An Overview on operational amplifier as Multivibrator

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ABSTRACT

Operational amplifier, which has high gain and high input impedance are the voltage amplifiers with two inputs and one output. The paper provides an overview of the operational amplifiers, from its history to the present innovation in the sectors of IC design. The paper also shells its intention on application of operational amplifier as Multivibrators. Astable, monostable and Bistable multivibrators are explained in different sections.

Keywords :-*Operational amplifiers , Differential op-amps*

A Brief History:

First developed by John R. Ragazzine in 1947 with vacuum tube. In 1960 at FAIRCHILD SEMICONDUCTOR CORPORATION, Robert J. Widlar fabricated operational amplifiers, with the help of IC fabrication technology. In 1968 FAIRCHILD introduced the op-amp that became the industry standard.

INTRODUCTION

The term “operational amplifier” denotes a special type of amplifier that, by proper selection of its external components, could be configured for a variety of operations.
An OP-AMP is voltage amplifier devices used with feedback components as resistance and capacitors in between the input and output terminal and with high gain amplifier with differential input to a single output.

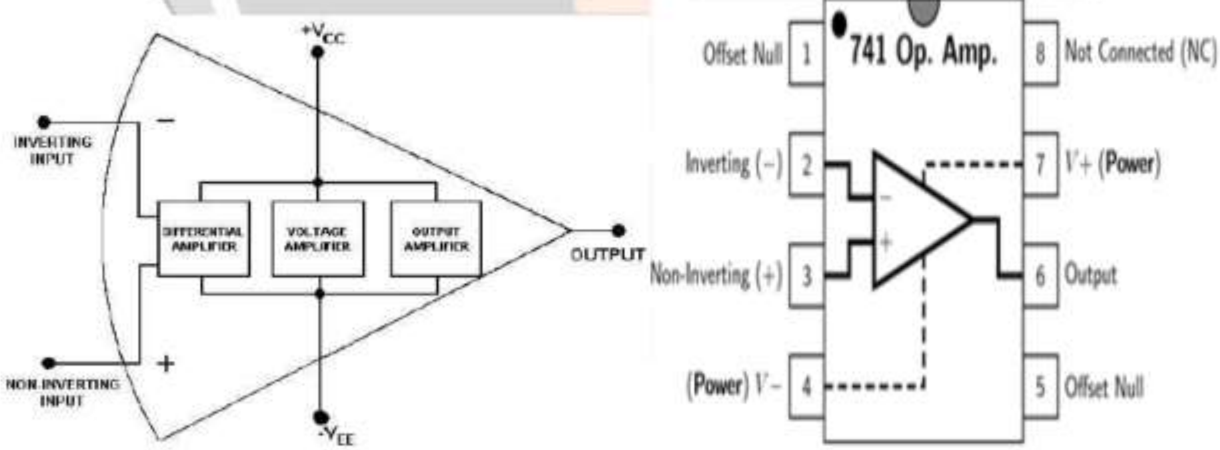


Fig 2.a

In figure 2.a, first diagram represents Block diagram of the operational amplifies and second diagram is the pin diagram of popular operational amplifier UA741.

OPERATIONAL AMPLIFIER AS A DIFFERENTIAL AMPLIFIER

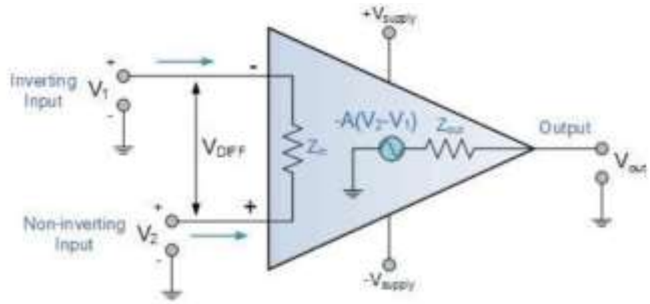


Fig 1a

There are two inputs at the input end namely(V+) and (V-). And the output is mentioned in the form of (Vout). Ideally when the both the inputs are connected to ground, the opamp must give a zero output. But due to the presence of the offset voltage and current, the output has some error in it.

