OPERATION MANUAL

FOR

MODEL 461 SWEEP GENERATOR

KIKUSUI ELECTRONICS CORP.

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1. GENERAL

Kikusui Electronics' Model 461 is an electronic sweep generator having a variable frequency range within 20Hz to 20 kHz (1000 times), allowing sine wave, triangular wave and square wave to be optionally selected.

The frequency of the output signal can be controlled not only by turning the dial manually, but by applying an external signal. Therefore, Model 461 can be used as a voltage control generator.

Model 461 provides two types of functional relationships between a control voltage applied and resultant oscillation frequency; that is, in one case, the control voltage is in linear proportion to the oscillation frequency, and in the other case, the logarithm of the oscillation frequency is proportional to the control voltage.

The repetition period of the sweep generator can be varied continuously within a range of 0.01 to 100 sec. The upper and lower limits in a sweep range can be optionally set within 20Hz to 20kHz to obtain the desired sweep width.

Considering the automation of frequency measurement, Model 461 is provided with time base output terminals for connecting an oscilloscope or X-Y recorder on the rear panel.

As described above, Model 461 can be widely applied to many types of measurements and tests such as frequency response test of audio amplifiers, filter characteristic measurement, FM signal source test or sound/vibration test as a voltage control generator, sweep generator or function generator as well as an ordinary generator.

2. SPECIFICATIONS

Oscillation mode	1. Manual frequency variation: Dial used. 2. VCG: Frequency control by means of external voltage; logarithmic and linear 3. Sweep by means of built-in time base; logarithmic and linear
Frequency range	Within 20 Hz to 20 kHz
Dial scale	20 Hz to 20 kHz; divided in nearly nearly geometric ratio
Accuracy	5% + 5 Hz
Frequency stability	Within ±0.5% against ±10% fluctuation of power voltage
Output waveform	Sine wave, triangular wave, square wave
Maximum open output voltage	More than 20 Vp-p
Output impedance	600 ±20%
Amplitude stability	Within ±0.5% against ±10% fluctuation of power voltage
Frequency characteristics	Within ±0.3 dB at 1 kHz

Distortion factor	Less than 2 % within 20 Hz to 50 Hz
	Less than 1 % within 50 Hz to 20 kHz
Controllable frequency range	20 Hz to 20 kHz
Control voltage	Approx. +10 mV to +10 V
Input frequency range	DC to 2 kHz
Repetition period of time base	0.01 sec to 100 sec
Ranges	0.01 to 0.1 sec, 0.1 to 1 sec, 1 to 10 sec, 10 to 100 sec
Accuracy	3 %
Sweep range	20 Hz to 20 kHz
Sync output	More than -10 Vpeak
Pulse width	Less than 5 μsec
Sweep sync output	More than -10 Vpeak
Pulse width	Less than 5 μsec
Time base output	10 Vpeak
Waveform	Sawtooth wave
Power requirement	100 V, 50/60 Hz, approx. VA

Dimensions	200(W) x 140(H) x 390(D)mm	
(Maximum dimensions)	200(W) x 155(H) x 450(D)mm	
Weight	Approx. 5.1 kg	
Accessories	Operation manual	1
	Type 941B terminal adapter	1

3. OPERATION

3.1 Parts on front panel (Fig. 3-1)

1. POWER

Power pushbutton switch. When pushed and locked, power is switched on, and the pilot lamp lights up simultaneously, indicating a ready state. When high accuracy is needed for frequency to be generated, a warm-up of more than 30 minutes should be allowed because Model 461 uses an oven for stabilizing transistors.

2. MODE

Switch for selecting frequency variation mode. VCG (LOG, LINEAR), DIAL and SWEEP (LOG, LINEAR) positions can be selected as appropriate.

G

VCG LOG LINEAR

When the MODE switch is set to LOG, the logarithm of the oscillation frequency is proportional to the input voltage applied; in LINEAR, the two are proportional to each other. The oscillation frequency, therefore, can be controlled by external voltage applied.

DIAL	When the frequency is controlled by the dial, this position should be set.
SWEEP LOG LINEAR	When Model 461 is used as a sweep generator, these positions should be selected. In LOG, the logarithm of the oscillation frequency is proportional to time; in LINEAR, the frequency to time.
3. VCG INPUT	VCG input terminal used when the oscillation frequency is controlled by an external voltage. When the input voltage increases from +10mV to +10V, the oscillation frequency increases up to 1000 times.
4. DIAL	Dial for varying oscillation frequency continuously. Clockwise turning increases the frequency. When the MODE switch is set to VCG, the dial is disconnected from the control circuit. In the SWEEP positions, this is used as a dial for setting the lowest frequency of a sweep bandwidth.
5. FUNCTION	Knob for selecting output waveform.

It selects sine wave (∼), triangular wave (/\/) or square wave (⊓⊔).

6. OUTPUT

Knob for controlling output voltage. Clockwise turning increases the output voltage. With no load, more than 20 Vp-p is obtained; when the output terminal is terminated with 600 Ω, more than 10 Vp-p. A UHF type receptacle located below this knob is the knob is the output terminal. The other metal terminal is connected to the circumference of the receptacle electrically. This metal terminal is in a DC-floating state from the cabinet.

7. SWEEP TIME

Knob for setting sweep repetition period.

8. VARIABLE

Knob for continuously varying repetition period within a range set by the SWEEP TIME knob(7).

9. SWEEP WIDTH

Knob for setting sweep width. The highest frequency in a sweep width is obtained by multiplying a dial frequency by a constant on this scale. Then, with SWEEP LOG, the outer scale is used; with SWEEP LINEAR, the inner scale is applied.

