Voltage - Controlled Oscillator

In the preceding oscillators, the frequency is determined by the RC time constant. However, there are applications, such as frequency modulation (FM), tone generators, and frequency shift keying (FSK), where the frequency needs to be controlled by means of an input voltage called control voltage. This function is achieved in the voltage-controlled oscillator (VCO), also called a voltage-to-frequency converter. A typical example is the Signetics NE/SE 566 VCO, which provides simultaneous square wave and triangular wave outputs as a function of input voltage. Figure 1 is a block diagram of the 566.

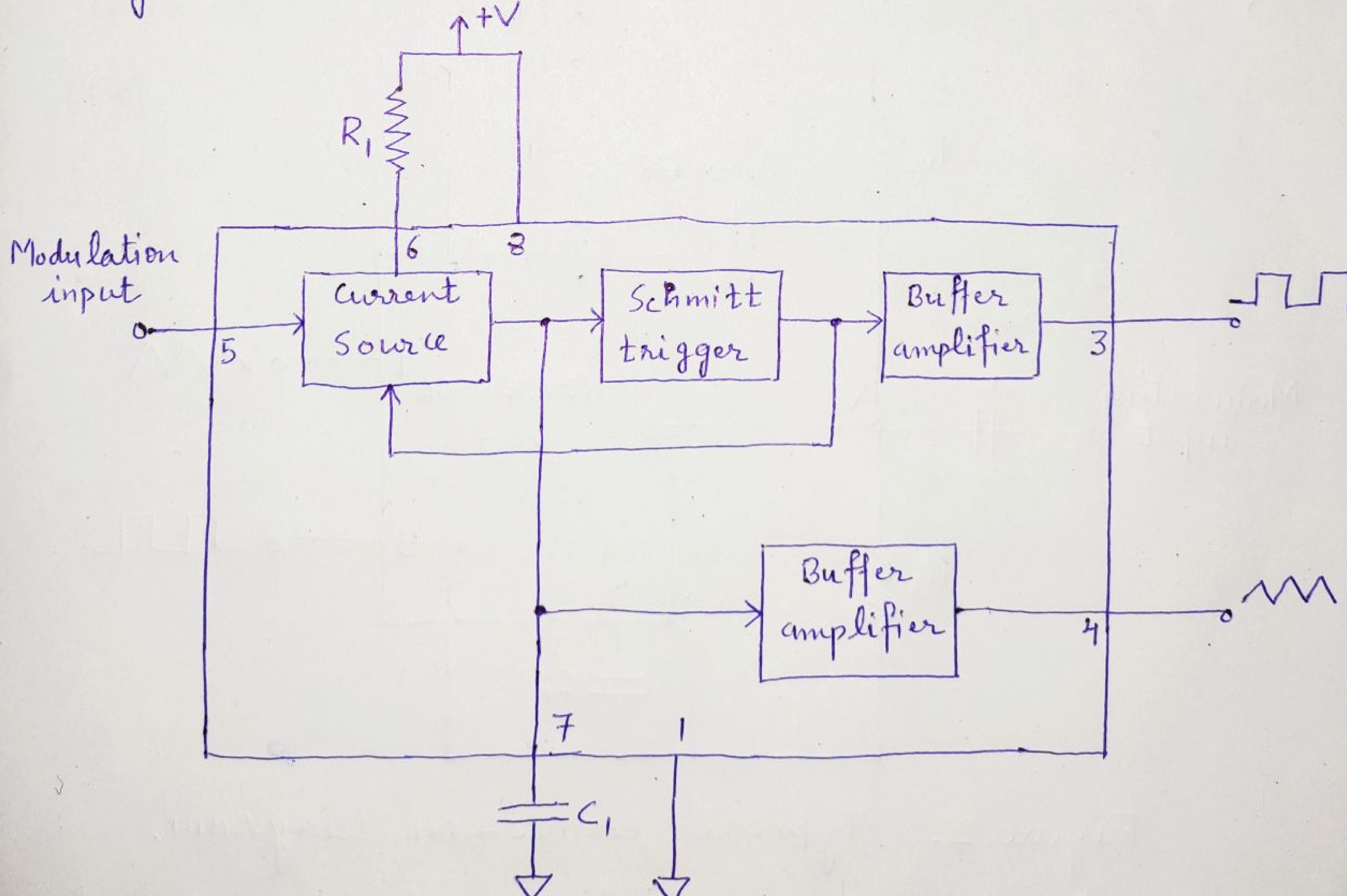

Figure 1. Block diagram of VCO 566.

