SECTION 3

PRE-SET LAW TEST STEP GENERATOR GE4/509

Introduction

The GE4/509 produces a video signal consisting of a ten-step staircase wave recurring at line frequency with intervening line and field blanking, and with sync pulses if required. The law of the step amplitudes relative to black level is governed by the values of 10 or 11 resistors carried on a small plug-in printed-wiring board. Although the generator as normally supplied is fitted with a board giving a linear rising staircase wave (Fig. 3.1), any other staircase waveform with step amplitudes which follow a law between $y = x^{0 \cdot 3}$ and $y = x^{2 \cdot 5}$ (Fig. 3.2) can be obtained by inserting a board with appropriately calculated resistors. The generator will not produce descending steps, nor is it intended to provide single step rises exceeding the greatest within the stated range of laws (i.e., a single rise of 50 per cent of the total staircase height), but within these limitations other forms of law or arrangements of steps are possible, and two or more successive steps can have the same level.

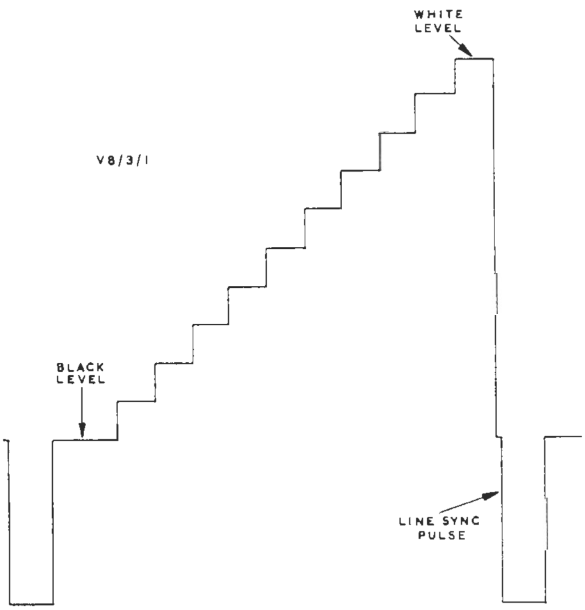


Fig. 3.1. GE4/509: Output Waveform in Line Periods

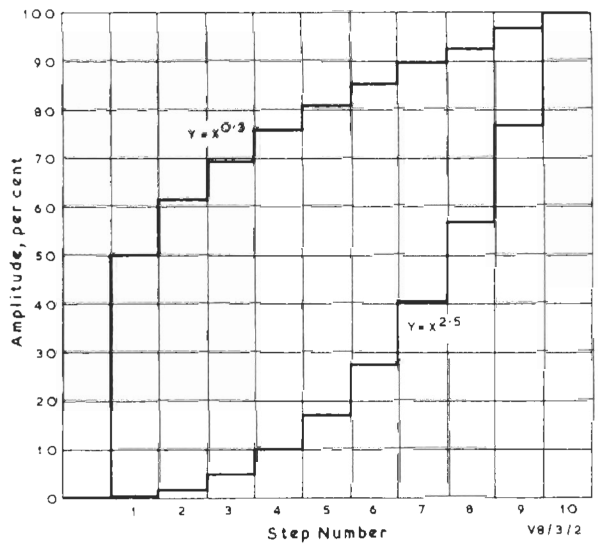


Fig. 3.2. GE4/509: Staircase Waveforms Corresponding to Laws $y = x^{0 \cdot 3}$ and $y = x^{2 \cdot 5}$

The generator is used for setting up non-linear amplifiers having prescribed laws, e.g., in television film recording. In one application, the generator is used to feed the amplifier under test with a staircase wave, the law of which is the reciprocal of the characteristic desired, while the amplifier output is displayed on an oscilloscope and adjusted for linearity. In another application, the generator is used to feed a particular series of steps to the amplifier to be adjusted, and the reproduction of these steps in the output waveform is examined and compared with levels marked on a special graticule; more than one step at black level and at white level may be generated, to extend these levels in from the ends of the lines, so that when the waveform is used to provide a tone wedge, the reproduction of the black and white levels can be seen at some distance from the edges of the picture.

The GE4/509 must be provided with an input of mixed blanking pulses. A sync pulse input must also be supplied if sync pulses are required in the output waveform. The generator will function on

405-line, 525-line or 625-line standards, but some readjustments may be necessary when changing between them.

Printed-wiring boards are used in the construction of the generator. Transistors and semiconductor diodes are used throughout.

General Data

Output Signal

One output of 1 volt peak-to-peak composite video test signal into 75 ohms. Between line blanking the waveform consists of a ten-step staircase wave.

Output Law

The staircase wave levels can be preset to a law between $y = x^{0\cdot 3}$ and $y = x^{2\cdot 5}$.

Accuracy of Output Step Levels

The deviation of a level from its correct amplitude above black level does not exceed 2 per cent of the amplitude of white level.

Input Signals

1. 2 volts peak-to-peak mixed sync pulses.
2. 2 volts peak-to-peak mixed blanking pulses.

Line Standards

405, 525 or 625, depending on input signals and setting of preset controls.

Output Impedance

75 ohms ±2 per cent.

Input Impedances

Greater than 3·3 kilohms at both inlets.

Output Rise and Decay Times

Sync pulses: 0·1 to 0·25 μsec.
Step rises: 0·2 to 0·5 μsec.
Blanking: 0·4 to 0·6 μsec.

Hum on Output

Less than 0·01 volt peak-to-peak.

D.C. in Output

The d.c. component of the output is less than +0·3 volt. The black level of the waveform is within ±0·1 volt with respect to chassis. (These figures apply with any output law in the specified range, but assume the presence of sync pulses.)

Output Variation With Mains Voltage

For ±7 per cent change in mains voltage: staircase wave variation is less than 0·1 dB; sync pulse variation is less than 0·1 dB.

For a change from 200 to 250 volts: staircase wave variation is less than 0·2 dB; sync pulse variation is less than 0·15 dB.

Operating Temperature

0 to 40 degrees C.

Mains Voltage

200 to 250 volts, 50 c/s.

Mains Input

25 mA at 240 volts, 50 c/s.

Weight

2 lb 12 oz.

Size

Constructed on a CH1/12B chassis.

Circuit Description (Fig. 3)

General

In this equipment, 10 rectangular waves are generated by a multivibrator (Fig. 3.3) during every line period between blanking. Pulses derived from each train of rectangular waves are used to drive a circuit which discharges a capacitor in uniform steps after the capacitor has been charged in every blanking period. The linear staircase wave thus obtained is applied to make ten circuits progressively switch current away from a common load. The changes in magnitude of the current withdrawn from the common load are determined by the values of the resistors on the plug-in printed-wiring board. A staircase wave with a law governed by the inserted resistors is thus developed across the common load of the switching circuits. Blanking is imposed on this staircase wave, which is then fed through an output amplifier to the outlet of the generator. If an input of mixed sync pulses is applied to the equipment, the sync pulses are clipped and amplified before being added to the output.