10. UPPER FREQ CHECK When this switch is pushed and locked, sweeping stops at the upper limit of the sweep width. Thus, when a frequency counter is connected to Model 461, the highest frequency of this sweep width can be easily calibrated with this button pushed.

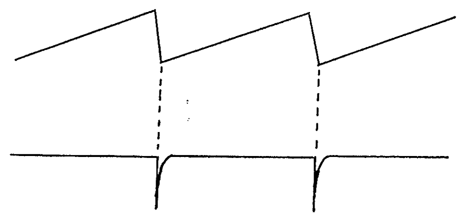
3.2 Parts on rear panel (Fig. 3-2)

11. TIME BASE OUTPUT When the MODE switch is set to SWEEP, a sawtooth wave synchronized with the period set by the SWEEP TIME switch is obtained at this output terminal. This terminal is used for connecting an oscilloscope or X-Y recorder to measure a frequency response.

12. SWEEP SYNC OUTPUT Pulses synchronized with the sweep repetition period (0.01 to 100 sec) are obtained at this terminal. These pulses can be used as an external trigger signal for an oscilloscope.

TIME BASE

Sync pulse



13. SYNC OUTPUT

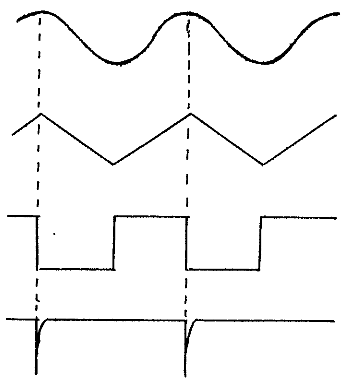
The sync pulses obtained at this terminal synchronize with the positive peak of the sine wave or triangular wave or the fall of the square wave, which are taken out at the OUTPUT terminal.

Sine wave

Triangular wave

Square wave

Sync pulse



14. FUSE — Used for AC power line. 0.5 A rated

15. Power cord — Connected to 100 V AC, 50/60 Hz.

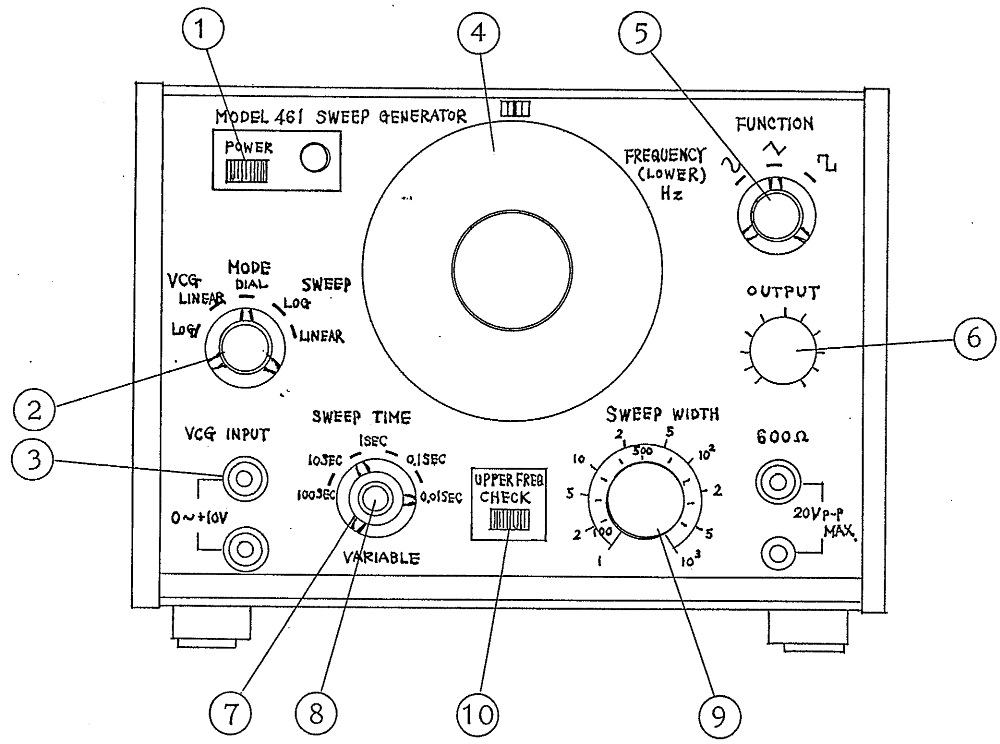


Fig. 3-1 Front panel

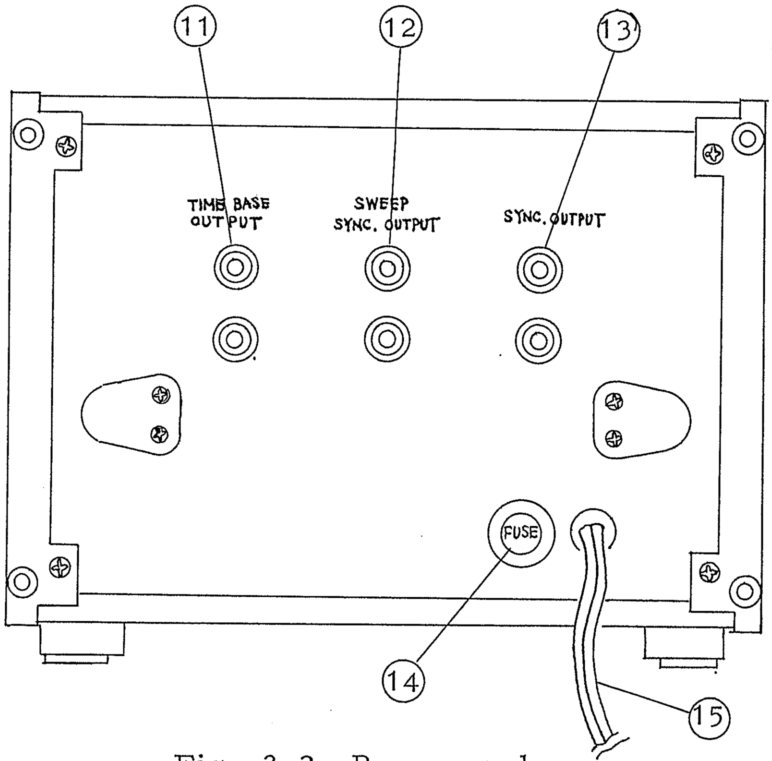


Fig. 3-2 Rear panel

3.3 Application

Model 461 has a wide range of applications.

