MODEL 456

FUNCTION GENERATOR

OPERATION MANUAL

70.10.24

KIKUSUI ELECTRONICS CORP.

CONTENTS

1. GENERAL DESCRIPTION

Kikusui's Model 456 is a function generator which provides signals of sine wave, triangular wave and square wave within a range of 0.01 Hz to 100 kHz; namely, two different waveform signals and two 180° out-of-phase signals with the same waveform can be obtained at two sets of terminals optionally.

As with the conventional generators, the oscillation frequency can be varied by turning a dial. In addition, use of a voltage control device extends each frequency range up to 1000 times variably.

To control the start and stop of oscillation, trigger function (generation of one cycle of waveform) and gate function (generation of tone burst waveform) are provided by using external signals or by manual operation.
The phase in the start and stop of the oscillation frequency can also be varied within a range of zero to ±90.

Model 456 can be used as a voltage control generator, tone burst generator or pulse generator for special waveforms as well as an ordinary generator. Therefore, it is very widely applied to many types of measurements and tests such as frequency response measurements of feedback amplifiers, tests of servo devices in automatic control systems, tests of analog computer function generators and signal tests of vibration exciters and sound equipment.

2. SPECIFICATIONS

Frequency Range	0.01 Hz ~ 100 kHz
	x 0.01, x 0.1, x1 (0.01 ~ 10 Hz), x 10 (0.1 ~ 100 Hz), x 100 (1 Hz ~ 1 kHz), x 1 k (10 Hz ~ 10 kHz), x 10 k (100 Hz ~ 100 kHz)
Dial Scale	0.5 ~ 10, equally divided
Accuracy	2% + (±0.05 of dial scale)
Frequency Stability	Within ±0.5% with respect to ±10% fluctuation of power voltage
Output Waveform	Sine wave, triangular wave and square wave at output terminals (1); sine wave, triangular wave, square wave and 180° out-of-phase waveform against that at terminal (1)
Maximum Open Output Voltage	More than 30 Vp-p
Frequency Characteristics	Within ±0.3 dB at 1 kHz
Distortion Factor (sine wave)	Less than 1% within 20 Hz to 20 kHz, Less than 2% within 20 to 100 kHz

Output Impedance	600Ω ±20%
Amplitude Stability	Within ±0.5% with respect to ±10% fluctuation of power voltage
Mutual Voltage Deviation	Less than 5% at 1 kHz
Controllable Frequency Range	0.01 Hz ~ 100 kHz in VCG
Input Frequency Range	DC ~ 10 kHz in VCG
Variable Frequency Range	More than 1000 times within one range
Control Voltage	Approx. +10mV ~ +10V when OFFSET is off approx. ±5V when OFFSET is maximum.
Input Impedance	Approx. 10 kΩ, unbalanced
Triggering Frequency Range	0.01 Hz ~ 100 kHz
Input Frequency Range	DC ~ 10 kHz
Oscillation Mode	Continuous oscillation, trigger, gate
Start/Stop Points	±90° variable in sine wave and triangular wave
Input Impedance	Approx. 1 kΩ, unbalanced
Trigger Signal Level	1 Vp-p ~ 10 Vp-p
Trigger Slope	Variable
Synchronization Output	More than -10V peak

Pulse Width	Less than 5μsec
Triggered Synchronization Output	More than -10V peak
Pulse Width	Less than 5μsec.
Power Source	--------V 50/60 Hz, approx. 30VA
Dimensions	430W x 160H x 275D mm
(Maximum Dimensions)	(445W x 173H x 310D)mm
Weight	9.6 kg
Accessories	Operation manual 1
	Type 941B terminal adaptor 2
	Short bar 1

3. OPERATION

3.1 Front panel and Rear panel descriptions (See Fig.3-1, 3-2)

[Front Panel]

① POWER	Power pushbutton switch. When pushed and locked, power is on and the pilot lamp lights to indicate a ready state.
② FREQ MODE	When this switch is set at DIAL, the oscillation frequency can be manually varied. When set at VCG (control by means of external voltage), the oscillation frequency is set by a voltage applied to VCG terminal.
③ RANGE	Selector switch for frequency range. When FREQ MODE ② switch is set as follows; i) at DIAL The oscillation frequency is the product of a range digit

(black) and dial scale value.

ii) at VCG

Within the range of a digit (green) showing bandwidth, the oscillation frequency can be varied according to VCG terminal voltage regardless of dial setting.

④	FREQ CONT	Knob for controlling frequency continuously when FREQ MODE switch is set at DIAL. Clockwise rotation increases the frequency.
⑤	FREQ FINE CAL'D	Used for fine control of frequency. The variable range is approx. 10%. Clockwise rotation increases the oscillation frequency. The dial scale has been calibrated at CAL'D position.
⑥	FUNCTION	Output waveform knob which selects sine wave (∿), triangular wave (∧) or square wave (⊓⊔).

(7)	OUTPUT	Output voltage control knob. Clockwise rotation increases the output voltage, and more than 15Vp-p output can be obtained at 600Ω load. UHF type receptacle under this knob is the output terminal. The metal terminal is connected to the circumference of this receptacle electrically. This GND terminal is DC-floating from the case.
(8)	FUNCTION	Not only the same waveform as at FUNCTION (6) but a waveform, inverted, in INVERT position, with respect to that set at FUNCTION (6) can be obtained.
(9)	OUTPUT	Used like (7).
(10)	VCG INPUT	Input terminal for controlling oscillation frequency by means of external voltage.