Step Timing

The incoming negative-going mixed blanking pulses are fed to the base of the transistor VT1 via C1 and R13. (Fig. 3). The emitter of VT1 is connected to the positive 6·25-volt supply. The collector of VT1 is connected via R14 to the base of VT5, which is in an astable multivibrator circuit with VT4. While a blanking pulse is applied, VT1 is fully conducting; between blanking pulses, VT1 is cut off. When VT1 is conducting, it effectively connects R14 to the positive 6·25-volt supply, and the positive bias then received by VT5 base suppresses the action of the multivibrator. Between blanking pulses, VT1 is effectively open circuit and the multivibrator is free to oscillate (Waveform 1). R13 prevents VT1 from passing excessive base current during blanking pulses and causes the circuit to present a high impedance to the source of the blanking input. Diode MR6 provides a reverse path in series with R13 for conducting away the charges acquired by C1 due to base current and prevents the development of positive bias.

The multivibrator in which VT4 and VT5 are employed is collector coupled. C6 and R23 govern the duration of one state in the cycle of oscillation of the multivibrator, and C7, R24 and RV1 govern the duration of the other state. Because C7 has the same value as C6, and the combination of R24 and RV1 has about the same value as R23, the circuit is nearly symmetrical and the output, at the collector of VT5, is a rectangular wave. The overall period of the cycle of oscillation depends on the setting of RV1. When RV1 is correctly adjusted, the multivibrator oscillates through ten full cycles in the interval between the end of one line blanking period and the beginning of the next.

Linear Staircase Wave Generation

As well as being fed to VT1 as previously described, the mixed blanking input is also applied to the base of VT3. The circuit of VT3 functions in the same way as that of VT1. Accordingly, VT3 is cut off between blanking pulses, but it conducts fully when a blanking pulse is applied and then bottoms. As a result, the blanking pulses are reproduced, clipped and inverted, at VT3 collector (Waveform 2). These positive-going pulses are passed by C4 and R17 to the base of the npn transistor VT8.

The emitter of VT8 is fed from the negative 6·25-volt supply via the decoupling circuit con-

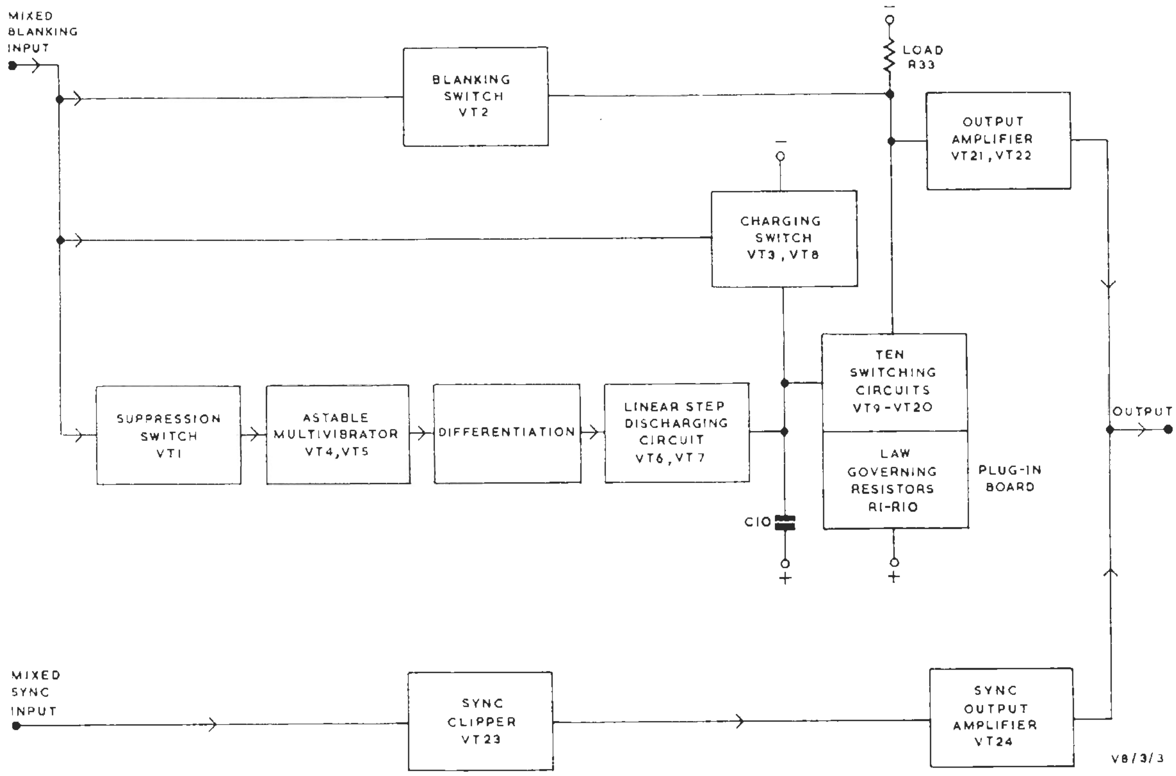


Fig. 3.3. GE4/509: Block Diagram

sisting of R19 and C11. The capacitor C10, in series with R20, is connected between the collector of VT8 and the positive 6·25-volt supply. During each blanking period, VT8 is switched on by the positive-going pulse at its base, and C10 charges to a voltage which is nearly the difference between the two supplies. Resistor R20 is connected between VT8 and C10 to prevent VT8 from passing excessive current when charging occurs. When the blanking period ends, VT8 becomes non-conducting, leaving C10 charged.

When the multivibrator including VT4 and VT5 becomes active, after a blanking period, the train of ten rectangular waves from VT5 collector is applied to C8, which is connected to the base of VT6. The values of C8 and resistor R26, which is between VT6 base and chassis, are such that differentiation occurs. VT6 is an npn transistor and only conducts during the positive-going pulses derived from the differentiation (Waveform 3). Corresponding negative-going pulses are produced at VT6 collector (Waveform 4) and are applied via R27 to the base of VT7.

The emitter circuit of VT7 consists of C9, shunted by RV2 and R29 in series, connected between the emitter and the positive 6·25-volt supply. The collector of VT7 is joined to the junction of C10 and R20. Thus VT7 and its emitter circuit are in parallel with C10. While C10 is being charged, during a blanking period, VT7 is not conducting, but when VT7 subsequently receives the first of the train of negative-going pulses from VT6 collector, VT7 passes current and C10 commences to share its charge with C9 through VT7. However, when C9 is charged to the state which causes the voltage at VT7 emitter to approach the voltage developed at VT7 base by the applied pulse, the current flow through VT7 is arrested until VT7 is cut off by the decay of the pulse. Then, C9 loses much of its charge through RV2 and R29 before the base of VT7 receives the next pulse. The action recurs with each of the train of pulses applied to VT7. Because C9 does not charge fully to the voltage across C10, and the capacitance of C9 is relatively small, C10 only loses a small fraction of its charge to C9 as a result of each pulse at VT7 base. Further, because each charging of C9 is limited to a voltage determined by the pulse voltage at VT7 base, C9 receives from C10 the same amount of charge with each pulse. As a result, the voltage across C10 drops in steps which are substantially the same with each pulse (Waveform 5); the base current drawn by VT9 from C10 has relatively little effect. Some control of the amplitude of the steps is provided by RV2, which governs the extent to which C9 approaches a state of complete discharge in the intervals when VT7 is not conducting. The first step is a little greater in amplitude than the rest because C9 is able to discharge to a greater extent in the preceding blanking period.