The following are a few fundamental examples.

Example (1) Logarithmic sweeping within 200 Hz to 20 kHz during a repetition period of 1 sec :

1. Set the MODE switch to SWEEP LOG.
2. Turn the SWEEP TIME switch to the 1-10 sec position and turn the VARIABLE knob fully clockwise.
3. Set the FREQ (LOWER) dial to 200 Hz.
4. Set the SWEEP WIDTH knob to 10^2 on the outer scale ($20\,kHz/200\,Hz = 10^2$).
5. To set the upper and lower limits of the sweep range to accurate frequencies, connect a frequency counter to the output terminal of Model 461. First, change over the MODE switch to DIAL, and set the FREQ (LOWER) dial to the lower limit frequency. Next, lock the UPPER FREQ CHECK switch and calibrate the upper limit frequency while monitoring the frequency counter.

Example (2). With sweep signal within 5 kHz to 10 kHz curing a repetition period of 0.1 sec, display of frequency response of amplifier on external oscilloscope (whose horizontal axis is used as a frequency axis):

1. Set the MODE switch, SWEEP TIME knob, FREQ (LOWER) dial and SWEEP WIDTH knob as in example(1).
2. Connect Model 461, the oscilloscope and the amplifier to be measured as shown in Fig. 3-3.
3. Set the vertical sensitivity range of the oscilloscope according to the output voltage level of the amplifier and set the horizontal axis to the external input terminal. Since the output voltage at the TIME BASE OUTPUT terminal is 0 to +10 V, adjust the horizontal sensitivity of the oscilloscope so that the desired trace is obtained on the CRT screen.

   When the sensitivity of the oscilloscope is set to 2 V/cm, a trace of 5 cm is obtained.

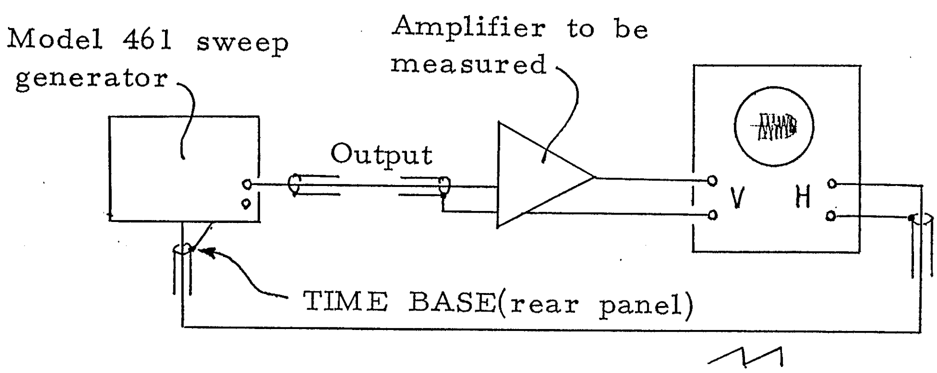


Fig. 3-3

4. If the amplifier has such a response that the amplitude at 10 kHz is reduced 6 dB with respect to that at 5 kHz, the amplitude at 10 kHz of the waveform displayed will be approximately one half that at 5 kHz as shown in Fig. 3-4.

5. When the MODE switch of the sweep generator is set to LOG, the frequency varies logarithmically within 5 kHz to 10 kHz; when set to LINEAR, the frequency varies linearly.

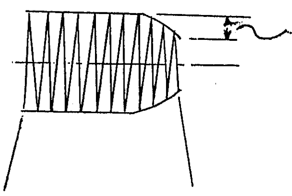


Fig. 3-4

Example (3) To control oscillation frequency within 1 kHz to 10 kHz by means of external voltage:

1. Change over the MODE switch to VCG LOG or VCG LINEAR. Charts 1 and 2 attached at the end show the relationship between the oscillation frequency and control voltage in the VCG LOG and LINEAR modes.

2. The VCG LOG mode uses voltage within 0 to +10 V to control oscillation frequencies within 20 Hz to

20 kHz; the VCG LINEAR mode uses control voltages within +10mV to +10V or oscillation frequencies within 20Hz to 20 kHz. Also, the impedance of the power source which supplied the control voltage should be less than 10 kΩ.

3. Fig. 3-5 shows such typical connections.

4. If the control voltage in an AC voltage, connect a regulated DC source in series with the control voltage source in order to prevent the control voltage input terminal from being brought to negative potential.