The oscillation frequency can be varied up to 1000 times per range by a voltage within a range of +10mV to +10V.

(11)	VCG OFFSET	0 ~ 5V When the lever switch is turned on, a voltage within a range of zero to +5V is added to VCG input by turning this knob clockwise, and the oscillation frequency is set by the addition of the input voltage applied to VCG input terminals and set voltage of OFFSET. Especially, when the control voltage varies over a positive and negative range, an input voltage of -5V minimum can be used by biasing by means of OFFSET.
(12)	TRIGGER/GATE	Selector switch for TRIGGER, GATE and CONT.

		TRIGGER and GATE functions are actuated by external signals or by using MANUAL. At CONT position, the continuous oscillation mode is possible.
13	START/STOP POINT	This knob controls the starting and stopping positions in oscillation of sine wave and triangular-wave signals. i) ±90° at OUTPUT 7 ii) ±90° or 180° ± 90° (at INVERT) at OUTPUT 9.
14	LEVEL	Knob adjusting trigger level. It controls the level of trigger signals.
15	SLOPE	Change-over switch of slope polarity of trigger signals. At + position, oscillation starts in the leading edge of the signal, and at - position, it starts in the trailing edge.

16 TRIGGER INPUT

Input terminals of trigger signals, which control the oscillation frequency within a range of 0.01 Hz to 100 kHz. The input level should be within a range of ±0.5 to ±5V.

17 TRIGGER SELECT

Used for trigger oscillation by means of external signal or manual switching.
When this switch is set at MANUAL, oscillation is triggered by pushing and locking PUSH switch 18. This manual triggering has the following two modes.

i) Only one cycle of oscillation (trigger mode); when TRIGGER/GATE switch 12 is set at TRIGGER and PUSH switch 18 is depressed and locked, one cycle of oscillation occurs.

ii) Manual start and stop (gate mode); when TRIGGER/GATE switch (12) is set at GATE and PUSH switch (12) is depressed and locked, oscillation starts. When PUSH switch (12) is depressed and unlocked, oscillation stops. As with application of external signals, the start and stop points can be controlled by START/STOP POINT knob (13).

(18)	PUSH	Manual pushbutton switch which is used together with TRIGGER SELECT switch (17).

3. [Rear Panel]

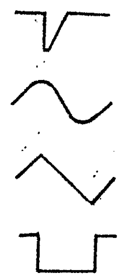
(19) SYNC OUTPUT — UHF type receptacle used as synchronization output terminal. More than -10V peak output signal synchronizing with the positive peak of sine wave or triangular wave, or with the fall of square wave can be obtained.

Synchronize pulse

Sine wave

Triangular wave

Square wave



(20) GND terminal — Like the metal terminal on the front panel, this terminal has been connected to the ground of the internal circuit.

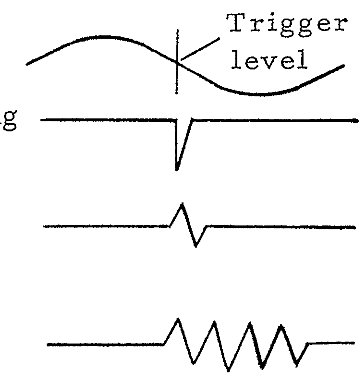
(21) TRIGGER SYNC OUTPUT — In the trigger and gate modes, an output synchronizing with the trigger input signal can be obtained at this connector.

Trigger input signal

Trigger synchronizing pulse

Output waveform in trigger mode

Output waveform in gate mode



22	GND terminal	The same GND terminal as 20.
23	FUSE	Fuse for AC source. 0.5A
24	Power cord	Connected to 50/60 Hz AC source.

