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Nagahama

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[54] **LINEAR VOLTAGE-CONTROLLED SAW-TOOTH OSCILLATOR**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** ..... **331/111;** 331/177 R

[51] **Int. Cl.²** **H03K 4/50**

[58] **Field of Search** ..... 331/111, 177 R, 143

[56] **References Cited**

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[57] **ABSTRACT**

In the inventive voltage-controlled oscillator, relationship between an input control voltage and an output oscillation frequency is made substantially linear by utilization of charging and discharging operations of a capacitor. The capacitor is charged with a constant current value of which is dependent upon the value of the control voltage, and the capacitor is being discharged when the charging voltage has reached a predetermined level. The charging level of the capacitor is variable and it drops as the oscillation frequency increases. This is achieved by providing a low-pass filter between the capacitor and a voltage source. According to this arrangement, as the frequency increases, the voltage applied to the capacitor equivalently decreases, whereby a discharging period of the capacitor is shortened and linearity in the relationship between the input control voltage and the output oscillation frequency is obtained.

1 Claim, 3 Drawing Figures

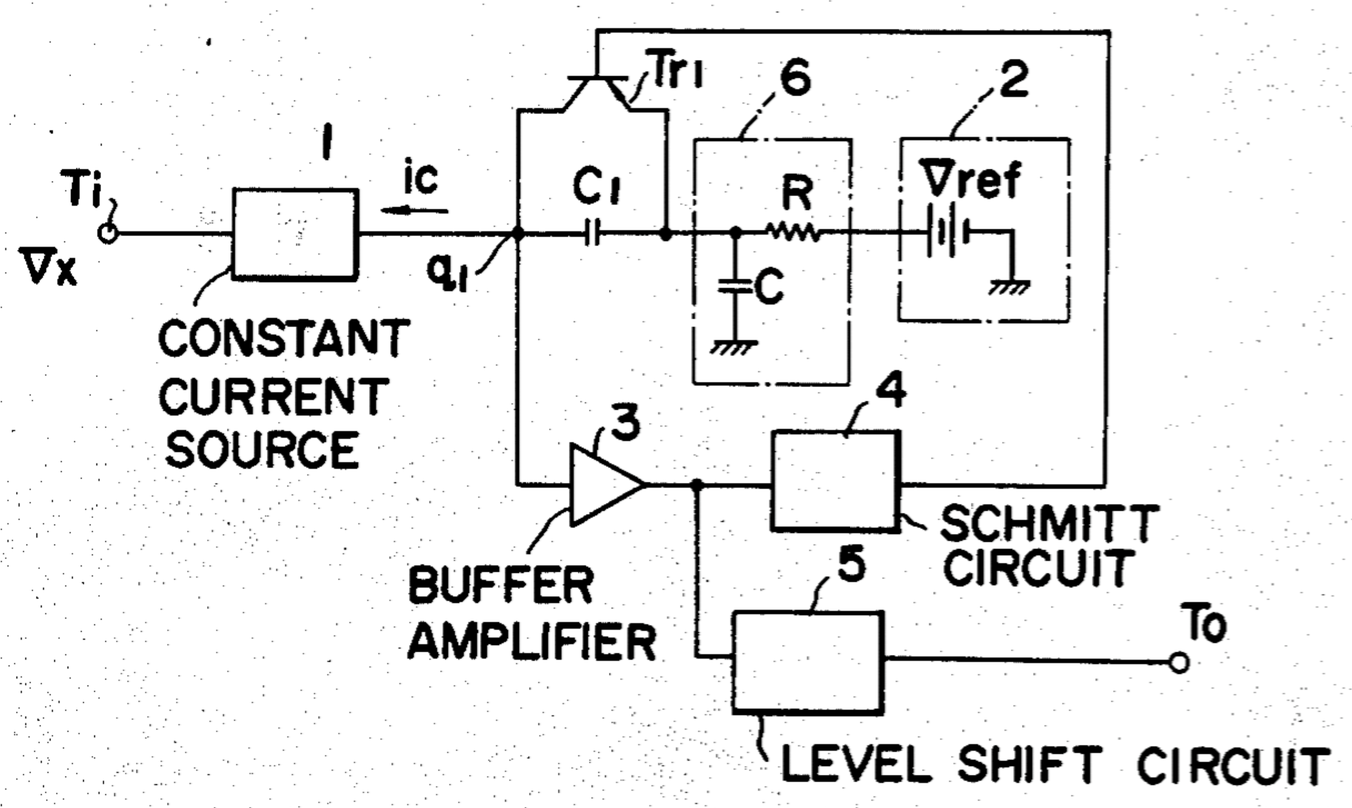


FIG. 1(a)