The frequency of oscillation is determined by an external resistor R_1, capacitor C_1, and the voltage V_c applied to the control terminal 5. The triangular wave is generated by alternately charging the external capacitor C_1 by one current source and then linearly discharging it by another. The charge-discharge levels are determined by Schmitt trigger action. The Schmitt trigger also provides the square wave output. The output waveforms are buffered so that the output impedance of each is $50\,\Omega$. The typical amplitude of the triangular wave is 2.4 V pp and that of the square wave is 5.4 V pp.

Figure 2 is a typical connection diagram. In this

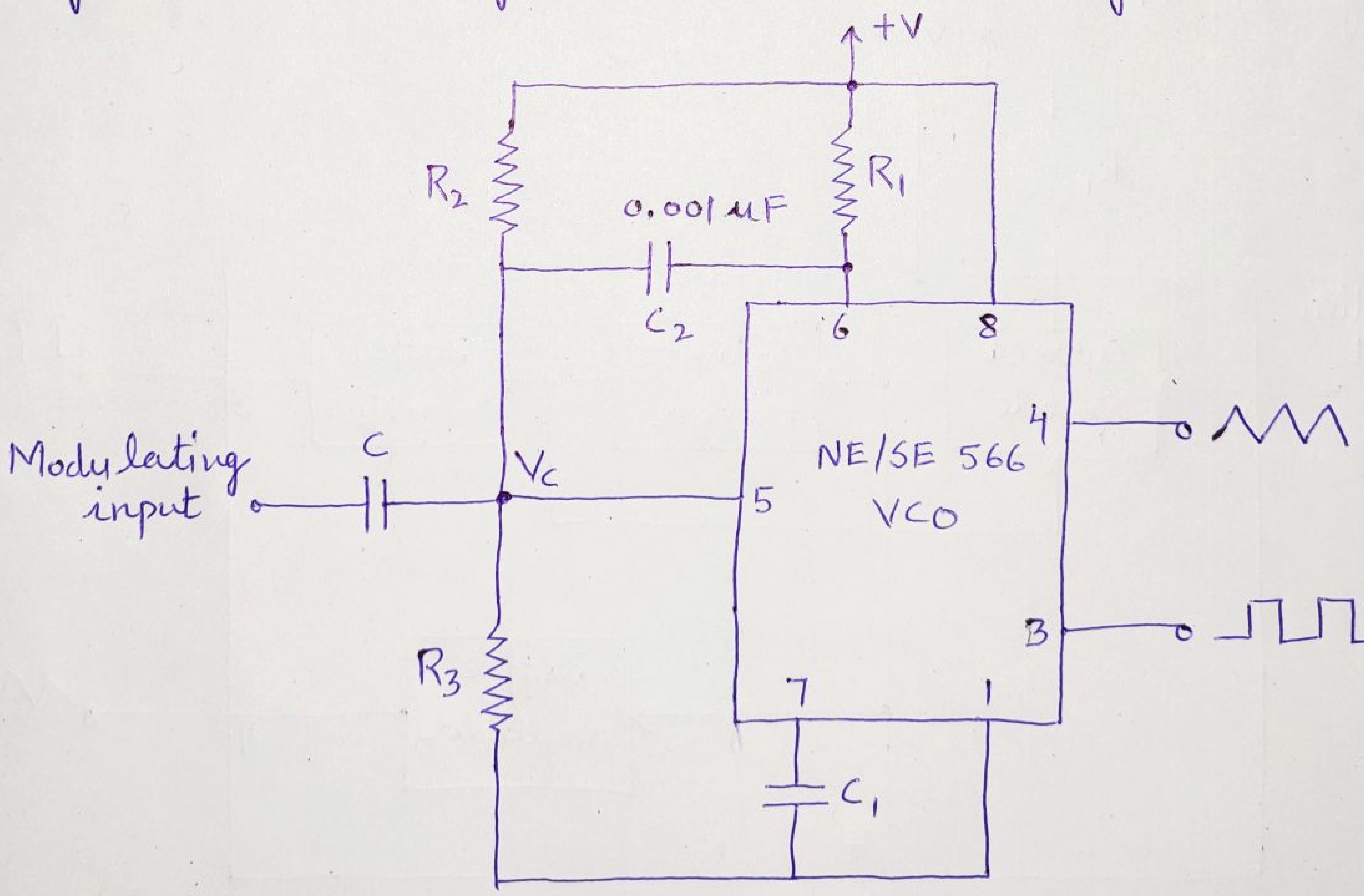

Figure 2. Typical Connection Diagram.

arrangement, the $R_1 C_1$ combination determines the free running frequency, and the control voltage V_c at terminal 5 is set by the voltage divider formed with R_2 and R_3. The initial voltage V_c at terminal 5 must be in the range

$$\frac{3}{4}(+V) \leq V_c \leq +V \quad \text{—— (1)}$$

where $+V$ is the total supply voltage. The modulating signal is ac coupled with the capacitor C and must be $< 3\ V_{pp}$. The frequency of the output waveforms is approximated by

$$f_o \cong \frac{2(+V - V_c)}{R_1 C_1 (+V)} \quad \text{—— (2)}$$

where R_1 should be in the range $2\ K\Omega < R_1 < 20\ K\Omega$. For a fixed V_c and constant C_1, the frequency f_o can be varied over a 10:1 frequency range by the choice of R_1 between 2 KΩ and 20 KΩ. Similarly, for a constant R_1C_1 product, the frequency f_o can be modulated over a 10:1 range by the control voltage V_c. In either case the maximum output frequency is 1 MHz. A small capacitor of 0.001 uF should be connected between pins 5 and 6 to eliminate possible oscillations in the control current source.

Comparators and Converters

A comparator, as its name implies, compares a signal voltage on one input of an op-amp with a known voltage called the reference voltage on the other input. In its simplest form, it is nothing more than an open loop op-amp, with two analog inputs and a digital output; the output may be (+) or (−) saturation voltage, depending on which input is the larger. Comparators are used in circuits such as digital interfacing, Schmitt triggers, discriminators, voltage-level detectors, and oscillators.

Basic Comparator

Figure 3 shows an op-amp used as a comparator. A fixed reference voltage Vref of 1V is applied to the (−) input, and the other time-varying signal voltage v_{in} is applied to the (+) input. Because of this arrangement, the circuit is called the noninverting comparator.