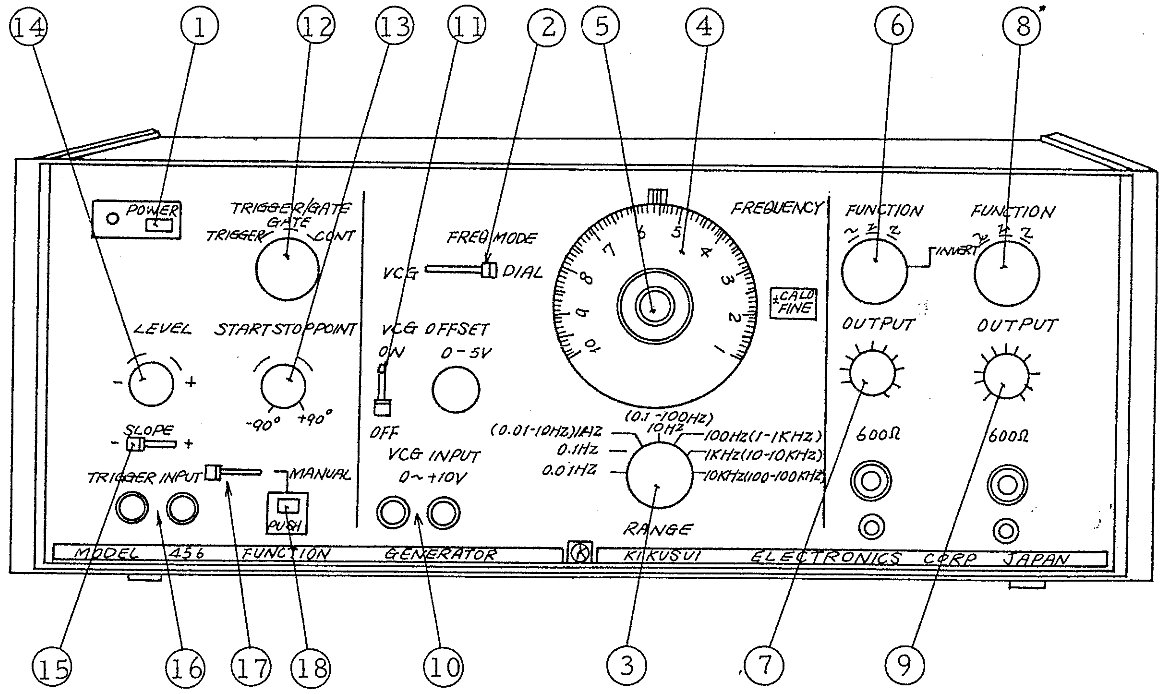


Fig. 3-1 Front panel

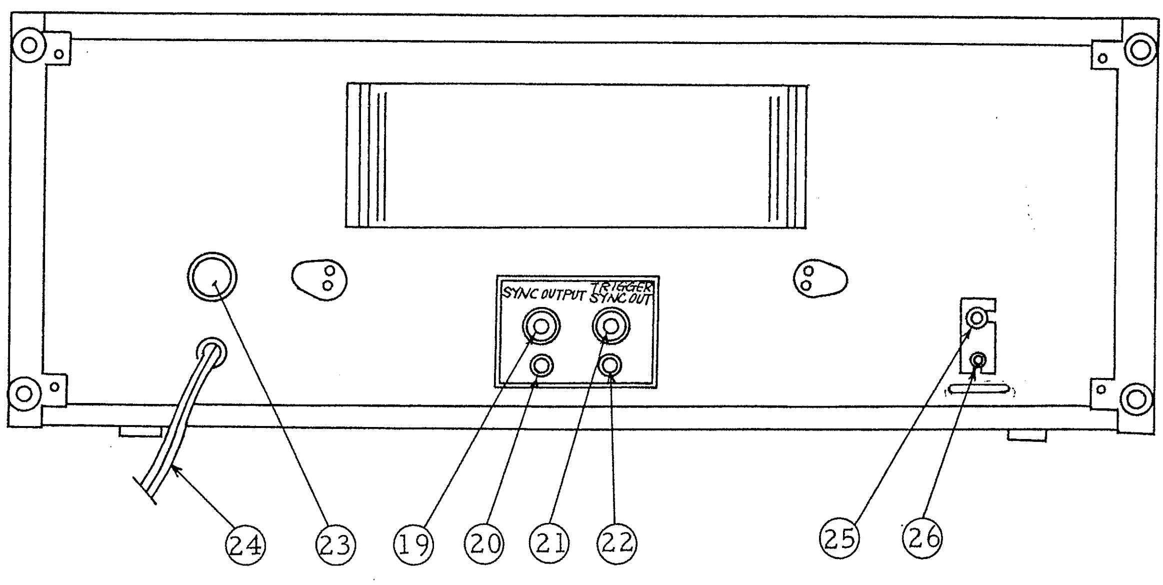


Fig. 3-2 Rear panel

4. PRINCIPLE OF OPERATION

4.1 Fundamental operation

Fig. 4-1 shows the fundamental block diagram of Model 456 function generator which is composed of a flip-flop circuit, integrator, voltage comparator and sine-wave composing circuit.

When the potential at point a in the flip-flop circuit is -E and the electric charge of capacitor C is zero immediately after power is turned on, the integrated output voltage at point b increases in the positive slope. When it reaches +Er, the voltage comparator generates a trigger pulse to invert the flip-flop circuit, causing the potential at point a to become +E.

Next, the potential at output point b of the integrator begins to decrease from +Er. When it reaches -Er, the voltage comparator generates a trigger pulse to change the flip-flop circuit back to the former state. A series of these operational procedures makes the oscillation continue.

The oscillation frequency is set by voltage Er at point a, setting of R1 and values of R2 and C. In general, after approximate oscillation range is set by R2 and C, the frequency is continuously adjusted by turning potentiometer R1.

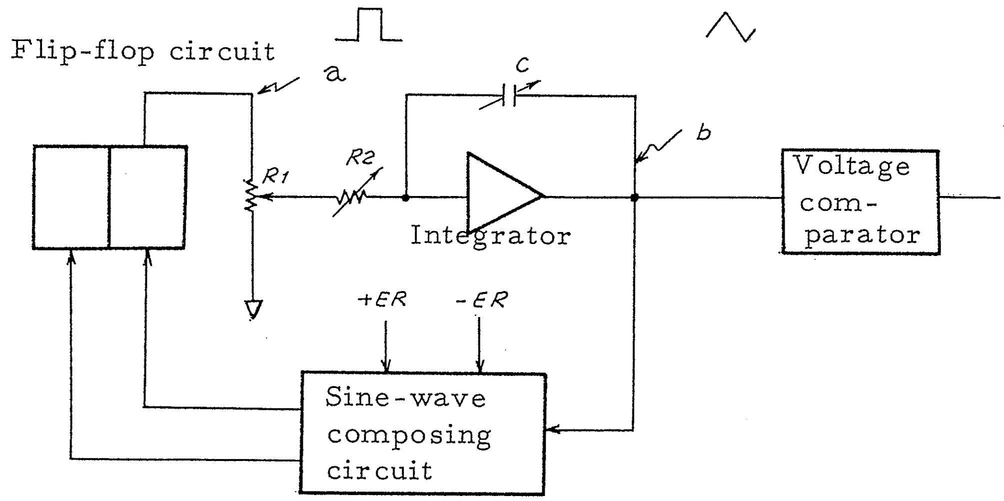


Fig. 4-1

Sine wave is composed of the triangular wave obtained from the integrator.