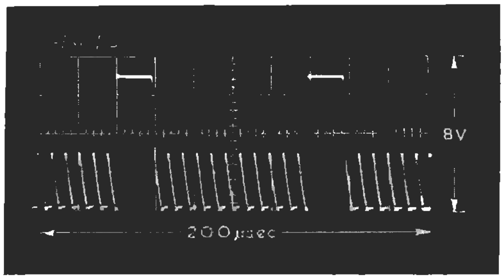
In practice, when RV1 is set so that the output of the generator is satisfactory and includes a tenth step having substantially the same duration as the others, it may be found that a train of eleven pulses is being produced at VT6 collector and that a brief eleventh step is generated at VT7 collector. Although this brief eleventh step is passed on and reaches the collector of VT10, it has no switching action in the pre-set law step generating circuits.

Pre-set Law Staircase Wave Generation

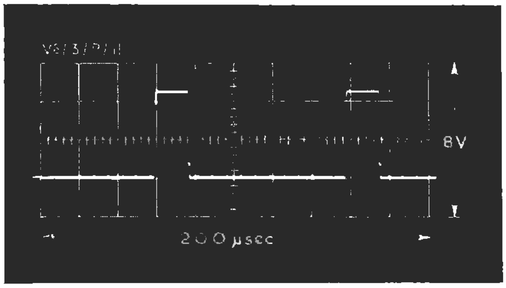
The base of VT9 is connected to the junction of R20 and VT8 collector. Thus, when VT8 is switched on, VT9 base receives the negative voltage applied to R20 for charging C10. Then, when VT8 is switched off and C10 is progressively discharged, VT9 base receives the positive-going linear staircase wave from C10 via R20 (Waveform 6). Acting as an emitter-follower, VT9 reproduces the staircase wave at its emitter.

The emitter of VT9 is fed from the positive 12·5-volt supply via R30, R31, RV3 and R34. The base of the npn transistor VT10 is connected to the junction of R30 and R31. The emitter of VT10 is connected to chassis (zero volts), and RV3 is normally set so that all the steps of the positive-going staircase wave at VT9 emitter cause VT10 to conduct and pass corresponding increments of current. In particular, RV3 permits adjustment of the operating conditions of VT10 at the start of the staircase wave. The linear staircase wave is reproduced in a negative-going form at the collector of VT10 (Waveform 7) and this wave is applied to the cathodes of the diodes MR8 to MR17.

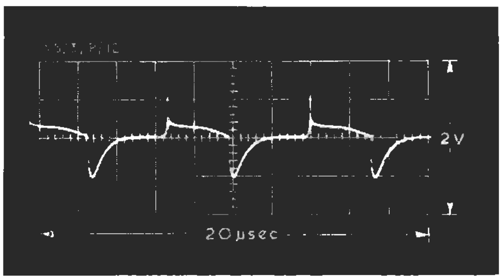
The anodes of MR8 to MR17 are connected to the emitters of VT11 to VT20 respectively. These emitters are fed individually from the positive 12·5-volt supply through resistors R10A, R9, R8, etc. to R1. (R10A may have a supplementary resistor, R10B, in parallel with it for reasons explained later.) The collectors of VT11 to VT20 are all connected to a common load, R33. The bases of VT11 to VT19 are fed from the junctions of resistors R35 to R44, which form a voltage dividing chain between chassis (zero volts) and the positive 6·25-volt supply, and the base of VT20 is fed from