From the fig 1a, it is evident that two ports (V1) and (V2) are internally shorted. And this figure a diffrential amplifier circuit. In this circuit, the output is equal to the diffrence of the two inputs.

$$V_{out} = A_g (V_+ - V_-)$$

Where Ag is the gain of the operational amplifier.

OPERATIONAL AMPLIFIERS AS MULTIVIBRATORS

The Op-amp Multivibrator is a non-inverting op-amp circuit that produces its own input signal with the aid of an RC feedback network.

Astable multivibrator switches continuously between its two unstable states without the need for any external triggering. But the problem with using these components to produce an astable multivibrator circuit is that for transistor based astables, many additional components are required, digital astables can generally only be used in digital circuits, and the use of a 555 timer may not always give us a symmetrical output without additional biasing components.

The operational amplifier multivibrator circuit however, can provide us with a good rectangular wave signal with the use of just four components, three resistors and a timing capacitor.

The Op-amp Multivibrator is an astable oscillator circuit that generates a rectangular output waveform using an RC timing network connected to the inverting input of the operational amplifier and a voltage divider network connected to the other non-inverting input.Unlike the monostable or bistable, the astable multivibrator has two states, neither of which are stable as it is constantly switching between these two states with the time spent in each state controlled by the charging or discharging of the capacitor through a resistor.In the op-amp multivibrator circuit the op-amp works as an analogue comparator. An op-amp comparator compares the voltages on its two inputs and gives a positive or negative output depending on whether the input is greater or less than some reference value, VREF.However, because the open-loop op-amp comparator is very sensitive to the voltage changes on its inputs, the output can switch uncontrollably between its positive, +V(sat) and negative, -V(sat) supply rails whenever the input voltage being measured is near to the reference voltage, VREF.

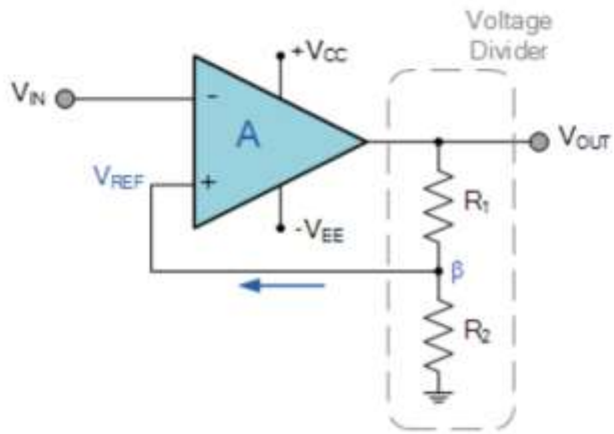
To eliminate any erratic or uncontrolled switching operations, the op-amp used in the multivibrator circuit is configured as a closed-loop Schmitt Trigger circuit. Consider the circuit below.

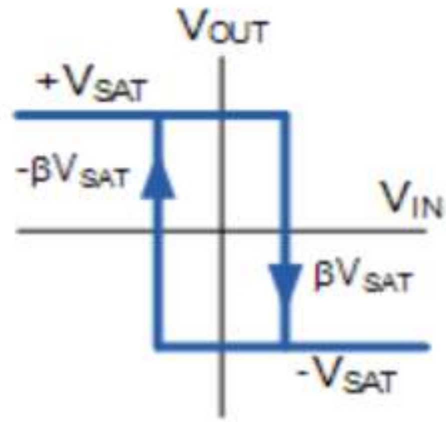
LITERATURE REVIEW

Bruce Carter, Texas Instruments Applications (Excerpts from) Thomas Brown’s original Preface

RESEARCH METHODOLOGY

Op-amp Schmitt Comparator





The op-amp comparator circuit above is configured as a Schmitt trigger that uses positive feedback provided by resistors R1 and R2 to generate hysteresis. As this resistive network is connected between the amplifiers output and non-inverting (+) input, when Vout is saturated at the positive supply rail, a positive voltage is applied to the op-amps non-inverting input. Likewise, when Vout is saturated to the negative supply rail, a negative voltage is applied to the op-amps non-inverting input.