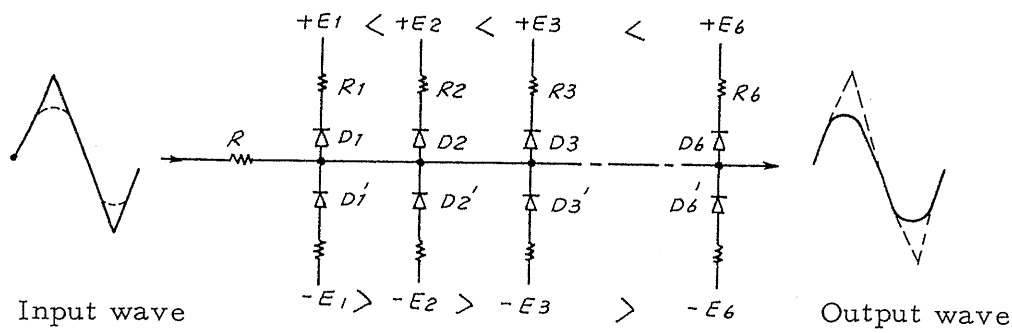


Fig. 4-2

Fig. 4-2 shows this principle.

Diodes D1 through D6 and D1' through D6' are connected as shown in Fig. 4-2. All diodes are connected with associated damping resistors in series in order to obtain the optimum approximate curve from the folded lines.

When instantaneous value e of the triangular wave input is

$$0 < e < +E1,$$

all the diodes are cut off. Therefore, the input waveform appears in the same slope on the output side as it was.
In the case of $+E1 < e < +E2$, D1 becomes conductive and the slope of the output decreases to $R1/(R1+R)$.
When D3 through D6 become conductive by turns, the slope becomes looser.
The negative process 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.

4.2 VCG (voltage control generator) operation

Generators which can control the oscillation frequency by voltages are termed VCG or VCO.

There are the following two methods of voltage-controlling function generators. In one, integration time constant CR remains constant and the input voltage is controlled.

In the other, a constant current charging capacitor C is controlled.

Model 456 uses the latter method (current control system) in order to extend the variable frequency range.

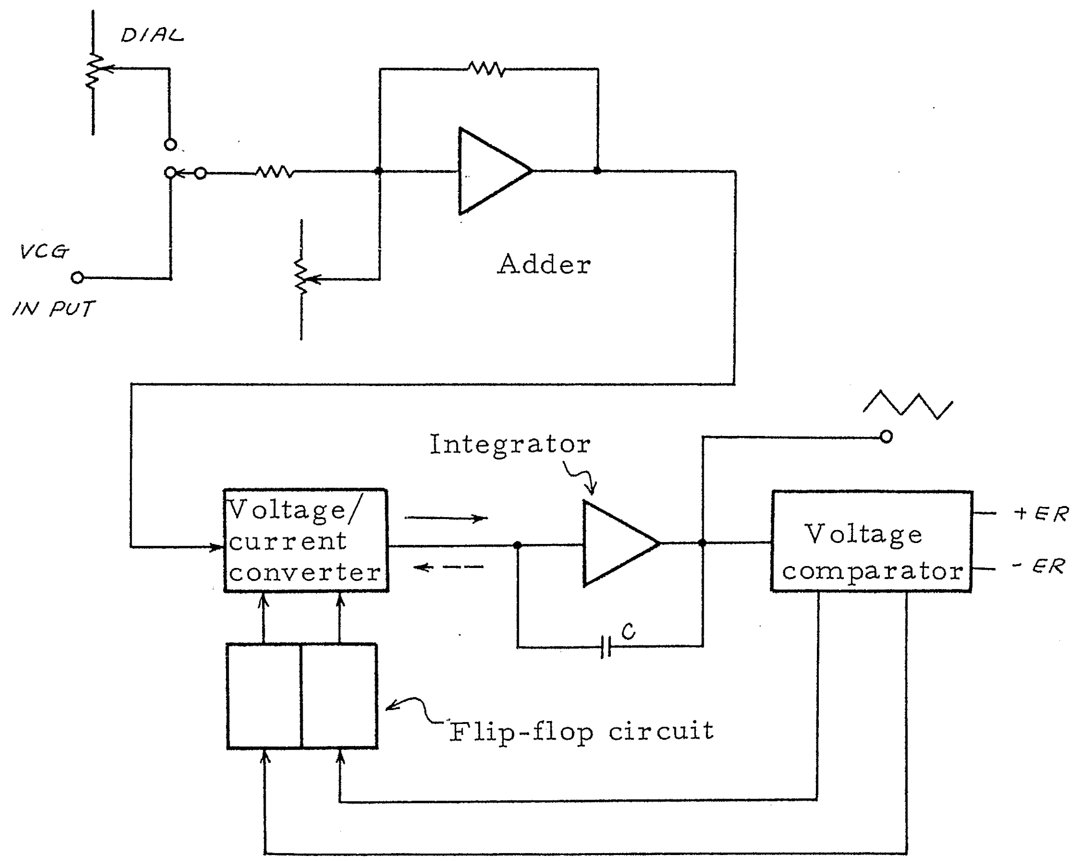


Fig. 4-3

When the constant current that is charging integrating capacitor C is expressed as I, and the voltage comparator is set at -Er and +Er, and time t from +Er to -Er is set as shown in Fig. 4-4, the following formula (1) can be obtained;