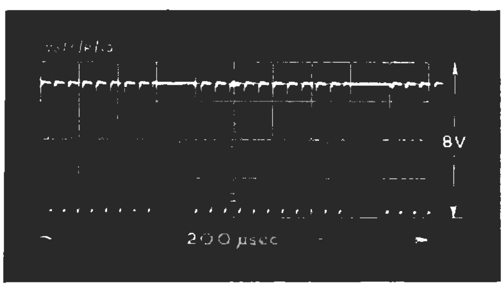
Waveform 1: VT1 Collector



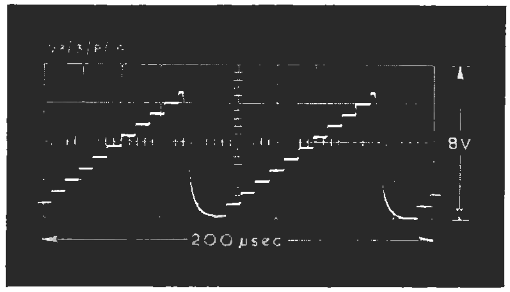
Waveform 2: VT3 Collector



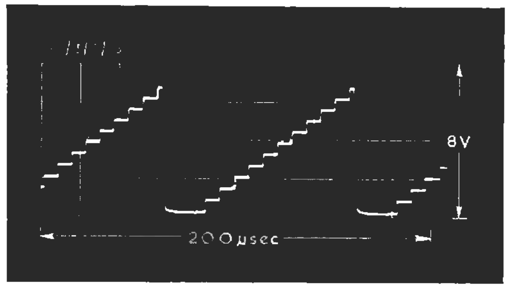
Waveform 3: VT6 Base



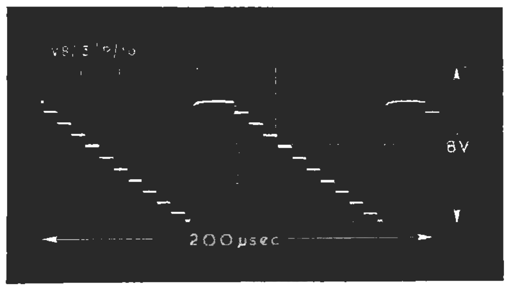
Waveform 4: VT6 Collector



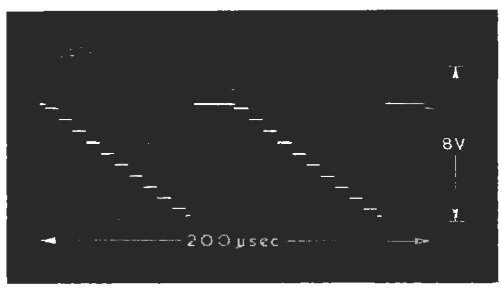
Waveform 5: VT7 Collector



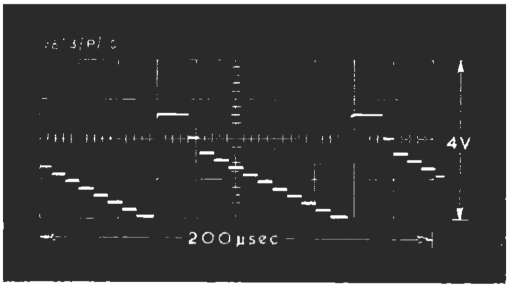
Waveform 6: VT9 Base



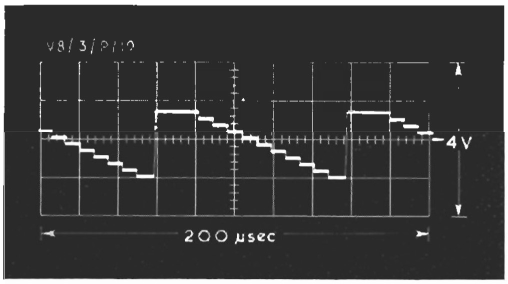
Waveform 7: VT10 Collector



Waveform 8: VT20 Emitter



Waveform 9: VT11 to VT20 Collectors



Waveform 10: VT22 Emitter

the positive end of the chain (+6·25 volts). During each blanking period, before the negative-going staircase wave develops at VT10 collector, MR8 to MR17 are all non-conducting because the voltage at their cathodes is more positive than the voltages at any of the emitters of VT11 to VT20. In this condition transistors VT11 to VT20 are all conducting and each one, behaving like an emitter-follower, draws sufficient current through its emitter resistor to make the emitter voltage almost the same as the voltage at the base. Because the resistors R36 to R44 are all equal in value, the base voltages, and therefore the emitter voltages, are progressively more positive in equal increments from VT11 to VT20. However, the currents drawn by the emitters of VT11 to VT20 are determined by the values of the emitter resistors R10 (A and B), R9, R8, etc. to R1.

Providing RV3 is correctly adjusted, when the first step occurs in the negative-going linear staircase wave at VT10 collector, the voltage at the cathodes of the diodes falls below the voltage which had been developing at VT20 emitter during blanking, and diode MR17 conducts. Consequently, the voltage at VT20 emitter (Waveform 8) is reduced to the step voltage applied to the diodes and VT20 is thereby switched off. When the second step is produced by VT10, the voltage at the diode cathodes falls below the voltage which had been developing at VT19 emitter, MR16 conducts, and VT19 is switched off. Similarly, providing RV2 is correctly adjusted, each negative-going step produced by VT10 cuts off another transistor, until the tenth step cuts off VT11. As a result, the currents flowing through the common collector load, R33, are progressively switched off and this causes the voltage at R33 to drop with a negative-going staircase waveform. The difference between the levels of any two adjacent steps is determined by the current previously flowing in the transistor switched off between those steps, and is governed by the emitter resistor of the transistor switched off. The level of any step relative to the base of the staircase waveform is determined by the sum of all the currents that have been switched off. For example, the difference in level between the second and third steps is determined by the current taken by VT18, as governed by R3, and the level of the third step relative to the base of the waveform is the result of the sum of the currents taken by VT20, VT19 and VT18.

Thus the law of the negative-going steps generated at the load R33 is governed by the values chosen for R1 to R10 (A and B). These resistors are mounted on a small printed-wiring board which plugs into a multi-way socket on the generator. A generator can be made to provide a staircase wave output with a particular law or arrangement of steps by inserting a board bearing resistors having appropriate values. In practice, the value chosen for R1 is less, and the current through VT20 is greater, than necessary to give the first step of the law at R33, because clipping is included in the action of the output amplifier and is adjusted (by RV5) to reduce the first step to the correct level. In calculating the values of the resistors required for a given law (as described later), a known small error in any step after the first is taken into consideration in calculating the resistance for the following step, but two parallel resistors (R10A and R10B) may be employed so that the last step can be set more accurately.

Blanking

The incoming mixed blanking signal, in addition to being applied to VT1 and VT3 as previously described, is also fed to the base of VT2. The circuit of VT2 functions in the same way as the circuits of VT1 and VT3. Each negative-going blanking pulse causes VT2 to switch from a non-conducting state to a fully-conducting state. Because VT2 emitter is connected to chassis (zero volts) and VT2 collector is connected directly to R33, the action of VT2 results in the addition of a positive-going pulse, corresponding to the blanking pulse, in advance of each complete negative-going staircase wave produced at R33. The first step of the staircase wave does not develop immediately the blanking ends, and so a short additional step is created preceding the ten-step staircase wave (Waveform 9). This step is eliminated by clipping in the output amplifier.

Output Amplifier

The staircase wave and blanking pulse produced at the load of the pre-set law step generating section, R33, is applied via C13 to the base of the output transistor VT22. The collector of VT22 is fed from the junction of R48 and R49, joined between the negative 6·25-volt supply and chassis. These two resistors are effectively in parallel forming an internal a.c. load across which the output signal develops, and the junction of the two resistors is connected directly to the output plug of the generator. The parallel value of the two resistors mainly determines the source impedance of the generator.

The emitter of VT22 is connected to chassis via R47 and RV4. These are not bypassed and the signal (Waveform 10) developing across them is fed to the base of VT21, which provides about 6 dB of negative feedback to the output stage. The amplitude of the output from VT22 collector is controlled by RV4.

Bias is applied to the base of VT22 from RV5. By adjustment of RV5, the more positive part of the wave from R33 is made to drive VT22 into cut-off. Normally RV5 is set so that this clipping action eliminates the blanking pulse and the post-blanking step from the waveform, and so that the level of the first step has the correct amplitude in the output waveform. (The value of R1 on the plug-in board is chosen to give the first step extra amplitude in preparation for this clipping.)

Addition of Sync Pulses

The incoming mixed sync pulses are applied to the base of the clipper VT23 via C17 and R52. Between sync pulses VT23 is cut off, but when a sync pulse tends to drive the base negative relative to the emitter, VT23 conducts fully and bottoms. R52 prevents excessive base current during sync pulses and causes the circuit to present a high impedance to the source of the sync input. Diode MR18 provides a reverse path in series with R52 for conducting away the charges acquired by C17 due to base current and prevents the development of positive bias. R53, in parallel with MR18, makes the circuit less sensitive to induced spurious signals, such as hum, if no source of sync signals is connected.

The positive-going pulses which are generated at the collector of VT23 are applied through a voltage-dividing network of resistors, including RV6, to the base of the sync pulse output transistor VT24. The collector of VT24 is connected to the junction of R48 and R49, which together form the internal load for the output signal as previously described. The control RV6 permits adjustment of the amplitude of the pulses applied to VT24; this is the means of setting the amplitude of the sync pulse component in the composite output of the generator.