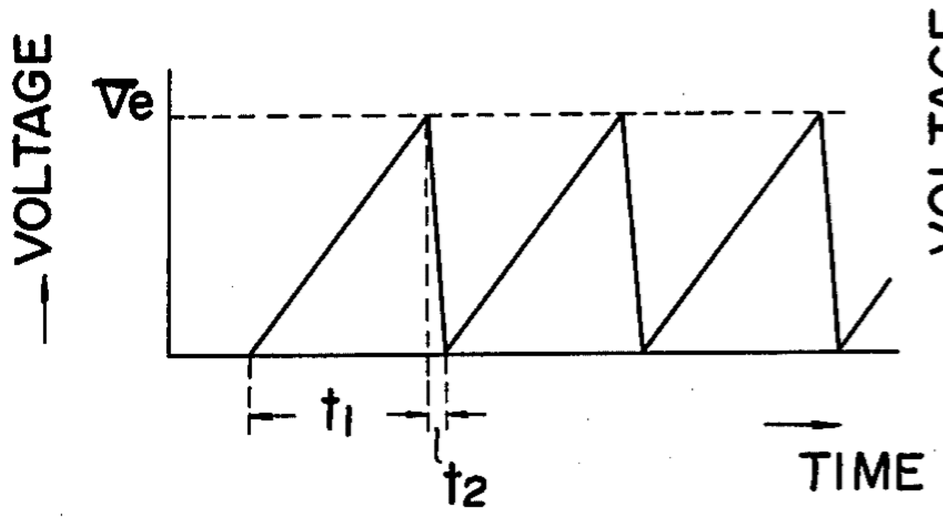


FIG. 1(b)

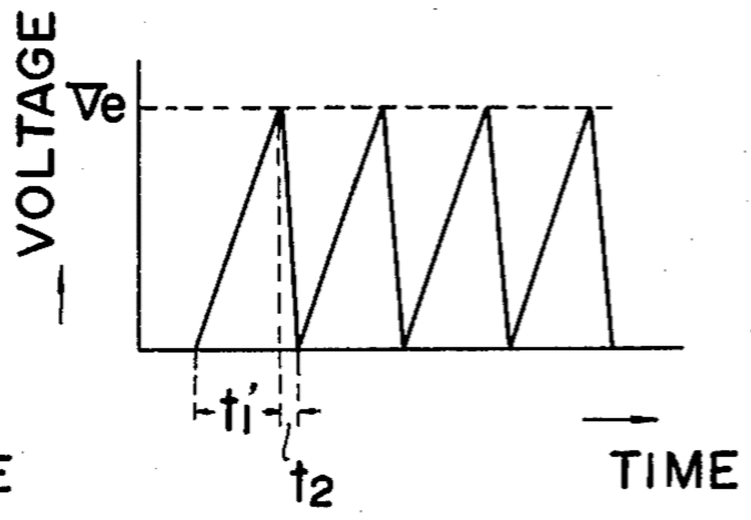
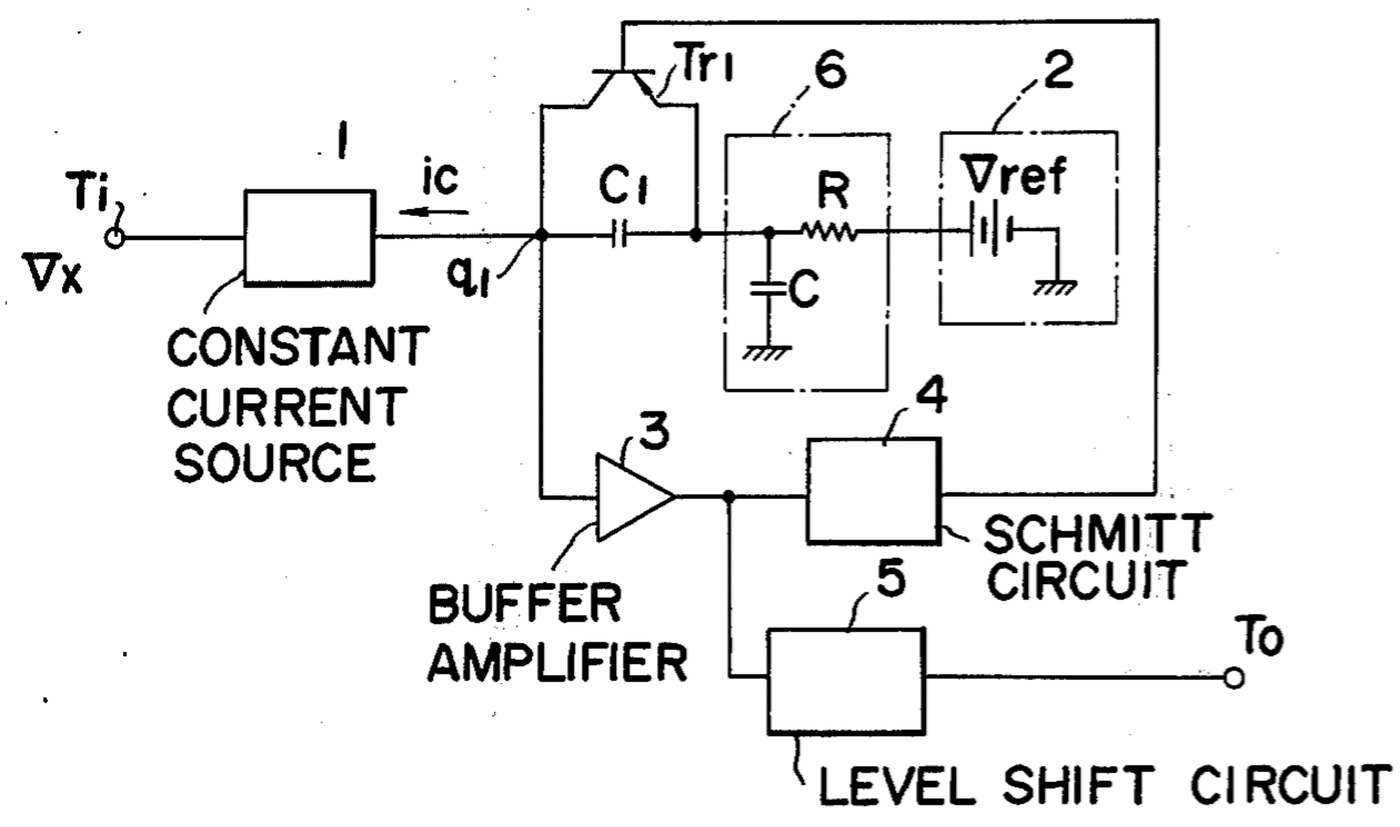