$$2\ Er = \frac{It}{C} \quad \ldots\ldots\ldots \quad (1)$$

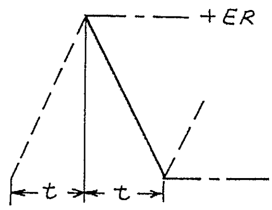


Fig. 4-4

Since oscillation frequency f is 1/2t as shown in Fig. 4-4, formula (1) is expressed as follows;

$$f = \frac{I}{4\ ErC} \quad \ldots\ldots\ldots \quad (2)$$

When capacitor C and the voltage comparator values are made constant in formula (2), oscillation frequency f is proportional to the constant current. Thus, it can be controlled by varying the current.

The voltage/current converter converts the input voltage into proportional current to charge and discharge integrating capacitor C. Polarity of the current is controlled by the flip-flop circuit to maintain oscillation.

The adder performs addition of OFFSET voltage within a range of zero to +5V and VCG signal voltage. Even when VCG input is negative, if more than -5V, the adder has been designed to operate properly.

The input voltage range of VCG is from +10mV to 10V when OFFSET is not set. When OFF SET is set, it is as follows;

$$+10\text{mV} < (\text{VCG input voltage} + \text{offset voltage}) < +10\text{V}$$

The lower limit of oscillation frequency, e.g. in a range of 100Hz to 100kHz, is 100Hz when the addition of VCG and OFFSET is +10mV, and itis 100kHz at 10V.

4.3 Trigger oscillation mode

Inthis mode, the generator provides only one cycle of oscillation by means of the manual switch or external trigger signal, namely, it performs a single stable operation.

Fig. 4-5 shows the block diagram for the trigger oscillation mode.

First, the circuit conditions prior to application of external or manual trigger signal are set as follows;

Output (b) is negative and CR1 is cut off and the current polarity of the current converter for the flip-flop circuit is set as shown in Fig. 4-5.

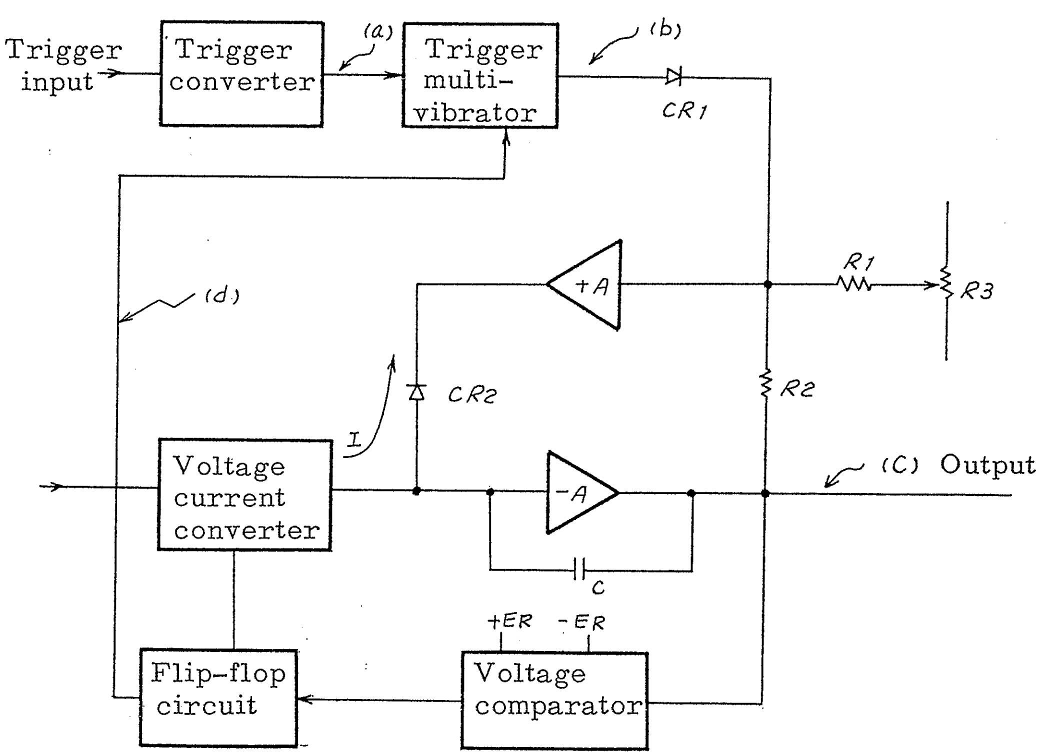


Fig. 4-5

Therefore, CR2 is conducting due to current I. Amplifier -A and the positive phase amplifier in the integrator and R compose one closed circuit.

The potential of output (C) can then be set positively or negatively by optionally setting R3, whereby the start and stop points of oscillation are also set.

When the trigger signal is applied, the trigger comparator is energized and generates a trigger pulse to invert the trigger multi vibrator, causing the voltage at (b) to be positive.

Diode CR1 then becomes conductive and the current through +A cuts CR2 off.