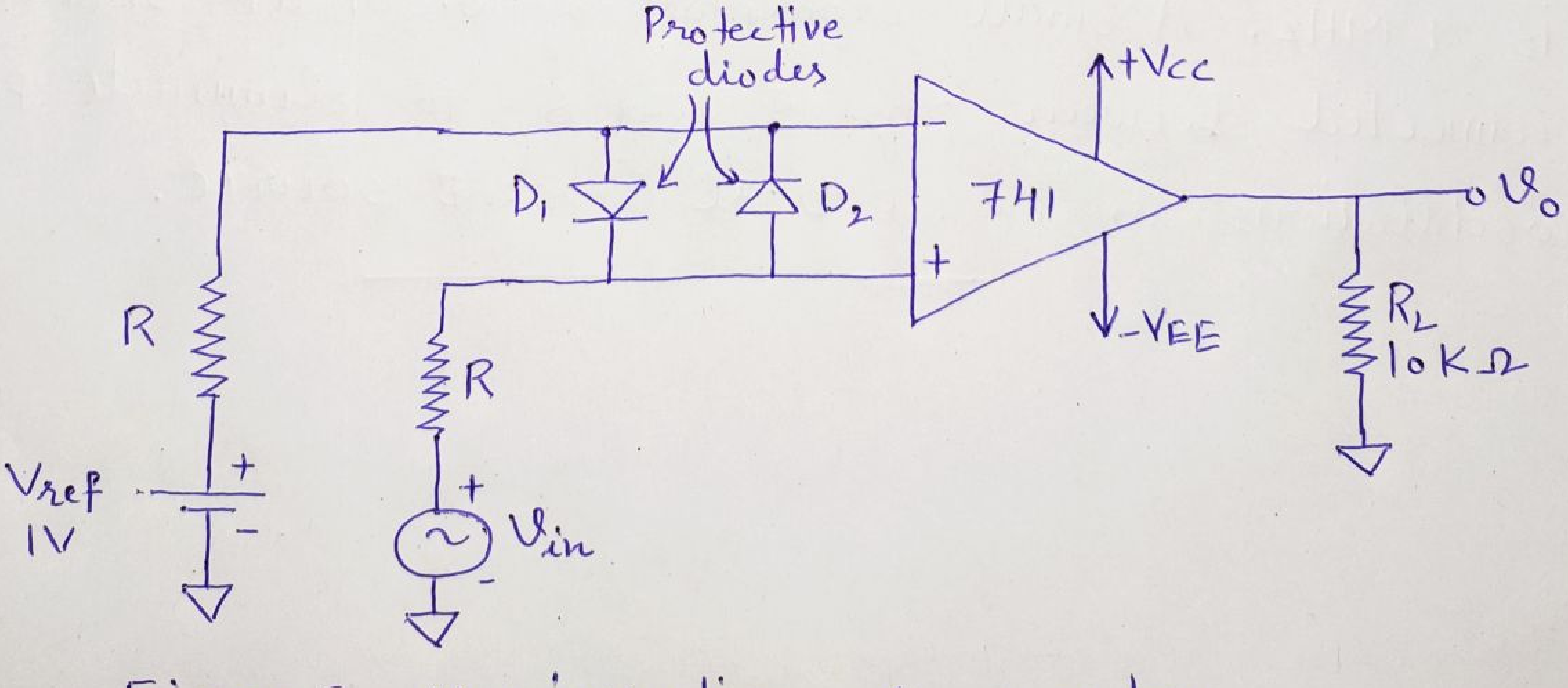

Figure 3. Noninverting Comparator.

When v_{in} is less than V_{ref}, the output voltage v_o is at $-V_{sat}$ ($\cong -V_{EE}$) because the voltage at the (−) input is higher than that at the (+) input. On the other hand, when v_{in} is greater than V_{ref}, the (+) input becomes positive with respect to the (−) input, and v_o goes to $+V_{sat}$ ($\cong +V_{CC}$). Thus v_o changes from one saturation level to another whenever $v_{in} \cong V_{ref}$ as shown in Figure 4(a). In short, the comparator is a type of analog-to-digital converter.