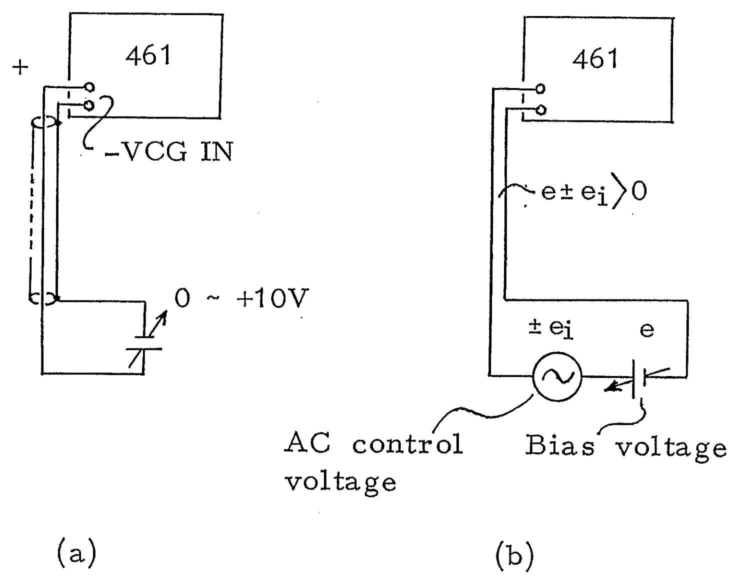


Fig. 3-5

5. Since the desired oscillation frequencies in this example are within 1 kHz to 10 kHz, the control voltages corresponding to the upper and lower limit frequencies are found, referring to Charts 1 and 2, as follows;

LOG:	1 kHz	Approx.	5.65 V
	10 kHz	"	9.0 V
LINEAR:	1 kHz	500 mV	
	10 kHz	5.0 V	

6. When higher accuracy is needed, calibrate the oscillation frequency and control voltage with the frequency counter and a digital voltmeter respectively.

4. OPERATION PRINCIPLE

4.1 Composition

As shown in Fig. 4-1, Model 461 comprises an impedance converter, two adders, an inverse-logarithm converter, a time base oscillator, a voltage control generator, a sine wave composer and an output amplifier.

Fundamental operation modes such as VCG (LOG, LINEAR), DIAL and SWEEP (LOG, LINEAR) are obtained by operating the MODE switch.

o VCG LOG In this position, Model 461 generates a signal with a frequency whose logarithm is proportional to the voltage applied to the VCG INPUT terminal. This applied voltages signal flows through the impedance converter, adder 1, inverse-logarithm converter and adder 2, and controls the oscillation frequencies of the voltage control no signals generator. The adder 1 is then supplied with other than the external signal.

o VCG LINEAR In this position, the input voltage signal flows through the same sections, except the ant. anti–logarithm converter, as in VCG LOG.

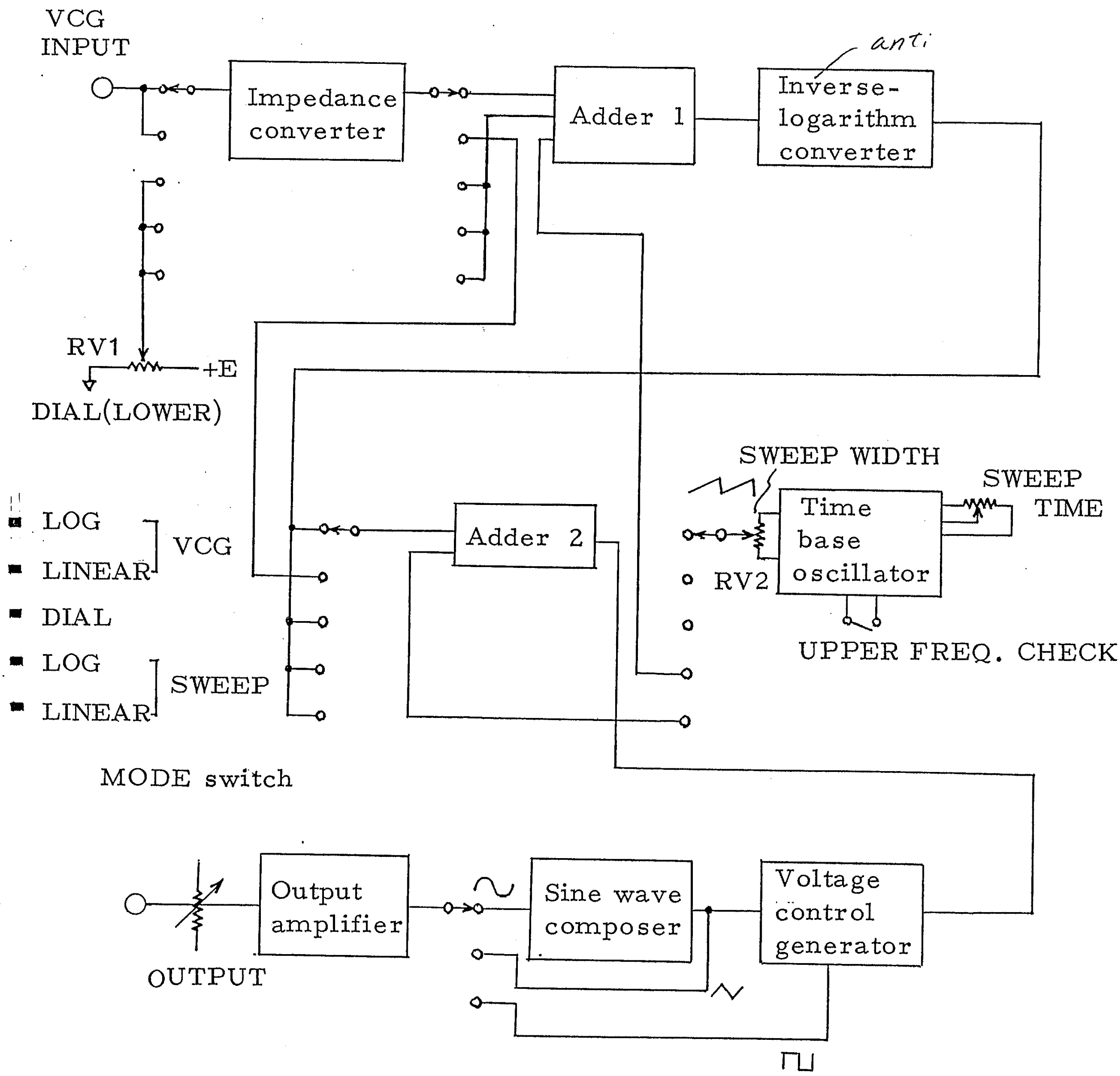

VCG INPUT
Impedance converter
Adder 1
anti
Inverse-logarithm converter
RV1
+E
DIAL(LOWER)
SWEEP WIDTH
SWEEP TIME
Time base oscillator
RV2
UPPER FREQ. CHECK
LOG
LINEAR
VCG
DIAL
LOG
LINEAR
SWEEP
Adder 2
MODE switch
Output amplifier
Sine wave composer
Voltage control generator
OUTPUT