The closed loop is then opened and current I starts to charge integrating capacitor C for integration.

When output (C) reaches -Er, the voltage comparator is energized and output (C) begins to increase. When it reaches +Er, the voltage comparator is energized, and the flip-flop circuit is inverted.

This inverted signal resets the trigger multivibrator to the former state.

When output voltage (C) reaches the preset value, +A, -A and R2 compose a closed circuit, and thereby oscillation stops.

Fig. 4-6 shows the relative waveforms in this operational sequence.

Fig. 4-7 shows the waveforms obtained when start and stop points change.

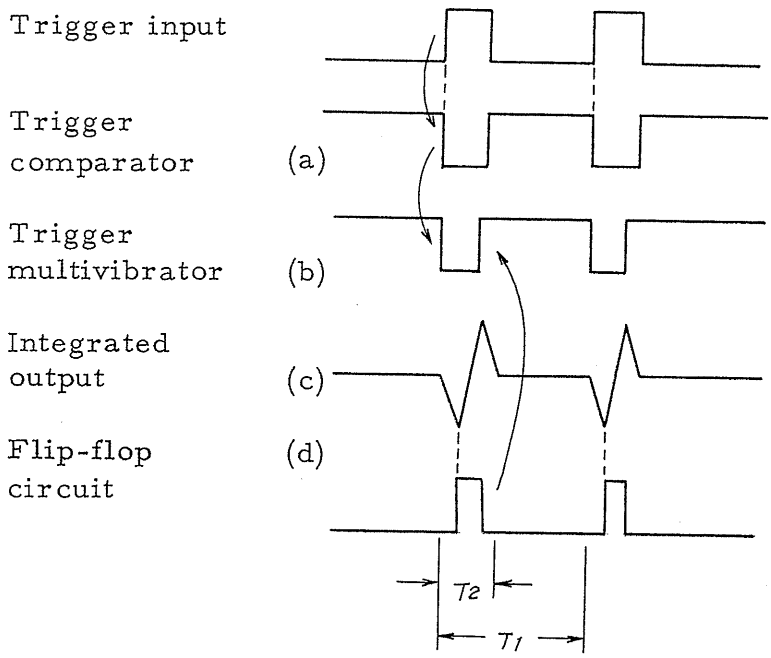


Fig. 4-6

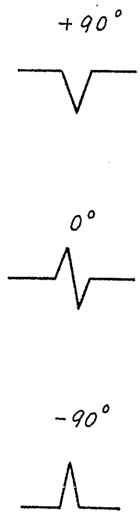


Fig. 4-7

Note: T1 is set by trigger input repetition period. T2 is set by oscillation period.

4.4 Gate oscillation mode

In the trigger oscillation mode, oscillation is triggered by only one cycle by applying a trigger signal, and it stops until the following trigger is applied.
In the gate oscillation mode, since oscillation is controlled by a gate signal generated in the trigger comparator, a multicycle waveform or tone burst waveform can be obtained.

Fig. 4-8 shows the waveforms in every circuit in the gate oscillation mode.
Unlike the trigger oscillation, during the period when output (b) of the trigger comparator is negative, the falling pulse of the flip-flop circuit is gated so that it does not enter the trigger multivibrator.
When the output of the trigger comparator is positive, the gate is opened to reset the trigger multivibrator, causing oscillation to stop.

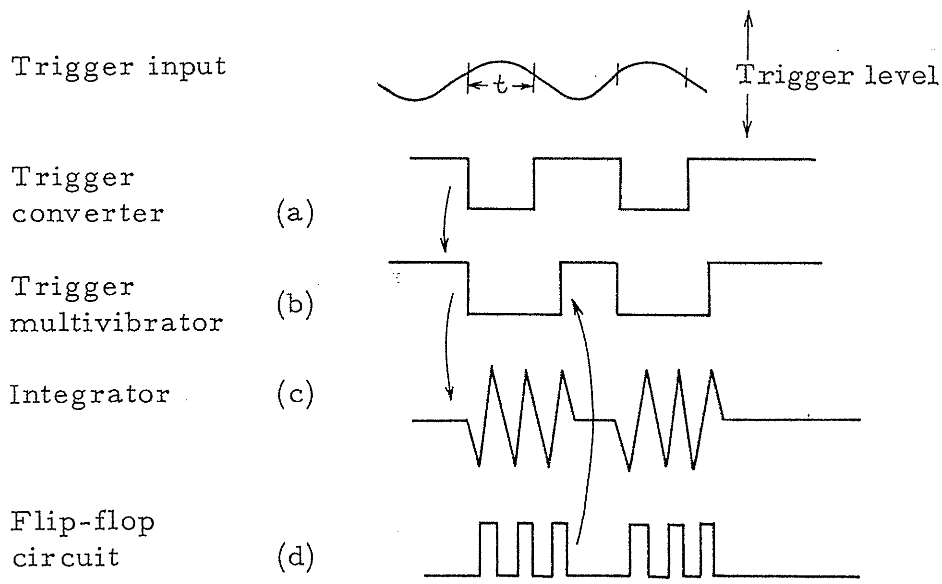


Fig. 4-8

The start and stop points can be varied as with the trigger oscillation mode.

Fig. 4-8 shows the waveforms at 0°.

When the trigger level is controlled by applying a triangular wave or sine wave within a range of ±0.5 to ±5V to the trigger input terminal, oscillation can be easily varied from one cycle to multicycles.