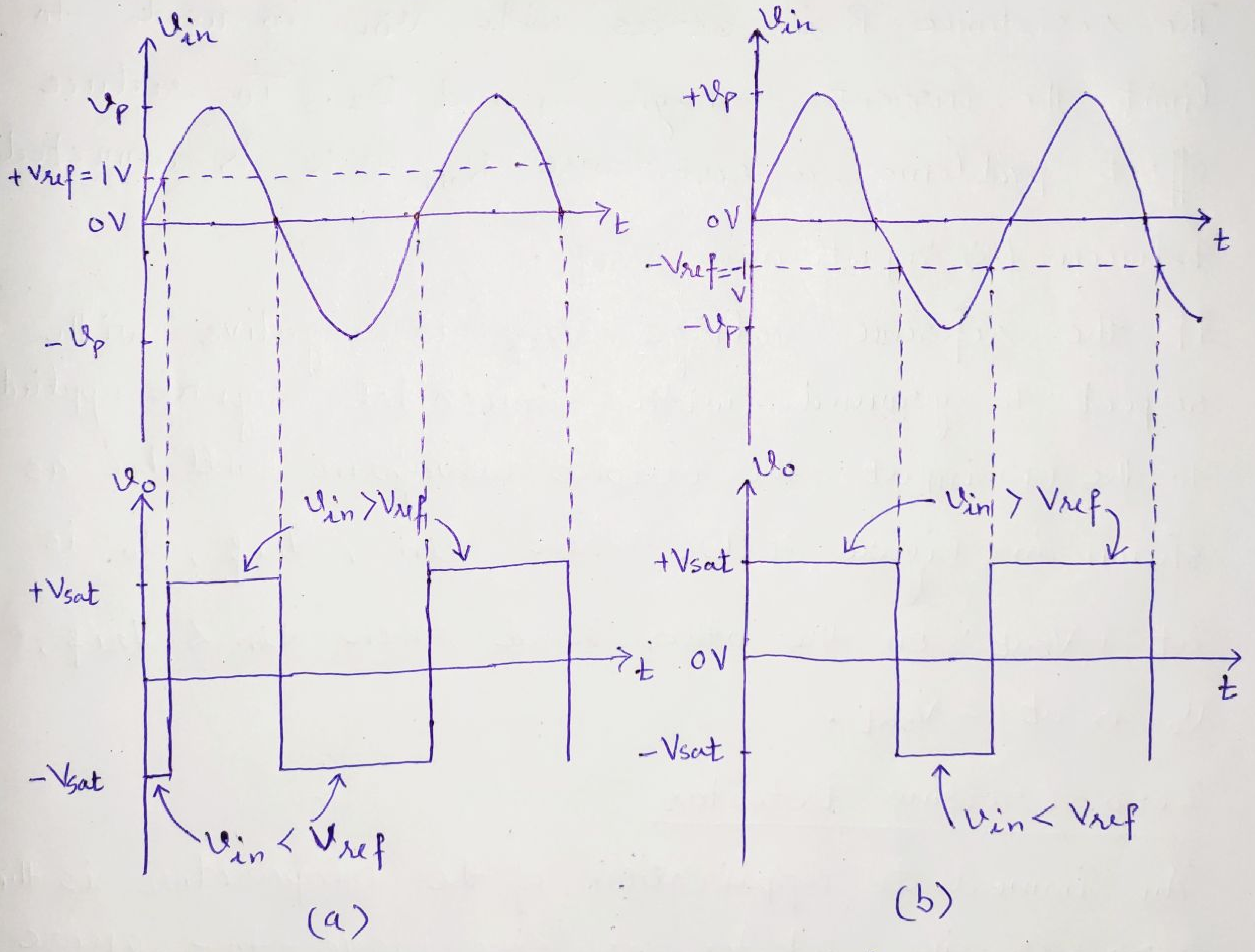

Figure 4. Input and Output waveforms (a) If V_{ref} is positive (b) If V_{ref} is negative.

At any given time the v_o waveform shows whether v_{in} is greater or less than V_{ref}. The comparator is

Sometimes also called a Voltage-level detector because, for a desired value of V_{ref}, the voltage level of the input v_{in} can be detected.

In Figure 3, the diodes D_1 and D_2 protect the op-amp from damage due to excessive input voltage v_{in}. Because of these diodes, the difference input Voltage V_{id} of the op-amp is clamped to either 0.7 V or -0.7 V; hence the diodes are called clamp diodes. The resistance R in series with v_{in} is used to limit the current through D_1 and D_2. To reduce offset problems, a resistance $R_{OM} \cong R$ is connected between (–) input and V_{ref}.

If the reference voltage V_{ref} is negative with respect to ground, with sinusoidal signal applied to the (+) input, the output waveform will be as shown in Figure 4 (b). When $v_{in} > V_{ref}$, v_o is at $+V_{sat}$; on the other hand, when $v_{in} < V_{ref}$, v_o is at $-V_{sat}$.