FIG. 2



LINEAR VOLTAGE-CONTROLLED SAW-TOOTH OSCILLATOR

This invention relates to an improvement in a voltage-controlled oscillator.

In a voltage-controlled oscillator, a capacitor is charged through a constant current source which is controlled by a control voltage and discharges upon reaching a predetermined charging potential resulting in oscillation of a saw-tooth wave signal corresponding in frequency to the control voltage. According to this type of oscillator, the frequency of oscillation can be varied over a relatively wide range by changing the input control voltage. The oscillation frequency is dependent upon the value of the constant current controlled by the control voltage. Strictly speaking, however, what is determined by the value of the constant current is a period of time t_1 during which the capacitor is charged and one period of the oscillation frequency is a sum of this charging period t_1 and a period of time t_2 during which the capacitor discharges, as illustrated in FIG. **1**(a). It will be noted from FIG. **1**(b) that only a charging period t_1' changes when the oscillation frequency changes and the discharging period t_2 remains unchanged because the amount of electric charge CVe of the charged capacitor does not change (the amplitude of the saw-tooth wave does not change). Accordingly, as frequency increases (i.e. as the charging period decreases), linearity of relationship between the output oscillation frequency and the input control voltage is increasingly impaired.

It is, therefore, an object of the invention to provide an improved voltage-controlled oscillator in which the output oscillation frequency is maintained in substantially linear relationship to the input control voltage. According to the invention, a low-pass filter circuit comprising a resistor and a capacitor is connected between an oscillation capacitor and a voltage source for supplying voltage to this oscillation capacitor, whereby the voltage applied to the oscillation capacitor decreases as the oscillation frequency increases, and, accordingly, the amplitude of the oscillated saw-tooth wave frequency decreases with a resultant improvement in linearity of the relationship between the output oscillation frequency and the input control voltage.

A preferred embodiment of the invention will now be described with reference to the accompanying drawing in which:

FIGS. **1**(a) and (b) are diagrams showing examples of output waveshapes of the prior art voltage-controlled oscillator; and

FIG. **2** is a block diagram showing the circuit construction of the preferred embodiment of the inventive voltage-controlled oscillator.