Power Supply

The mains input is applied to the primary winding of transformer T1 via fuses FS1 and FS2. The transformer has two 12-volt secondary windings, which are connected in series. These feed the rectifier bridge consisting of MR1 to MR4. The rectified output from the bridge is smoothed by the reservoir capacitor C16 and is applied, via R11, to the Zener diodes ZD1, ZD2 and ZD3 in series. The junction of ZD1 and ZD2 is connected to chassis. Three stabilised d.c. supplies are provided by this arrangement: a supply of −6·25 volts relative to chassis from the junction of ZD1 and R11, a supply of +6·25 volts from the junction of ZD2 and ZD3, and a supply of +12·5 volts from the opposite side of ZD3. Smoothing capacitors C14 and C15 shunt ZD1 and ZD2 respectively.

Calculation of Values of Law-governing Resistors

General

In this generator, the method of producing a staircase waveform in which the steps follow a particular law or arrangement is one whereby currents proportional to the required level differences are diverted at regular time intervals from a common resistive load, R33. The sum of all the currents previously switched from this load at a particular time determines the total amplitude between the level at that time and the base of the staircase waveform. Thus the amplitude of the *n*th level is dependent on *n* different values of current. (In numbering the levels, the level commencing at the beginning of the first full-duration step period after blanking is regarded as the first level, and the level before this, which is always black level, can be called level nought.)

The currents are determined by fixed resistors R1 to R10, which are connected between pairs of points having effectively constant potential differences. The values of these voltages are given later. In general, therefore, the task is to find the currents required and from them the resistor values by Ohm's law.

Resistor Accuracy Requirements

It is possible to select from a number of ±10 per cent resistors a resistor to as near a required calculated value as thought desirable. However, this is not only difficult in practice but is in general unnecessary. If, instead, a choice is made of a ±2 per cent resistor having the nearest preferred value in the standard series for ±5 per cent resistors, the current resulting will usually be sufficiently accurate. It is specified that the accuracy of the generator shall be such that the maximum deviation of a level from its correct amplitude above black level will not exceed 2 per cent of the amplitude of white level. Therefore, providing the sum of the preceding steps is correct, an individual small step rise has a large tolerance. For example, a step rise of 10 per cent of white-level amplitude can be anywhere between 8 and 12 per cent to be within specification, which is a tolerance on the required resistor of ±20 per cent.

Cancellation of Errors

Choosing the nearest preferred value in the 5 per cent tolerance series involves small errors which, though not separately important, may, when ten such errors are added together, result in a deviation out of specification. It is therefore part of the procedure to calculate (using the nominal values of the resistors) the theoretical error for each level and choose the resistor value for the succeeding level to correct for it as closely as possible. Then, the only errors remaining are:

(a) the tenth level error modifying the total amplitude,
(b) those due to the ±2 per cent tolerance of the chosen resistors,
(c) slide rule errors, and
(d) other errors in the equipment.

That arising from (a) is dealt with in the manner described in the next subsection. Errors (b), (c) and (d) are estimated to result in less than ±1 per cent error in the accuracy of the generator as defined previously. For the generator to remain within specification therefore, the calculated error must be within ±1 per cent, making an overall possible error of ±2 per cent.

Tenth Level Error

It is necessary that the last step rise is set to greater accuracy so that the tenth level has the prescribed amplitude and the other levels have the intended accuracy. For this purpose, provision is made for two resistors, R10A and R10B, to be connected in parallel for the last step rise.

First Level Amplitude

The amplitude of the first level is not decided entirely by the fixed resistor R1, but is also set by means of the pre-set variable resistor RV5, which governs the level at which the staircase waveform is clipped at the bottom. This control requires adjustment on change of law whenever the mean d.c. content of the waveform is altered. Since the clipping is done on a non-linear characteristic, it is found necessary to provide a step of sufficient amplitude to permit a clean cut. The first level is therefore initially made greater in amplitude than its theoretically required value.

Calculation Procedure

It is advisable to tabulate all the relevant figures when calculating the resistor values required to obtain a particular law or series of steps. The procedure is as follows:

1. Number the levels 1 to 10, in order of time. Each level number will then correspond to the reference number of the resistor producing the step rise to that level.
2. Write down the required amplitude of each step level relative to black level, expressing each amplitude as a percentage of white level (the tenth level).
3. Enter the amount by which the amplitude of each level exceeds the amplitude of the preceding level.
4. Divide each level difference by ten. The figures obtained are the increments of current in mA required to produce the step rises. (The total of these current increments should be 10 mA.)
5. Write down the voltages available to produce the required incremental currents. These are: 6·00, 6·57, 7·14, 7·71, 8·29, 8·86, 9·43, 10·00, 10·57 and 11·14 volts for R1 to R10 (A and B) respectively.

6. Add 0·5 mA to the incremental current required for the first step. (This is the extra current approximately required to make the first step rise excessive in preparation for clipping.) Divide 6·00 volts by the sum of the two currents. Choose the preferred value of resistance nearest to the quotient. This is the value that resistor R1 must have.
7. Divide 6·57 volts by the incremental current required for the second step rise. Choose the preferred resistance value nearest to the quotient. This is the value that R2 must have. Find the incremental current produced when R2 has the chosen preferred value and the potential difference of 6·57 volts is developing across it. Add this current to the current required for the first step rise, excluding the extra 0·5 mA, and so find the total current effectively produced. Compare this with the nominal total current required, which is the sum of the nominal incremental currents required for the first and second steps, and note the error current caused by employing the preferred value instead of the exact value of resistance calculated. Mark the error current positive or negative depending on whether the current produced exceeds or is less than the current required.
8. Subtract the error current (with the due regard to sign) of the second level from the nominal incremental current required for the third step rise; this gives the actual incremental current required for the third step rise. Divide 7·14 volts by the actual incremental current required. Choose the preferred resistance value nearest to the quotient. This is the value that R3 must have. Find the incremental current produced when R3 has the chosen preferred value and the potential difference of 7·14 volts is developing across it. Add this current to the total current produced for the previous level (as entered) and compare the sum with the nominal total current required for the third level. Note the error current as before.
9. Repeat operation 8 to find the resistor values for the fourth to ninth levels, employing the appropriate voltages.
10. To find the value that R10A must have for the tenth step rise, divide 11·14 volts by the actual incremental current required and choose the preferred resistance value nearest to the quotient. However, if it is found that a resistor of this value will give a positive error current exceeding 0·02 mA, choose instead the next greater preferred value so that the error current is negative. When a negative error current exceeding 0·02 mA is obtained from the choice of value for R10A, a supplementary resistor, R10B, is needed in parallel with R10A. Accordingly, divide 11·14 volts by the error current and choose the preferred resistance value nearest to the quotient. This is the value that R10B must have. The remaining error current will be negligible.