As the two resistors are configured across the op-amps output as a voltage divider network, the reference voltage, Vref will therefore be dependant upon the fraction of output voltage fed back to the non-inverting input. This feedback fraction, β is given as:

$$\beta = \frac{R_2}{R_1 + R_2}$$

$$V_{out} = V_{sat}$$

$$V_{ref} = V_{out}\frac{R_2}{R_1 + R_2} = \beta V_{sat}$$

Where +V(sat) is the positive op-amp DC saturation voltage and -V(sat) is the negative op-amp DC saturation voltage.

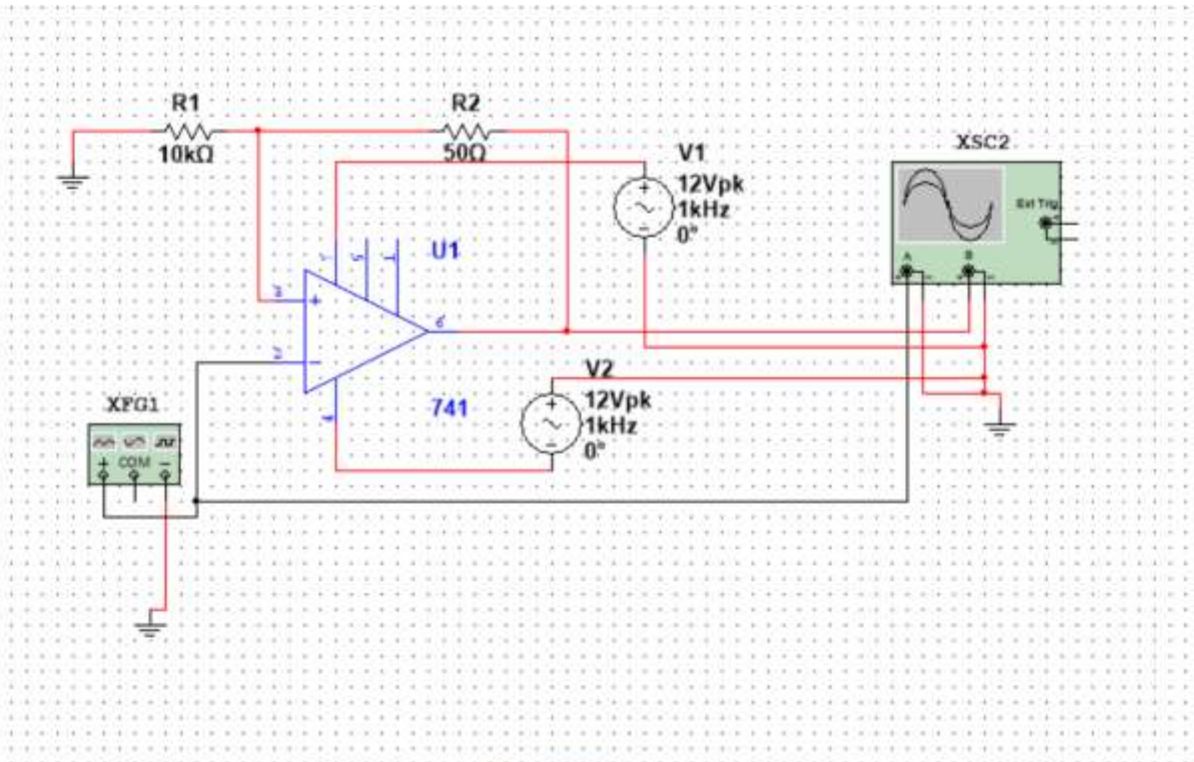
Then we can see that the positive or upper reference voltage, +Vref (i.e. the maximum positive value for the voltage at the inverting input) is given as: +Vref = +V(sat)β while the negative or lower reference voltage (i.e. the maximum negative value for the voltage at the inverting input) is given as: -Vref = -V(sat)β.