Zero Crossing Detector

An immediate application of the comparator is the zero-crossing detector or sine wave-to-square wave converter. The basic comparator of Figure 3 can be used as the zero-crossing detector provided that V_{ref} is set to zero ($V_{ref} = 0$ V). Figure 5 shows the inverting comparator used as a zero-crossing detector.

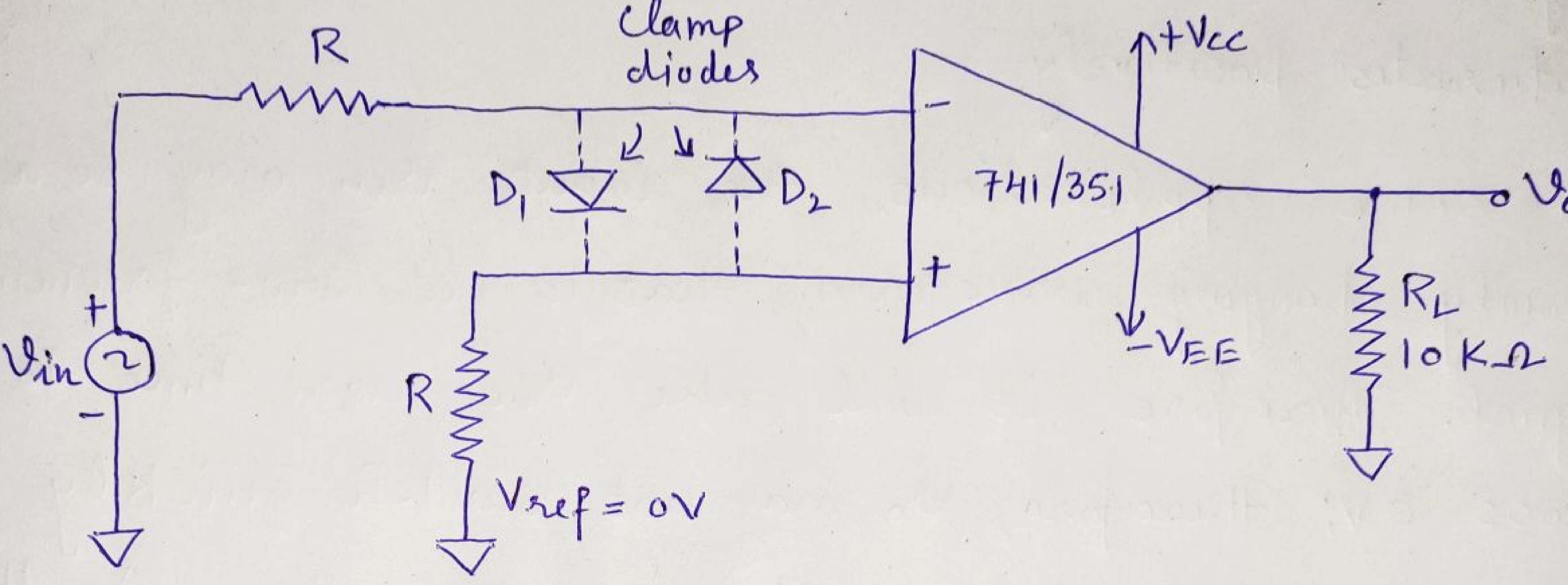

Figure 5. Zero-crossing detector

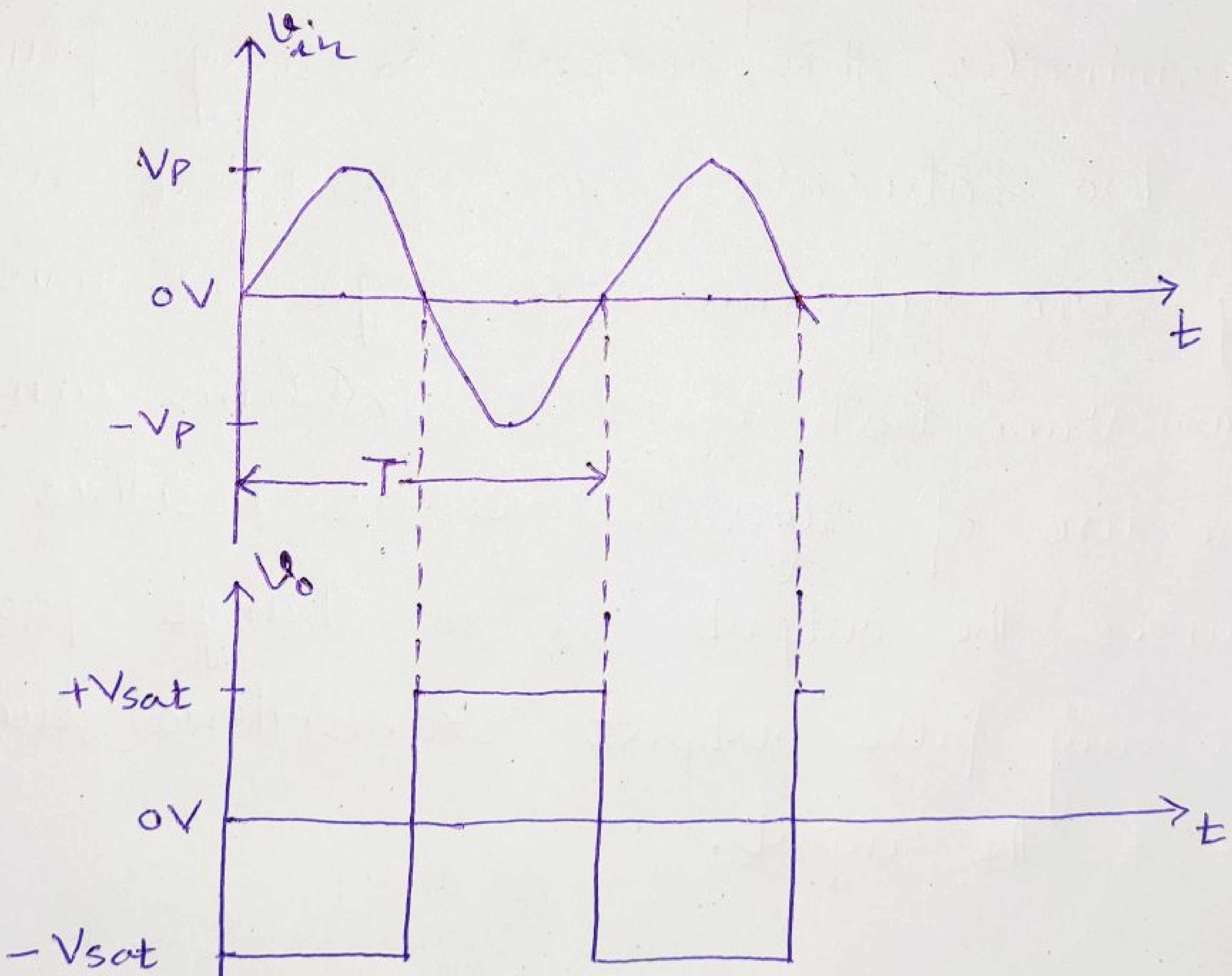

Figure 6. Typical input and output waveforms.

The output voltage v_o waveform in Figure 6 shows when and in what direction an input signal v_{in} crosses zero volts. That is, the output v_o is driven into negative saturation when the input signal v_{in}

passes through zero in the positive direction. Conversely, when v_{in} passes through zero in the negative direction, the output v_o switches and saturates positively.

In some applications, the input v_{in} may be a slowly changing waveform, that is, a low-frequency signal. Therefore, it will take v_{in} more time to cross 0V; therefore, v_o may not switch quickly from one saturation voltage to the other. On the other hand, because of the noise at the op-amp's input terminals, the output v_o may fluctuate between two saturation voltage $+V_{sat}$ and $-V_{sat}$, detecting zero reference crossings for noise voltages as well as v_{in}. Both of these problems can be cured with the use of regenerative or positive feedback that causes the output v_o to change faster and eliminate any false output transitions due to noise signals at the input.