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Design and Implementation of Opamp based Relaxation Oscillator

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***Abstract*—*A Relaxation oscillator is an oscillator circuit that generates a non-sinusoidal output; the time period of which depends on the charging time of the capacitor connected as a part of the oscillator circuit. Opamp adapt very well to the construction of Relaxation oscillator that produces a rectangular output. Opamp Relaxation oscillator is a simple square wave generator which is also known as a free running oscillator. The state of the art presented in the paper is the non- sinusoidal waveform generation in the form of rectangular waveform using opamp µA-741 IC.*

***Keywords*—** *Charging time of capacitor, non-sinusoidal output, opamp, rectangular waveform, relaxation oscillator.*

I. INTRODUCTION

Among various general purpose linear Integrated circuits, operational amplifier IC popularly known as Opamp is unarguably the most widely used IC.

Operational amplifier is a high gain differential amplifier having the ability of amplifying signals right down to DC because of the use of direct coupling in the device's internal architecture. Owing to its high differential gain, high input impedance, low output impedance, high bandwidth and various other desirable features, Opamps fit into almost every conceivable circuit applications ranging from amplifiers to oscillators, computational building blocks to data conversion circuits, active filters to regulators and so on. [1]

A Relaxation oscillator is defined as a non-linear electronic oscillator circuit that generates a continuous or repetitive non-sinusoidal output signal in the form of rectangular wave, triangular wave or a sawtooth wave. The Relaxation oscillator basically contains of a feedback loop that has a switching device in the form of transistor, relays, operational amplifiers, comparators or a device having negative resistance like a tunnel diode, that charges a capacitor or an inductor repetitively through a resistance till it reaches a threshold level, then discharges it again. The period of oscillation is dependent on the time constant of the capacitor or the inductor circuit. Owing to the abruptly switching of the active device between charging and discharging modes, it results in the generation of discontinuously varying repetitive waveform [2], [3], [5]. Basically Relaxation oscillator circuits are used to generate low frequency signals, that finds applications in blinking lights, electronic beepers as well as in Voltage controlled oscillators (VCOs), Inverters, switching power supplies, dual slope Analog to Digital converters and function generators.

The rest of the paper is organized into sections as follows: Section II describes the Opamp Relaxation oscillator overview. Section III focuses on the system design. Experimental results and discussions are reported in Section IV. Finally, Section V summarizes the paper and presents the concluding remarks.

II. OPAMP RELAXATION OSCILLATOR OVERVIEW

A. Concept of Rectangular Waveform Generation Using Opamp

It is possible to create or generate an output signal with no externally applied input signal. Feedback plays a vital role in order to achieve this. To be precise with positive feedback, oscillator as well as other circuits can be build that can generate an output signal in the absence of external input signal. Opamp circuits can be used to generate non-sinusoidal signals such as square waveform, rectangular waveform triangular waveform, ramp waveform etc. In the proposed system the designed opamp circuit with positive feedback is used to generate a Rectangular waveform. [2-4].

B. Working of Opamp Relaxation Oscillator

Figure 1 shows the basic circuit arrangement of an opamp based Relaxation oscillator circuit.

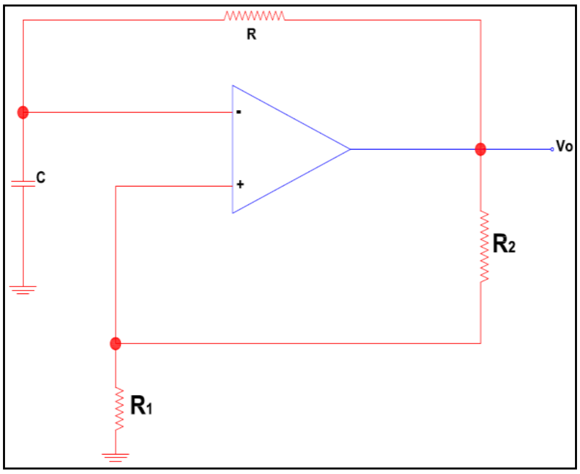

Fig. 1. Opamp relaxation oscillator circuit.

The circuit functions as follows Let us assume that the output is initially in positive saturation. Due to this, voltage at the non-inverting input of opamp is given by "(1)".

$$+V_{SAT} \text{ x } R_1/ (R_1+ R_2) \quad (1)$$

This compels the output to remain in the positive saturation level as the capacitor C is initially in fully discharged stage. Now the capacitor C begins to charge towards $+V_{SAT}$ through the resistance R. As the capacitor

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voltage exceeds the voltage at the non-inverting input of the opamp, the output switches to the negative saturation voltage -V_{SAT}. Thus the voltage at the non-inverting input also changes as per "(2)".

$-V_{SAT} \times R_1/(R_1+R_2)$ (2)

The capacitor now begins to discharge and after reaching zero it starts to discharge towards -V_{SAT}. Again, as soon as it becomes more negative than the negative threshold appearing at the non-inverting input of the opamp, the output switches back to +V_{SAT}. In this way the cycle repeats thereafter, resulting in a rectangular wave as output. The equation for the time period output waveform is derived from the exponential charging and discharging process and is given by "(3)".

$T = 2RC \ln[(1+\beta)/(1-\beta)]$ (3)

Where $\beta = R_1/(R_1+R_2)$.

Figure 2 shows relevant waveforms. The time period of the output can be conveniently varied by varying the value of resistor R. [2-4].