So if Vin exceeds +Vref, the op-amp switches state and the output voltage drops to its negative DC saturation voltage. Likewise when the input voltage falls below -Vref, the op-amp switches state once again and the output voltage will switch from the negative saturation voltage back to the positive DC saturation voltage. The amount of built-in hysteresis given by the Schmitt comparator as it switches between the two saturation voltages is defined by the difference between the two trigger reference voltages as: $V_{HYSTERESIS}$ = +Vref - (-Vref).

Sinusoidal to Rectangular Conversion

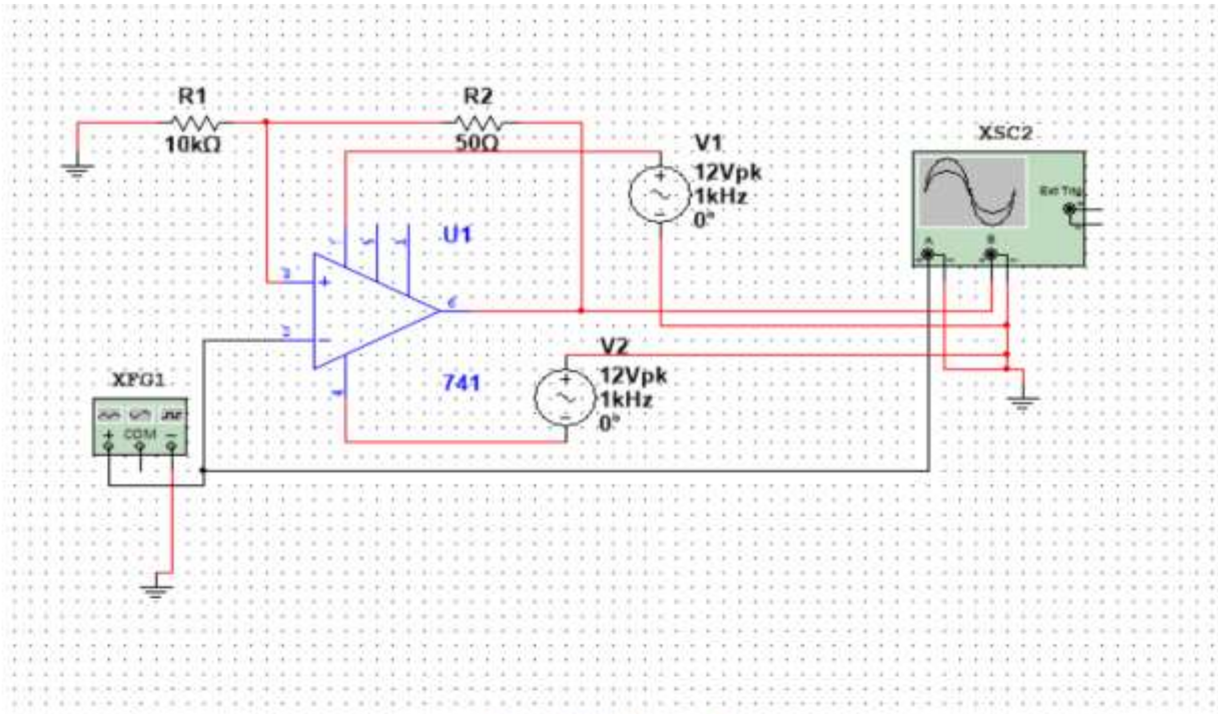
One of the many uses of a Schmitt trigger comparator, other than as an op-amp multivibrator, is that we can use it to convert any periodic sinusoidal waveform into a rectangular waveform providing the value of the sinusoid is greater than the voltage reference point.