Fig. 4-1

o DIAL When the frequency is controlled manually by the dial, the MODE switch should be set to this position. Since the dial scale is divided in geometric ratio the anti-logarithm converter is used for this position as with the VCG LOG position. Unlike VCG LOG, the reference voltage generated inside Model 461, instead of input signal from outside, is divided by potentiometer RV1 and fed to the impedance converter. The dial is directly connected to this RV1.

o SWEEP LOG In this mode, the logarithm of the oscillation frequency is proportional to time and the frequency is swept during the repetition period of the time base generator. In this state, the lower limit frequency is set by the dial. By this setting, the voltage divided by potentiometer RV1 is fed to the adder 1 together with the sawtooth wave signal, divided by potentiometer RV2, from the time base generator. After this adding operation, the resultant signal is fed as a control signal to the voltage control generator through the inverse-logarithm converter.

o SWEEP LINEAR In this position, the oscillation frequency is swept in proportion to time. The repetition period is the same as in the SWEEP LOG mode.

The voltage signal set by RV1 flows through the impedance converter, adder 1 and inverse-logarithm converter and is added to the output of the time base generator by the adder 2, and fed to the voltage control generator.

4.2 Oscillation principle

Fig. 4-3 shows the fundamental block diagram of Model 461's oscillation principle. It comprises a flip-flop, an integrator, a voltage comparator and a sine wave composer.

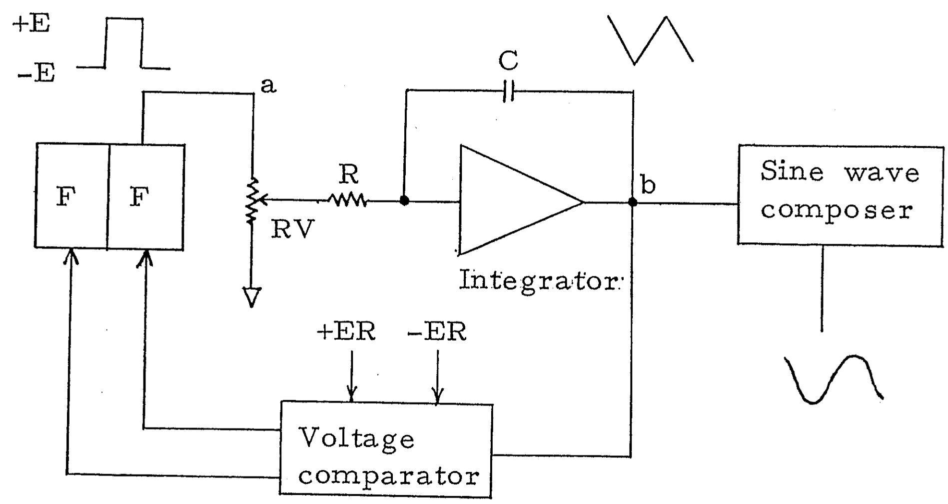


Fig. 4-2

Next, operation in Fig. 4-2 will be described.

Assume that the potential at point a of the flip-flop is -E and capacitor C is discharged immediately after the power switch is turned on. Then, the voltage at b, output point of the intergrator, increases from 0 V in a positive slope.

When the increasing voltage reaches +ER, a value preset by the voltage comparator, the voltage comparator generates a trigger signal, and inverts the flip-flop, switching the potential at point a of the flip-flop to +E.

This inversion, therefore, causes the potential at point a, output point of the integrator, to start decreasing. When it reaches -ER, the voltage comparator operates, and resets the flip-flop to the original state, releasing the potential at point a to +E. Such a series of operations performed in provides oscillation.

This oscillation mode provides square wave at point a of the flip-flop and triangular wave at output point b of the integrator. Sine wave is also generated by the sine wave composer by using the triangular wave obtained from the integrator.

Fig. 4-3 shows the principle of sine wave production. Diodes D1 through D6 and D1' through D6' are connected as shown in Fig. 4-3. Each resistor connected in series with diodes is a damping resistor for obtaining the optimum approximate curve from the folded lines during sine wave production.

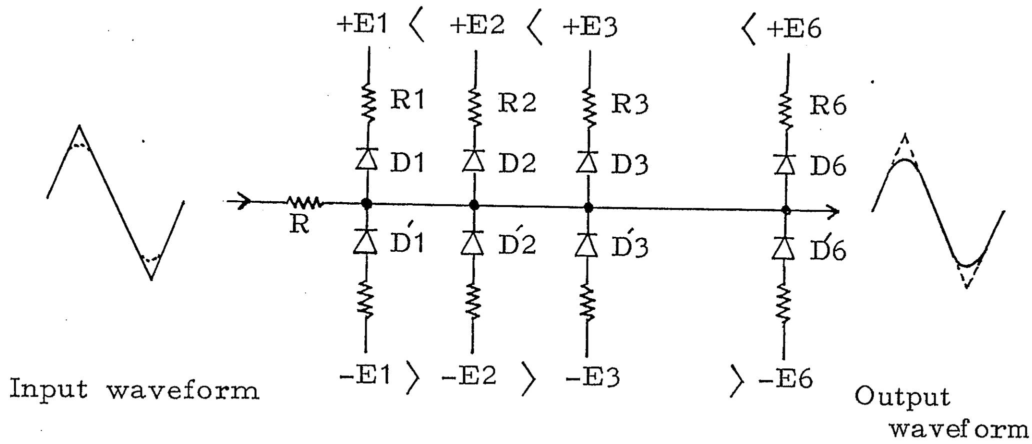


Fig. 4-3

When instantaneous value e of the trianglular wave input is $0 < e < +E1$, all the diodes are cut off. The input waveform, therefore, appears in the same slope on the output side as it were.