Referring to FIG. **2,** when a control voltage V_x is applied to an input terminal T*i* of a constant current source **1,** a constant current i_c flows through the constant current source **1.** This constant current i_c is controlled by the control voltage V_x (i.e. varying in proportion to the control voltage V_x or a function of the control voltage V_x). Accordingly, the constant current i_c flows from a voltage source **2** through an oscillation capacitor C_1 charging this capacitor C_1. Voltage across the capacitor C_1 rises in proportion to a period of time during which the capacitor C_1 is charged. The inclination representing the voltage increase is linear because the capacitor is charged with a constant current. The

voltage change at a point q_1 which is at one end of the capacitor C_1 is of an inclination in a negative direction and this voltage at the point q_1 is applied to a buffer amplifier **3** and thence to a Schmitt circuit **4** and a level shift circuit **5.** The buffer amplifier **3** may be composed of an impedance transforming circuit comprising, for example, a field-effect transistor.

When the voltage at the point q_1 drops to a level at which the output of the buffer amplifier **3** brings an input transistor (not shown) of the Schmitt circuit **4** out of conduction, the output transistor (not shown) of the Schmitt circuit **4** conducts thereby causing the Schmitt circuit **4** to produce a pulse of the negative direction. This output pulse is applied to the base of a pnp transistor Tr_1 connected in parallel to the oscillation capacitor C_1 and the transistor Tr_1 thereby becomes conductive. This causes the capacitor C_1 to discharge in a short period of time. Upon completion of discharging, the capacitor C_1 starts to be charged again. The charging and discharging of the capacitor C_1 are repeated and a saw-tooth wave signal is oscillated from an output terminal T_o. The level shift circuit **5** which is provided for shifting the d-c level of the saw-tooth wave signal functions to produce from the terminal T_o a saw-tooth wave which oscillates in the positive and negative directions from the ground potential.

Since the oscillation frequency is determined by the capacity of the capacitor C_1 which is constant and the value of the constant current i_c, the oscillation frequency varies with the value of the constant current i_c, i.e. the value of the control voltage V_x.

A low-pass filter circuit **6** composed of a resistor R and a capacitor C is connected between the oscillation capacitor C_1 and the voltage source **2.** The constant current i_c flows from the voltage source **2** through the low-pass filter circuit **6** and the oscillation capacitor C_1. The cyclic variation in voltage due to the charging and discharging of the capacitor C_1 (i.e. the oscillation frequency) causes the output voltage of the low-pass filter circuit **6** to vary accordingly and this output voltage becomes an equivalent power source for the oscillation capacitor C_1. If the oscillation frequency is low, reactance of the capacitor C of the low-pass filter circuit **6** is large and, accordingly, voltage Vref of the voltage source **2** is developed at the output terminal of the low-pass filter circuit **6** without any modification. In this case, the saw-tooth wave signal is oscillated with a normal amplitude. If, on the other hand, the oscillation frequency increases beyond the cut-off frequency of the filter circuit **6,** output impedance of the filter circuit **6** drops and the voltage applied to the oscillation capacitor C_1 drops accordingly. This causes the amplitude of the saw-tooth wave to decrease with a result that the fall time of the saw-tooth wave, i.e. the discharging time t_2 described above, is shortened. The higher the oscillation frequency, the shorter becomes the discharging time t_2. Consequently, linearity of the input control voltage V_x or constant current i_c relative to the output oscillation frequency is remarkably improved. It will be understood that the cut-off frequency of the low-pass filter circuit **6** should be suitably determined within a frequency range in which linearity would not be impaired by the operation of the oscillator which would be performed if the low-pass filter circuit **6** was not provided in the oscillator.

What is claimed is:

1. In a voltage-controlled oscillator for oscillating a saw-tooth wave signal of a frequency corresponding to

an input control voltage comprising a voltage source for charging a capacitor, a constant current control circuit for controlling a charging current to become a value corresponding to the input control voltage, and discharging means for causing the capacitor to discharge by short-circuiting upon detection of voltage across the charged capacitor when the voltage has reached a predetermined value, the voltage variation

caused by the charging and discharging of the capacitor being output from the oscillator as the saw-tooth wave signal, an improvement comprising additionally a low-pass filter circuit connected between the voltage source and the capacitor for making relationship between the input control voltage and the output oscillation frequency substantially linear.

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