In fact the Schmitt comparator will always produce a rectangular output waveform independent of the input signal waveform. In other words, the voltage input does not have to be a sinusoid, it could be any wave shape or complex waveform. Consider the circuit below.



As the input waveform will be periodical and have an amplitude sufficiently greater than its reference voltage, Vref, the output rectangular waveform will always have the same period, T and therefore frequency, *f* as the input waveform.
By replacing either resistor R1 or R2 with a potentiometer we could adjust the feedback fraction, β and therefore the reference voltage value at the non-inverting input to cause the op-amp to change state anywhere from zero to 90^{o} of each half cycle so long as the reference voltage, Vref remained below the maximum amplitude of the input signal.

We can take this idea of converting a periodic waveform into a rectangular output one step further by replacing the sinusoidal input with an RC timing circuit connected across the op-amps output. This time, instead of a sinusoidal waveform being used to trigger the op-amp, we can use the capacitors charging voltage, Vc to change the output state of the op-amp as shown.



Op-amp Multivibrator

So how does it work. Firstly let's assume that the capacitor is fully discharged and the output of the op-amp is saturated at the positive supply rail. The capacitor, C starts to charge up from the output voltage, Vout through resistor, R at a rate determined by their RC time constant.

We know about RC circuits that the capacitor wants to charge up fully to the value of Vout (which is +V(sat)) within five time constants. However, as soon as the capacitors charging voltage at the op-amps inverting (-) terminal is equal to or greater than the voltage at the non-inverting terminal (the op-amps output voltage fraction divided between resistors R1 and R2), the output will change state and be driven to the opposing negative supply rail.

But the capacitor, which has been happily charging towards the positive supply rail (+V(sat)), now sees a negative voltage, -V(sat) across its plates. This sudden reversal of the output voltage causes the capacitor to discharge toward the new value of Vout at a rate dictated again by their RC time constant.

Op-amp Multivibrator Voltages

Once the op-amps inverting terminal reaches the new negative reference voltage, -Vref at the non-inverting terminal, the op-amp once again changes state and the output is driven to the opposing supply rail voltage, +V (sat). The capacitor now see's a positive voltage across its plates and the charging cycle begins again. Thus, the capacitor is constantly charging and discharging creating an astable op-amp multivibrator output.
The period of the output waveform is determined by the RC time constant of the two timing components and the feedback ratio established by the R1, R2 voltage divider network which sets the reference voltage level. If the positive and negative values of the amplifiers saturation voltage have the same magnitude, then t1 = t2 and the expression to give the period of oscillation becomes:

$$\beta = \frac{R_2}{R_1 + R_2}$$

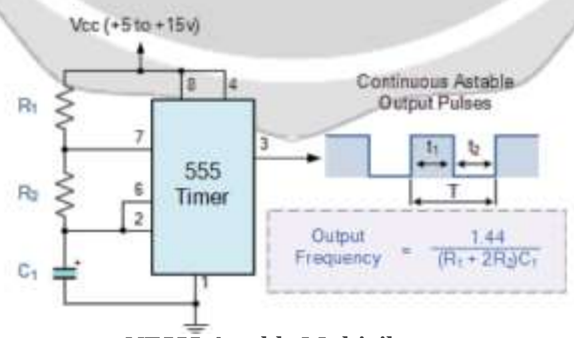
$$T = 2RC\ln\frac{1+\beta}{1-\beta}$$

$$\therefore f = \frac{1}{T}$$

Then we can see from the above equation that the frequency of oscillation for an Op-amp Multivibrator circuit not only depends upon the RC time constant but also upon the feedback fraction. However, if we used resistor values that gave a feedback fraction of 0.462, (β = 0.462), then the frequency of oscillation of the circuit would be equal to just 1/2RC as shown because the linear log term becomes equal to one.