5. APPLICATION

5.1 To linearly sweep a range of 100 Hz to 100 kHz at a 10 sec. repetition period, set each knob as follows;

1) FREQ MODE	at VCG
2) TRIGGER/GATE	at CONT
3) VCG INPUT	Apply 10Vp-p sawtooth wave
4) RANGE	(100 Hz ~ 100 kHz).

* Set the repetition period of the sawtooth wave at 10 sec. When its amplitude changes over a positive and negative range, set OFFSET at ON.

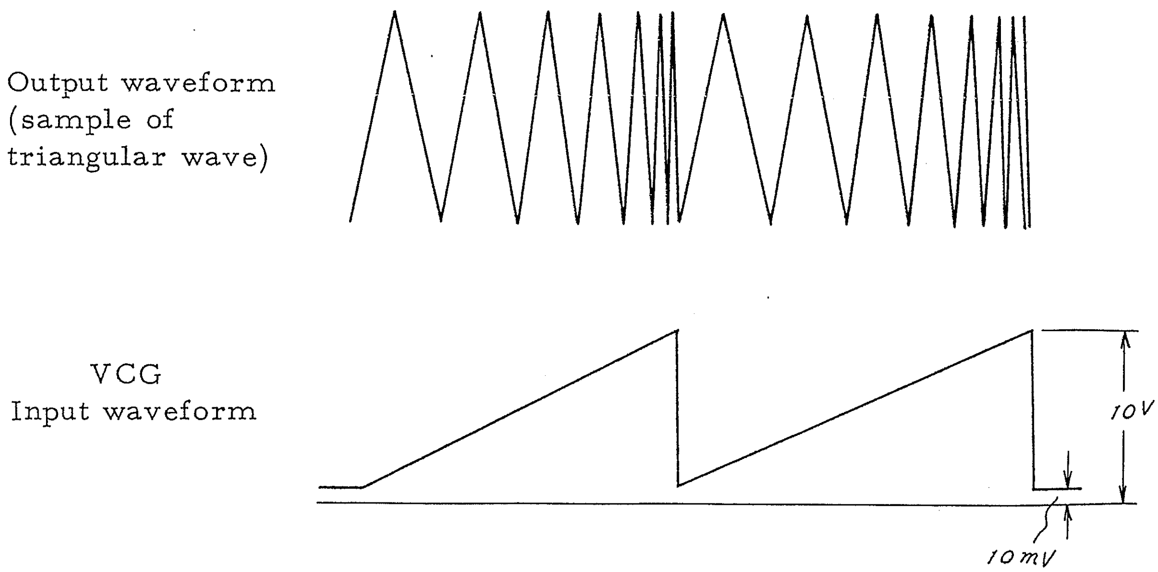


Fig. 5-1

Fig. 5-1 shows a triangular waveform. A sine waveform or square waveform can also be obtained.

5.2 To perform FM modulation of 10 kHz ± 5 kHz, set each knob as follows;

1) FREQ MODE at VCG

2) TRIGGER/GATE at CONT

3) RANGE at 10 Hz ~ 100 kHz

4) OFFSET at ON

Turn OFFSET until the oscillation frequency is set at 10 kHz by monitoring on an oscilloscope. Apply approx. ±500mV signals for modulation to VCG terminals, and an FM-modulation output waveform of 10 kHz ± 5 kHz can be obtained.

To obtain more accurate oscillation, use a counter and DC power source in order to calibrate Model 456.