If two or more steps are required at the same amplitude (i.e., with no step rise between levels), carry over any error current in the first of these steps to the first following step that has a rise. Similarly, if the first level, or levels, are to be zero, add the extra 0·5 mA, normally supplementing the first step, instead to the current required for the first non-zero step.

The output staircase waveform will have the required levels within the specified accuracy of the generator providing none of the calculated error currents exceeds 0·1 mA.

Example of Calculation

Table 1 shows the data given and derived in calculating the resistor values for a particular series of steps.

Rows 1, 2, 3, 4, 6 and 10 are completed from information given. Row 1 contains the level numbers, which are also the resistor circuit reference numbers. Row 2 contains the levels required. The differences between the levels are entered in row 3. The level differences divided by ten, giving the nominal incremental currents required in mA, are entered in row 4. The voltages available to produce the increments of current are contained in row 6. The nominal total currents required are entered in row 10.

In the first column of figures, dealing with level 1, the actual incremental current required, entered in row 5, is the same as the nominal incremental current required, 1·0 mA, because there is no error current of a previous step to be subtracted, but for the purpose of finding the resistor value, 0·5 mA is added as explained previously. From the resultant current, 1·5 mA, and the voltage in the sixth row, 6·00 volts, a resistance value of 4 kilohms is obtained, and therefore the nearest preferred value, 3·9 kilohms, is entered in row 7. Although the true incremental current produced is 1·54 mA (i.e., 6·00/3·9 mA), a current of 1·0 mA is shown in rows 8 and 9 because the first-step

TABLE 1

Row 1	Level No. and R No.	1	2	3	4	5	6	7	8	9	10A	10B
2	Law (Per Cent of White Level)	10	21·5	35	50	63	75	84	89	92	100	100
3	Step Rise (Per Cent of White Level)	10	11·5	13·5	15	13	12	9	5	3	8	
4	Nominal Incremental Current Required (mA)	1·0	1·15	1·35	1·5	1·3	1·2	0·9	0·5	0·3	0·8	
5	Actual Incremental Current Required (mA)	1·0 (+0·5)	1·15	1·33	1·56	1·35	1·21	0·93	0·49	0·29	0·80	0·06
6	Voltage	6·00	6·57	7·14	7·71	8·29	8·86	9·43	10·00	10·57	11·14	11·14
7	Resistance Chosen (kΩ)	3·9	5·6	5·6	5·1	6·2	7·5	10	20	36	15	180
8	Incremental Current Produced (mA)	1·0 (+0·54)	1·17	1·27	1·51	1·34	1·18	0·94	0·50	0·29	0·74	0·06
9	Total Current Produced (mA)	1·0 (+0·54)	2·17	3·44	4·95	6·29	7·47	8·41	8·91	9·20	9·94	10·0
10	Nominal Total Current Required (mA)	1·0	2·15	3·5	5·0	6·3	7·5	8·4	8·9	9·2	10·0	10·0
11	Error Current (mA)	0	+0·02	−0·06	−0·05	−0·01	−0·03	+0·01	+0·01	0	−0·06	0

clipping is adjusted to give a level that would result from 1·0 mA, and no error current is entered in row 11.

In the second column, dealing with level 2, no error current is applied from column 1 to modify the nominal incremental current required, 1·15 mA, and therefore this current is also entered as the actual incremental current required in row 5. From this 1·15 mA and the voltage in the sixth row, 6·57 volts, a resistance value of 5·72 kilohms is obtained, and therefore the nearest preferred value, 5·6 kilohms, is entered in row 7. The incremental current produced is accordingly 1·17 mA (i.e., 6·57/5·6 mA), which is entered in row 8. The sum of this current and the 1·0 mA which is the previous total current effectively produced makes a total of 2·17 mA for level 2, which is entered in row 9. Because the nominal total current for R10A is the next preferred value *above* the resistance obtained from the actual incremental current required, 0·80 mA, and the voltage in the sixth row, 11·14 volts. This resistance alone would result in the error current of −0·06 mA entered in row 11. The nearest preferred value to the resistance which would pass 0·06 mA is 180 kilohms, and this is entered as the value chosen for the supplementary resistor R10B.

The resistor values to be used to obtain the required output staircase wave are accordingly those entered in row 7.

Resistor Values for Laws $y = x^{0·4}$ and $y = x^{2·5}$

The levels and resistor values (±2 per cent tolerance) for these commonly-encountered laws are shown in Table 2. The tenth level does not require two resistors in either instance.

TABLE 2

Level No. and R No.		1	2	3	4	5	6	7	8	9	10
Law: $y = x^{0·4}$	Level (Per Cent of White Level)	39·8	52·5	61·8	69·3	75·8	81·5	86·7	91·5	95·9	100
	Resistance (kΩ)	1·3	5·1	8·2	10	12	16	18	20	24	27
Law: $y = x^{2·5}$	Level (Per Cent of White Level)	0·3	1·8	4·9	10·1	17·7	27·9	41·0	57·2	76·8	100
	Resistance (kΩ)	10	43	22	15	11	8·2	7·5	6·2	5·6	4·7

is 2·15 mA, as shown in row 10, an error current of +0·02 mA is recorded in row 11.

In the third column, dealing with level 3, after subtracting (with due regard to sign) the level-2 error current, +0·02 mA, from the nominal incremental current required, 1·35 mA, the current left is 1·33 mA, and this is entered in row 5 as the actual incremental current required. The other values found for the third level result from using the same procedure as for the second level.

The values found for levels 4 to 10 are derived similarly. However, the value 15 kilohms entered

Resistor Values for Linear Law

Because a particularly high degree of accuracy in the step levels is desirable when the generator is used to provide a linear staircase waveform, the resistors fitted on the linear-law plug-in board that is normally supplied with each generator are specially ordered and have resistance values intended to produce 10 per cent step rises exactly. Since this requires that 1-mA incremental currents shall be passed, the resistors have values in kilohms corresponding to the step-producing voltages, as shown in Table 3. The tolerance of these resistors is ±1 per cent. An exception is R1; this has a

TABLE 3

Level No. and R No.	1	2	3	4	5	6	7	8	9	10
Resistance (kΩ)	3·9	6·57	7·14	7·71	8·29	8·86	9·43	10·0	10·57	11·14

preferred value and a tolerance of ±2 per cent because the amplitude of the first level is initially made too great and is finally set by RV5.

Setting-up Procedures*

Apparatus Required

Tektronix Oscilloscope type 515 or 545.

Supplies of mixed sync and mixed blanking pulses, each providing 2 volts peak-to-peak amplitude across 75 ohms. (Line standards to be those on which the generator will be operated.)

Cable Termination Block type PN3A/2 made up for use with the GE4/509, including Musa plugs fitted (in place of lead-through adaptors) and connected to form an outlet for the generator signal, an inlet for the mixed sync pulses, and an inlet for the mixed blanking pulses, and also additional plugs in parallel with each of the two inlets to permit loading.

Two 75-ohm Musa socket terminations.