555 Timer Circuit used as astable multivibrator.
Astable multivibrator can be easily designed by a commonly available waveform generating IC's and to create timing and oscillator circuit. Relaxation oscillators can be designed by connecting passive components to their input pins and waveform generator type IC being the classic 555 timer.

The 555 Timer is a very versatile low cost timing IC that can produce a very accurate timing periods with good stability of around 1% and which has a variable timing period from between a few micro-seconds to many hours with the timing period being controlled by a single RC network connected to a single positive supply of between 4.5 and 16 volts.
Some of the types of 555 timer include ICM7555, CMOS LM1455, DUAL NE556 . The 555 connected as an Astable Multivibrator is shown below.



NE555 Astable Multivibrator

Here the 555 timer is connected as a basic Astable Multivibrator producing a continuous output waveform. Pins 2 and 6 are connected together so that it will re-trigger itself on each timing cycle, thereby functioning as an Astable oscillator. Capacitor, C1 charges up through resistor, R1 and resistor, R2 but discharges only through resistor, R2 as the other side of R2 is connected to the discharge terminal, pin 7. Then the timing period of t_1 and t_2 is given as:

$$t_1 = 0.693\,(R_1 + R_2)\,C_1$$
$$t_2 = 0.693\,(R_2)\,C_1$$
$$T = t_1 + t_2 = 0.693\,(R_1 + 2R_2)\,C_1$$

The voltage across the capacitor, C1 ranges from between 1/3 Vcc to approximately 2/3 Vcc depending upon the RC timing period. This type of circuit is very stable as it operates from a single supply rail resulting in an oscillation frequency which is independent of the supply voltage Vcc.

CONCLUSION

It is evident that the operational amplifiers are universal, they can be used as voltage comparators, precision rectifiers, analog to digital converters, Accurate testing and measurement instruments and are highly stable and reliable. Though the disadvantages like ; it can be used only for low power operation, long range transmission issues exist; operational amplifiers are the only option left for many applications.

As multivibrators are used as frequency dividers, saw tooth generators, wave and pulse generators, standard frequency source, and are implemented in radar, TV circuits ; operational amplifies are the main components in such circuits. Hence by this paper the importance of operational amplifiers as multivibrators is demonstrated.

REFERENCES

1. P. R. Gray, R. G. Meyer, Analysis and Design of Integrated Circuits, New York:Wiley, 1977.
2. R. S. Muller, T. I. Kamins, Device Electronics for Integrated Circuits, New York:Wiley, 1977.
3. V. Ruediger, *Das Impulsverhalten von Operationsverstaerkern*, 1979.
4. J. E. Solomon, "The monolithic op amp: A tutorial study", *IEEE J. Solid-State Circuits*, vol. SC-9, pp. 314-332, Dec. 1974.
5. D. Fullager, "A new high performance monolithic operational amplifier", *Fairchild Semiconductor App. Brief.*, May 1968.
6.Ramakant A. Gayakward, Op-Amps and Linear Integrated Circuits: Pearson Education.
7.National Semiconductor, LM741 Operational Amplifier: August 2000.
8. S. Pennisi, High-performance CMOS current feedback operational amplifier, in Proc. IEEE Int.Symp. on Circ. and Syst. (ISCAS), II, Kobe, Japan, pp. 1573–1576 (2005)
9. Heydari, P., Mohavavelu, R., “Design of Ultra High-Speed CMOS CML buffers and Latches,” Proceedings of the 200 Int’l Symposium on Circuits and Systems, Vol. 2, May 2003[5] Application note by Interstil, Converting from Voltage-Feedback to Current-Feedback Amplifiers.
10.Application note by Texas Instruments, Voltage Feedback vs. Current Feedback Op-Amps.