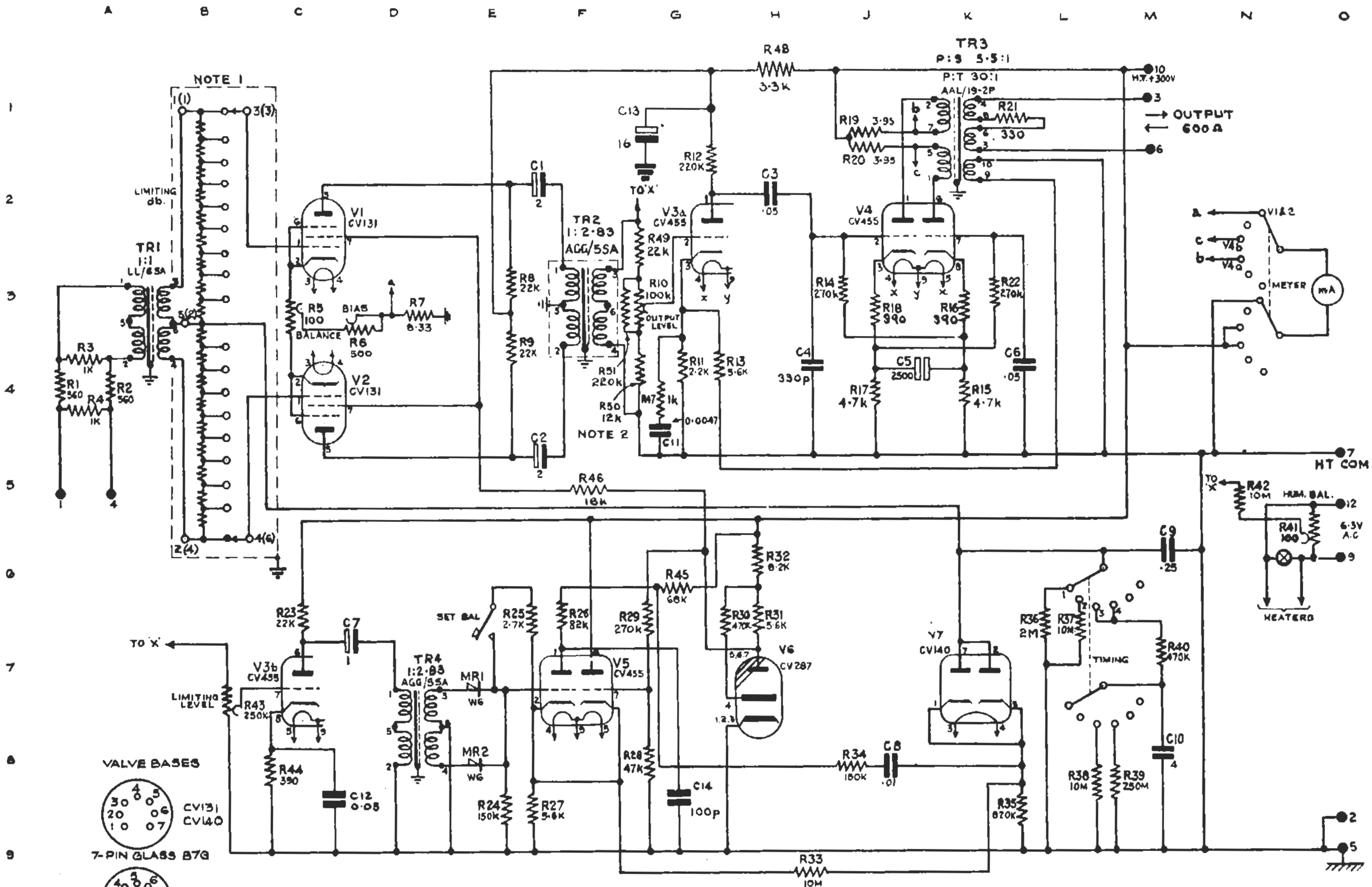

NOTES:- 1. INPUT 'LIMITING db' CONTROL IS TYPE PNN/4M1 ON LIM/5 & TYPE PNN/4M2 ON LIM/5A. TAG Nos. IN BRACKETS REFER TO LIM/5A
2. R49, R50 & R51 ARE FITTED ON LIM/5A ONLY
3. LIM/5A IS FOR USE ON 19-INCH BAYS

LIMITERS LIM/5 & 5A: CIRCUIT

FIG 46
ISSUE 5