One 75-ohm Series 83 (F. & E. type) plug termination.

One Series 83 coaxial T-junction adaptor.

Full Adjustment Procedure

1. Insert a linear-law plug-in board in the generator and set all the generator controls anticlockwise.
2. Plug the generator into the termination block and apply the mains to the generator, via the block.
3. Feed mixed sync and mixed blanking signals to the generator via the appropriate plugs on the termination block. Load these inputs with 75-ohm terminations using the parallel plugs on the block.
4. Apply the output of the generator to the oscilloscope. Use the T-junction adaptor on the oscilloscope inlet and fit the 75-ohm Series 83 termination to the free arm of the junction so that the output of the generator is simultaneously loaded by 75 ohms.
5. Set the oscilloscope to display the output waveform of the generator over a line period.
6. Adjust RV6 to make the displayed sync pulse amplitude 0·3 volt.
7. Turn RV5 clockwise until a step rise corresponding to the trailing edge of line blanking is seen. This can be identified by the short duration of the following step level, which should be about half the duration of the other succeeding step levels.
8. Turn RV4 clockwise to obtain a staircase wave amplitude of about 0·7 volt above the sync pulses. At this stage the staircase wave should consist of a set of steps which is only roughly linear. The steps should be of equal duration and number less than ten (excluding the first step which is of shorter duration). Successive steps may have the same level.
9. Turn RV1 clockwise until the number of equal-duration steps is increased to ten.
10. Readjust RV5 to raise the beginning of the staircase wave about 0·3 volt above the sync pulses.
11. Turn RV3 clockwise until the first full-duration step level is in line with the post-blanking short-duration step level. Then turn RV3 anticlockwise to the first position where the full-duration step is above the short-duration one and is 'clean' (i.e., not blurred by hum).
12. Turn RV2 clockwise to make all the step rises equal in amplitude, except the rise preceding the first full-duration step level, which should be about 50 per cent greater than the others. Set RV2 so that all the step rises and levels are clean.
    Note:—The controls RV3 and RV2 will be found to cover ranges over which the step rises and levels are clean. Settings at the centres of these ranges should be used.
13. Turn RV5 anticlockwise until the post-blanking short-duration step is completely eliminated, and adjust RV5 so that the step rise preceding

*Derived from Designs Department Technical Memorandum No. 8.115(62) and Specification No. 8.56(62).

the first full-duration level has the same height as the other step rises.

14. Readjust RV4 to make the amplitude of the staircase wave, from the post-sync nought level (black level) to the tenth level (white level), 0·7 volt. The generator is now set up for a linear-law output.
15. To obtain an output having a non-linear series of steps, replace the linear-law plug-in board by a board bearing the appropriate resistors and readjust RV5 so that the first step rise has the required amplitude. If the new series of steps produces a large or small mean amplitude relative to that of the linear-law waveform, it may be necessary to retrim RV2 and RV3; see operations 11 and 12.

The full procedure can be carried out with a non-linear-law board inserted providing that some familiarity with the generator has been gained. If this is done, in operation 13 control RV5 must be set so that the first step rise has the required amplitude relative to the overall height of the staircase wave.

Maintenance Adjustments

If the generator has been set up once but requires trimming, it is sufficient to repeat operations 11, 12, 13 and 14 of the full procedure just described, providing that, when the steps are non-linear, RV5 must be set (in operation 13) so that the first step rise has the required amplitude relative to the overall amplitude of the staircase wave. Operation 11 can be abbreviated with experience.

Change of Law

When the plug-in board is replaced by another which produces a different series of steps, it may be sufficient to readjust RV5 so that the first step rise has the required amplitude. However, if the mean amplitude of the waveform is much changed, it may be necessary to trim RV2 to RV5 as described under *Maintenance Adjustments*.

Change of Line Standards

By employment of the full setting-up procedure, the generator is adjusted for the line standards of the input pulses used. When the line standards of the input pulses are changed, particularly between 405-line standards and either 625-line or 525-line standards, control RV1 must be readjusted to obtain ten steps in the output. It may also be necessary to trim RV2 to RV5 as described under *Maintenance Adjustments*.

Operation Without Sync Pulses

If sync pulses are not required in the output waveform, the generator will function normally in other respects if the sync pulses are removed by disconnection of the sync signal input.

Semiconductor Electrode Voltages

Table 4 shows a representative set of voltages, relative to chassis, measured on a generator in correct working condition and operating on 405-line standards. The measurements were made on an Avometer 8 switched to its 10-volt d.c. range. The voltages developed by the supply line Zener diodes were 6·7, 6·3 and 6·5 volts across ZD1, ZD2 and ZD3 respectively.