With $+E1 < e < E2$, D1 becomes conductive and the slope of the input waveform. When D3 and D4 become conductive, R2 and R3 remain connected in parallel and the slop of the output becomes more gradual than that of the input.

The negative cycle is the same as the positive one; D1' through D6' become conductive by turns and a sine wave approximating to the folded lines can be obtained on the output side.

4.3 Frequency control by voltage

In Fig. 4-2, oscillation frequency f is

$$f = \frac{1}{2E_R\,RC} \cdot e_i \qquad (4\text{-}1)$$

Where,

$\pm e_i$	:	voltage at center of potentiometer
R	:	resistance connected to integrator
C	:	capacitance
$\pm E_R$	:	set voltage of voltage comparator

Thus, if E_R.R.C is kept constant and e_i is varied, oscillation frequency f is proportional to e_i.

e_i voltage, then, assumes either a positive or negative value, equal in the absolute value.

Fig. 4-4 shows the principle figures.

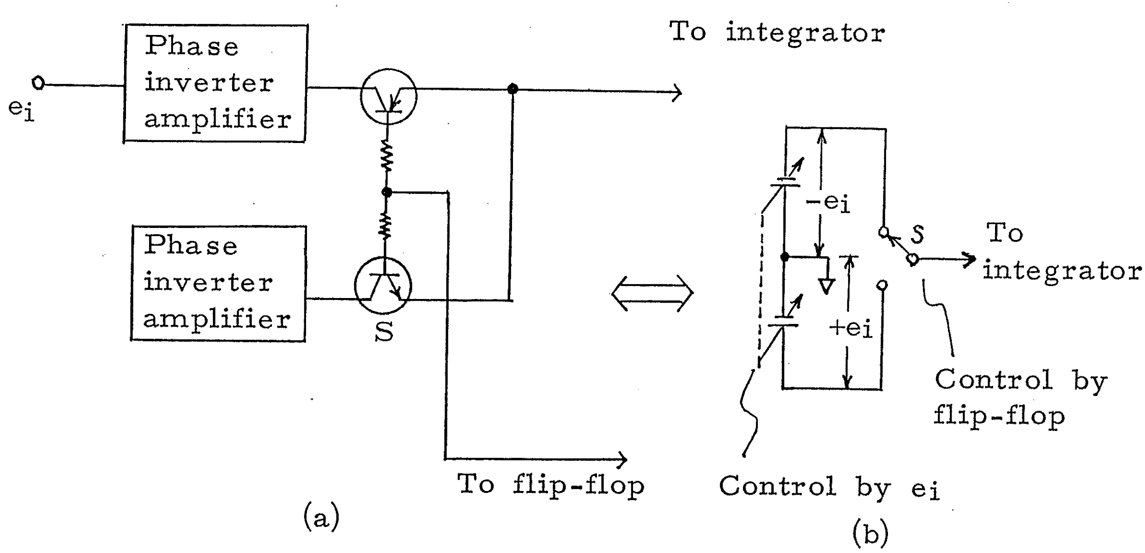


Fig. 4-4

Fig. 4-4-b is the circuit equivalent to Fig. 4-4-a.

The output of the integrator is compared by the voltage comparator, and according to its result, switch S is changed over. For voltage e_1 to be applied to the integrator, positive and negative voltages equal in absolute value, are obtained by using the phase inverter amplifier.

Switch S shown in Fig. 4-4-a is an electronic switch using NPN and PNP transistors, whose bases are controlled by the flip-flop.

4.4 Time base generator

The time base generator generates a sawtooth wave signal having a repetition period within 0.01 to 100 sec as a sweep signal for the voltage control oscillator.

Fig. 4-5 shows the composition of the time base generator.