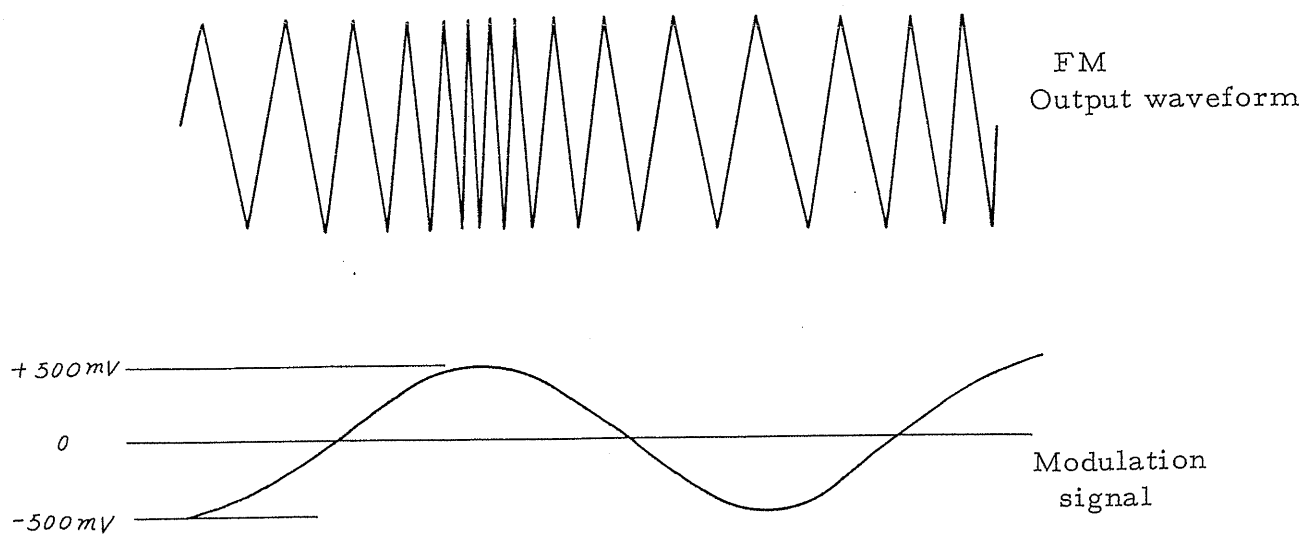


Fig. 5-2

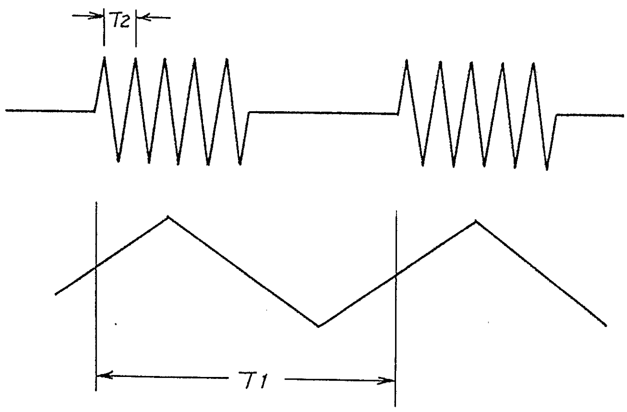
5.3 Generation of tone burst wave

1) To obtain multicycle, set each knob as follows;

1) FREQ MODE	at DIAL or VCG
2) TRIGGER/GATE	at GATE
3) TRIGGER INPUT	Apply sine wave or triangular wave with repetition period T1 (Fig. 5-3) ± (0.5 ~ 5V).
4) START/STOP	at center
5) LEVEL	at center
6) SLOPE	at (+) or (-)
7) TRIGGER switch	at TRIGGER INPUT

To select the cycle of tone burst wave, adjusting LEVEL control while monitoring the output by means of an oscilloscope. Period T2 shown in Fig. 5-3 is set by the dial setting by Model 456 or VCG input level.

Multicycles



One cycle

Fig. 5-3

ii) To obtain one cycle of oscillation, set TRIGGER/GATE at TRIGGER.

Set the other knobs the same as for multicycles.

6. MAINTENANCE

6.1 Internal inspection

Remove the four screws at the rear corners and the feet.

Pull back both side plates, top plate and rear plate slowly.

Internal inspection is then possible.

Caution: When the front panel is slanted fowards by catching the handles, with the feet of the rear plate removed, the side plates may be detached from the frame.

6.2 Arrangement

Fig. 6-1 shows arrangement of the main parts of Model 456.

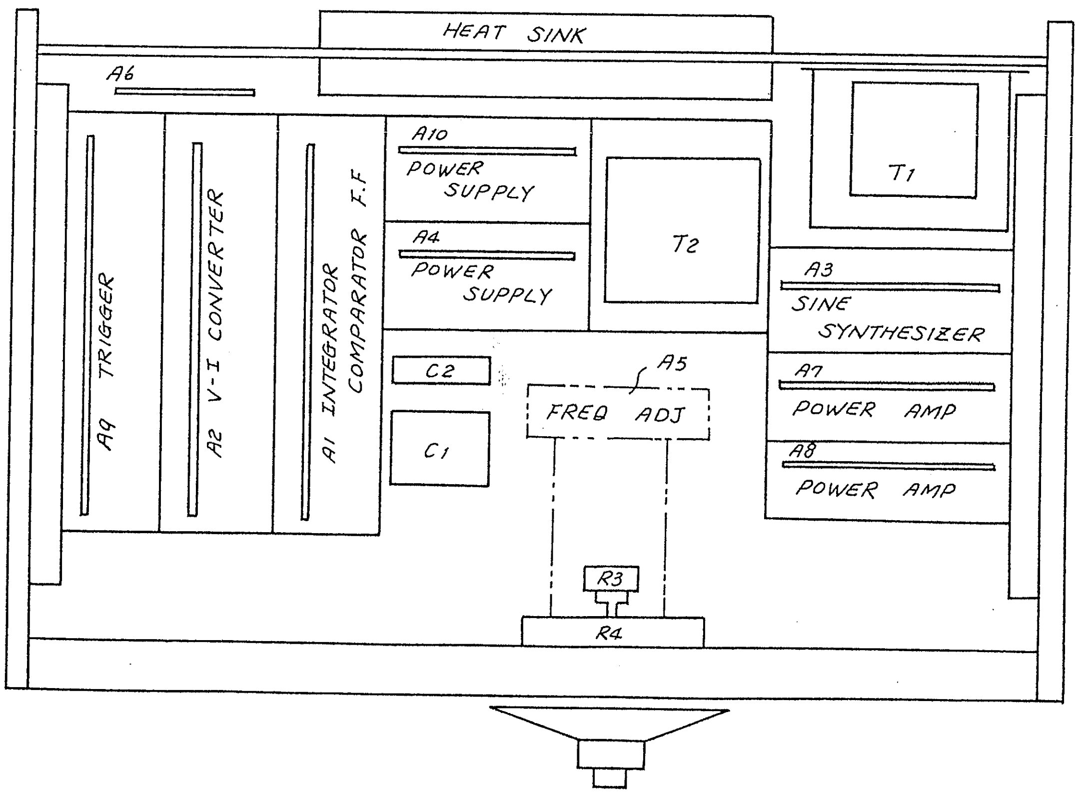


Fig. 6-1