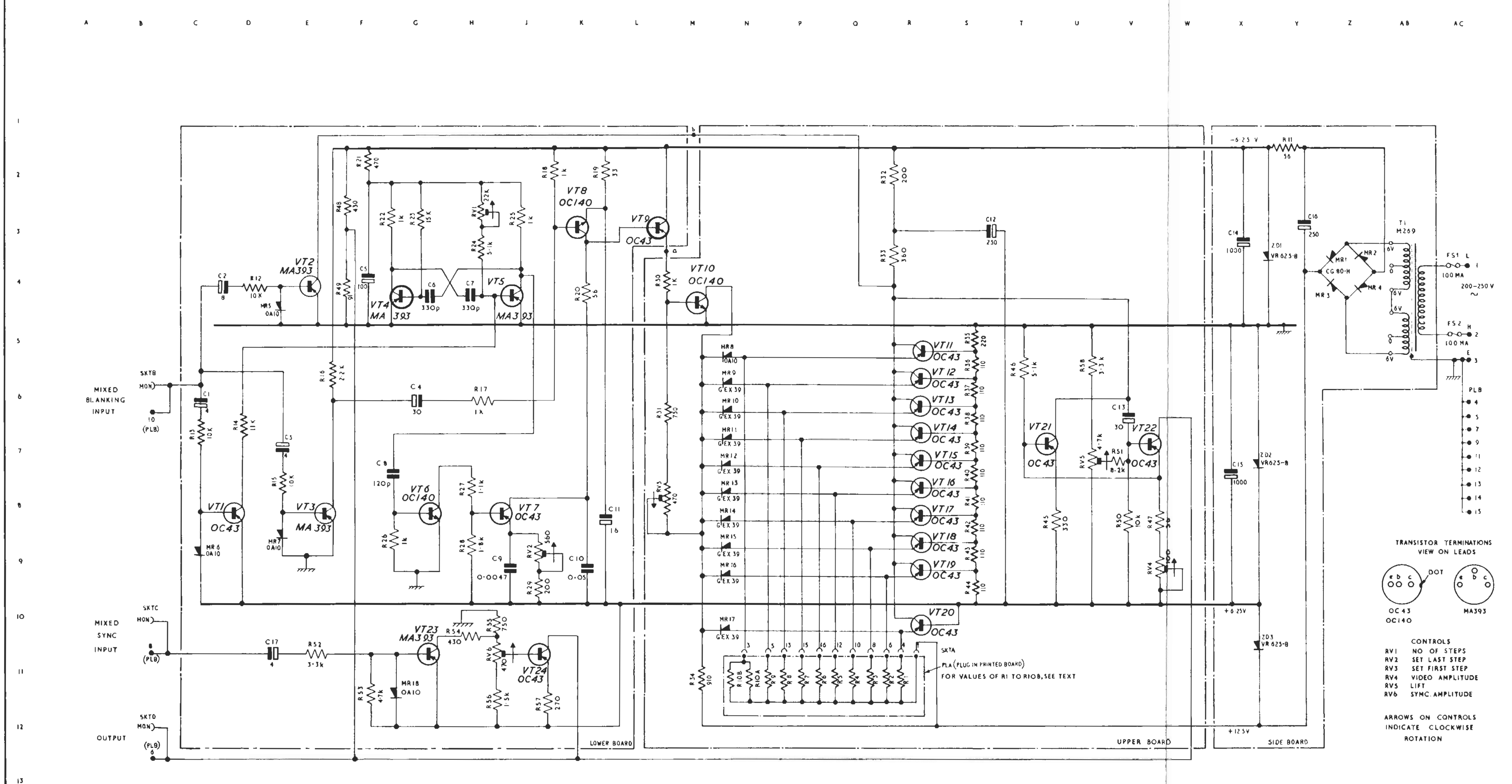
TABLE 4

Transistor	*Collector*	*Base*	*Emitter*
VT1	+2·0		
VT2	−1·5		
VT3	−3·7		
VT4	−1·2		
VT5	—2·7		
VT6	+5·2		
VT7	−3·7	+5·6	+5·1
VT8	−3·9	−7·2	−6·6
VT9	−6·7	−3·9	−3·7
VT10	+4·0	+0·1	
VT11	−1·5	+1·1	+1·2
VT12	−1·5	+1·7	+1·8
VT13	−1·5	+2·3	+2·3
VT14	−1·5	+2·8	+2·7
VT15	−1·5	+3·4	+3·1
VT16	−1·5	+4·0	+3·4
VT17	−1·5	+4·6	+3·7
VT18	−1·5	+5·2	+4·0
VT19	−1·5	+5·7	+4·2
VT20	−1·5	+6·3	+4·5
VT21	−1·5	+5·5	+5·6
VT22	+0·2	+5·5	+5·5
VT23	+2·2	+6·3	+6·3
VT24	+0·2	+2·5	+2·7

COMPONENT TABLE : FIG. 3

Comp.	Loc.	Type	Tolerance per cent	Comp.	Loc.	Type	Tolerance per cent
C1	C6	U.C.C. SM56S 12V		R24	H3	Erie 109 0·25W	2
C2	C4	U.C.C. SM42S 6V		R25	J3	Erie 109 0·25W	2
C3	D7	U.C.C. SM56S 12V		R26	F9	Erie 109 0·25W	2
C4	G6	U.C.C. SM65S 12V		R27	H8	Erie 109 0·25W	2
C5	F4	U.C.C. SC541/8LS 6V		R28	H9	Erie 109 0·25W	2
C6	G4	T.C.C. CSM20N 350V		R29	J10	Erie 109 0·25W	2
C7	H4	T.C.C. CSM20N 350V		R30	L4	Erie 109 0·25W	2
C8	F7	T.C.C. CSM20N 350V		R31	L7	Erie 109 0·25W	2
C9	H9	T.C.C. SM3N 350V		R32	R2	Erie 109 0·25W	2
C10	K9	T.C.C. CP35N/PVC 350V		R33	R4	Erie 109 0·25W	2
C11	K8	U.C.C. SM90S 25V		R34	M11	Erie 109 0·25W	2
C12	S3	U.C.C. SC584/6LS 12V		R35	S5	Erie 109 0·25W	2
C13	V6	U.C.C. SM65S 12V		R36	S6	Erie 109 0·25W	2
C14	X3	U.C.C. SC603/6LS 12V		R37	S6	Erie 109 0·25W	2
C15	X7	U.C.C. SC603/6LS 12V		R38	S7	Erie 109 0·25W	2
C16	Y3	Hunt MEF45T 50V		R39	S7	Erie 109 0·25W	2
C17	D11	U.C.C. SM56S 12V		R40	S8	Erie 109 0·25W	2
				R41	S8	Erie 109 0·25W	2
				R42	S9	Erie 109 0·25W	2
FS1	AC3	Belling Lee L562/0·100		R43	S9	Erie 109 0·25W	2
FS2	AC5	Belling Lee L562/0·100		R44	S10	Erie 109 0·25W	2
				R45	U9	Erie 109 0·25W	2
				R46	T6	Erie 109 0·25W	2
R1	R11	Erie 109	2	R47	W8	Erie 109 0·25W	2
R2	R11	Erie 109	see text	R48	F3	Erie 109 0·25W	2
R3	Q11	Erie 109	see text	R49	F4	Erie 109 0·25W	2
R4	Q11	Erie 109	see text	R50	V8	Erie 109 0·25W	2
R5	Q11	Erie 109	see text	R51	V7	Erie 109 0·25W	2
R6	P11	Erie 109	see text	R52	E11	Erie 109 0·25W	2
R7	P11	Erie 109	see text	R53	F11	Erie 109 0·25W	2
R8	P11	Erie 109	see text	R54	H11	Erie 109 0·25W	2
R9	N11	Erie 109	see text	R55	H10	Erie 109 0·25W	2
R10A	N11	Erie 109	see text	R56	H12	Erie 109 0·25W	2
R10B	N11	Erie 109	2	R57	J12	Erie 109 0·25W	2
R11	Y2	Painton P301A	5	R58	U6	Erie 109 0·25W	2
R12	D4	Erie 109 0·25W	2				
R13	C7	Erie 109 0·25W	2				
R14	D7	Erie 109 0·25W	2	RV1	H3	Plessey 404/1/00142/223	
R15	E8	Erie 109 0·25W	2	RV2	J9	Plessey 404/1/00142/561	
R16	E5	Erie 109 0·25W	2	RV3	M8	Plessey 404/1/00142/471	
R17	H6	Erie 109 0·25W	2	RV4	W9	Plessey 404/1/00142/101	
R18	J2	Erie 109 0·25W	2	RV5	U8	Plessey 404/1/00142/472	
R19	K2	Erie 109 0·25W	2	RV6	H11	Plessey 404/1/00142/471	
R20	K4	Erie 109 0·25W	2				
R21	F2	Erie 109 0·25W	2				
R22	F3	Erie 109 0·25W	2	T1	AB4	M269	
R23	G3	Erie 109 0·25W	2				

FIG 3



PRE-SET LAW TEST STEP GENERATOR GE4/509 : CIRCUIT