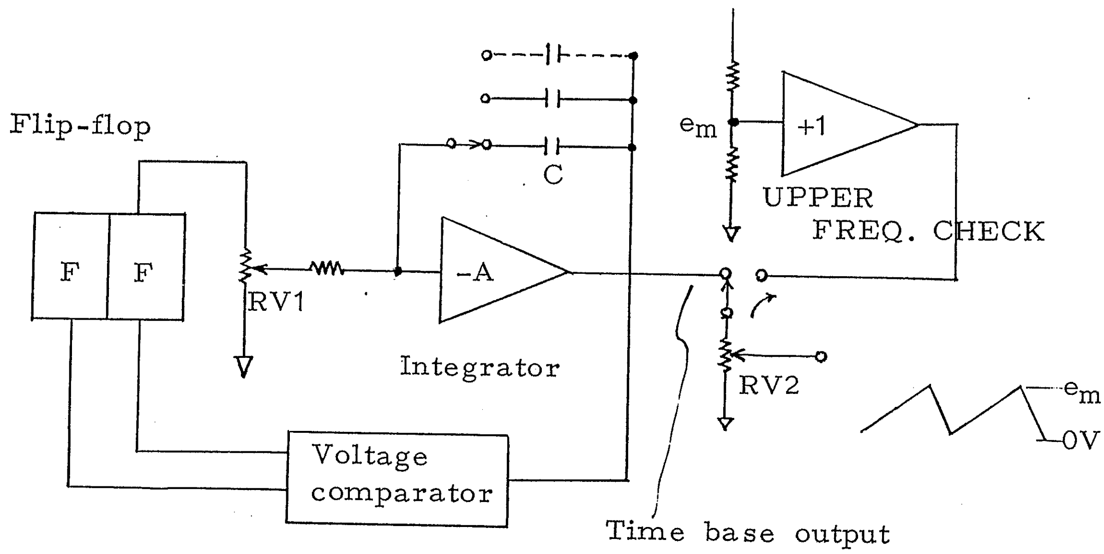


Fig. 4-5

The principle of this generator is the same as in Item 4-2, but the output voltage of the flip-flop is designed to be asymmetrical in absolute value in order to obtain a sawtooth wave. The ranges of the oscillation frequency can be selected by changing over capacitors C connected between the input and output of the integrator, and the frequency in each range can be continuously varied by RV_1.

RV_2 located on the sawtooth output side is the SWEEP WIDTH knob for setting sweep width. This varies the amplitude of the sawtooth wave signal, thus controlling the input voltage to the voltage control generator.

The UPPER FREQ CHECK switch shown in Fig. 4-5 is provided to set the upper limit frequency of the sweep range. This allows a DC voltage accurately corresponding to the peak value e_m of the sawtooth wave voltage to be taken out on the output side; namely, the frequency of the signal generated by this DC voltage becomes equal to that generated at the peak of the sawtooth wave, thus permitting the upper limit frequency to be calibrated.

4.5 Anti-logarithm converter

The voltage control generator generates not only a signal having a frequency proportional to the voltage applied, but a signal having a frequency whose logarithm is proportional to the voltage applied in combination with the anti-logarithm converter. Fig. 4-6 shows the circuit of this converter used in Model 461.

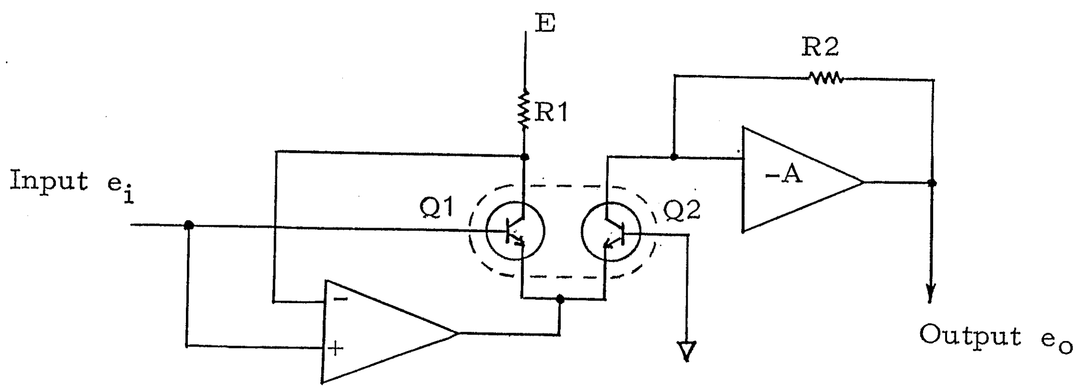


Fig. 4-6

As a non-linear device for obtaining anti -logarithm, this circuit uses the relationship between the voltage applied between the base and emitter of the transistor and current following through the transistor.

Transistor collector current Ic is expressed as follows;

$$Ic = Is\exp\left(\frac{qVbe}{KT}\right) \qquad (4\text{-}2)$$

Where, Vbe : Voltage between base and emitter

Is : Saturated current

When Q1 and Q2 have the same characteristics in Fig. 4-6, collector current Ic_2 of transistor Q_2 is

$$Ic_2 = Ic_1 \ \exp\left(\frac{-q}{KT} Vbe\right) \qquad (4\text{-}3)$$

When Ic_1 is fixed by keeping voltage E and resistance R_1 constant in formula (4-3), the voltage characteristic of the input to output is

$$eo = E \frac{R_2}{R_1} \ \text{epx}\left(\frac{-q}{KT} Vbe\right) \qquad (4\text{-}4)$$

When the input is at 0 V, voltage $E\frac{R_2}{R_1}$ is generated. As the input increases, the voltage decteases exponentially.

Model 461 is designed so that the input voltage is proportional to the logarithm of the oscillation frequency by using the zero-shifted inverse-amplifier in the prestage of the above-mentioned circuit.

This converter also uses a thermostatic oven to stabilize the two transistors having the same characteristics.

5. MAINTENANCE

5.1 Inspection of inside parts

Remove the feet by unscrewing at the four corners of the back. Push the side panels and top and bottom plates slowly backward, and the inside parts can be inspected.

Be careful since the top plate is detached from the cabinet frame if the front panel is inclined forward and held at the handles, with the feet on the rear panel removed.

5.2 Arrangement

Fig. 5-1 shows the arrangement of the main parts of Model 461.

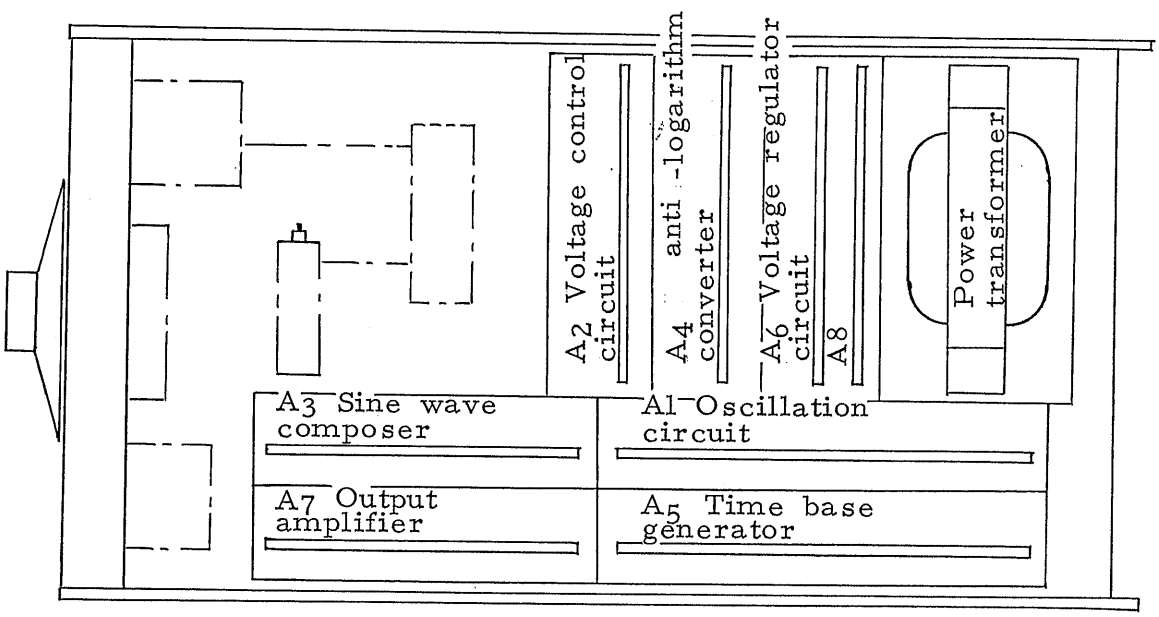


Chart 1 VCG LOG frequency to voltage characteristics

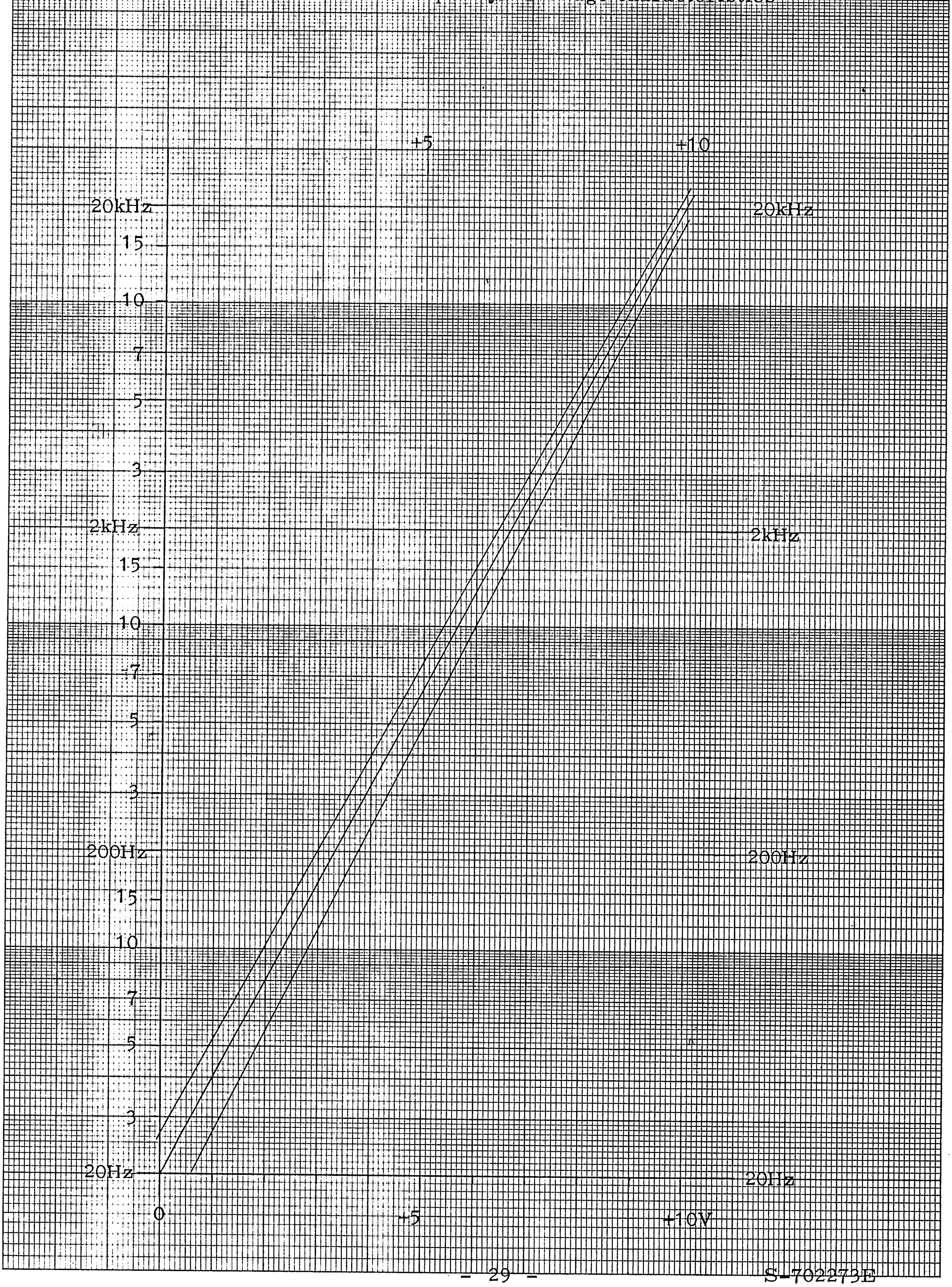


Chart 2 VCG LINEAR frequency to voltage characteristics