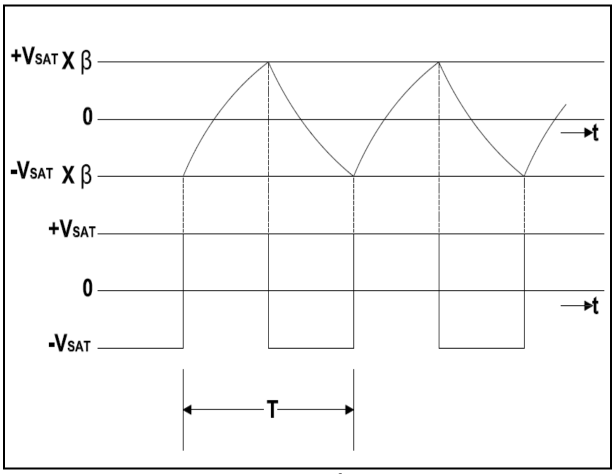

Fig. 2. Waveforms.

III. SYSTEM DESIGN

A. Hardware Design

The time period T of the rectangular output waveform is given by "(4)".

$T = 2RC \ln[(1+\beta)/(1-\beta)]$ (4)

In equation 4 the natural logarithm is used, which is logarithm to base *e*. β is the feedback fraction also known as feedback factor and is given by "(5)"

$\beta = R_1/(R_1+R_2)$ (5)

In "(5)" when $R_1 = R_2$, "(4)" becomes

$T = 2RC \ln(3)$ (6)

If we choose $R_2 = 1.16\, R_1$, then "(4)" becomes

$T = 2RC$ (7)

For a frequency of design 1 kHz means,

$T = 1/f$ (8)

$T = 1/10^3$

$T = 10^{-3}$

Hence, T = 1ms

Let $R_1 = 10K\Omega$, then $R_2 = 11.6\ K\Omega$ (use a 20 KΩ potentiometer)

Choosing a suitable value of C, the value of R can be calculated using "(7)".

Let C = 0.1µF, then R = T/2C

$R = (1 \times 10^{-3})/(2 \times 0.1 \times 10^{-6})$

Therefore, R = 5 KΩ.

Based on the hardware design, the circuit schematic for the Opamp Relaxation oscillator is shown in figure 3.

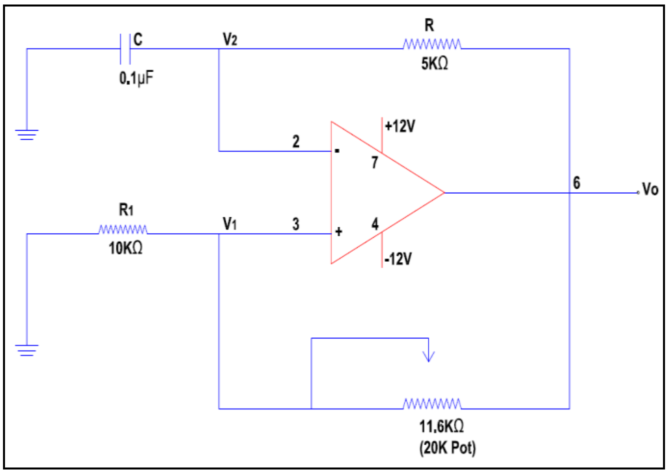

Fig. 3. Circuit schematic.

B. Proposed System Specifications

The table I illustrates the system specifications.

TABLE I. Proposed system specifications.

Sl. No.	Specifications
1.	Domain: Analog Electronics, Electronic circuits
2.	Digital I.C trainer kit
3.	Power Supply: DC regulated power supply (+12V, -12V)
4.	Opamp I.C : µA-741
5.	Resistors : 5KΩ, 10KΩ
6.	Capacitor : 0.1µF
7.	Multimeter
8.	Potentiometer : 11.6 KΩ (20K-pot)
9.	Connecting probes, patch cords, single stranded connecting wires, crocodile clips.
10.	Cathode ray oscilloscope (CRO)
11.	Simulation software: Multisim 11.
12.	Applications: Non- sinusoidal waveform generation such as Rectangular, Ramp etc.

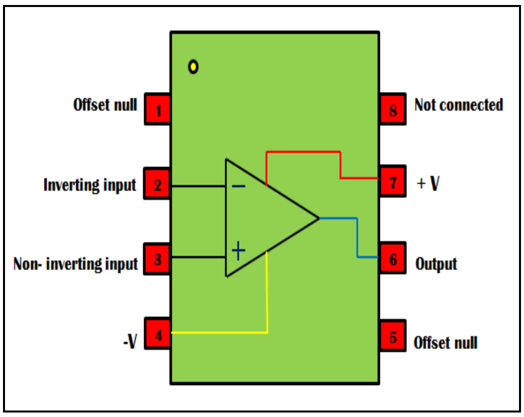

Fig. 4. Pin diagram opamp IC µA-741.

C. Opamp IC µA-741 Overview

The IC µA-741is a general purpose operational amplifier featuring offset voltage null capability. The device is short circuit protected and the internal frequency compensation ensures stability without external components. The µA-741 is specified for operation from ±5 V to ±15 V and is characterized for operation from 0° C to 70° C. Fig. 4 shows the pin diagram of opamp IC µA-741. It is an 8 pin IC packed in dual in line package. [8]

Different pins of the IC are designated as Offset null (pin no.1), Inverting input (pin no.2), Non-inverting input (pin no.3), Negative supply –V (pin no.4), Offset null (pin no.5), Output (pin no.6), Positive supply (pin no.7) and No connection (pin no.8).

D. *Proposed System Set Up*

The experimental set up was done in the Analog and Digital electronics laboratory. Based on the system design the required components were taken and the resistors were checked using a Multimeter. The system was rigged up as per the circuit schematic on a Digital IC trainer kit and the power supply was switched ON to get output waveform in the form of rectangular waveform and then to get a capacitor voltage waveform in the form of a ramp waveform. The rigged up circuit for the two cases are depicted in figure 5 and 6 respectively.

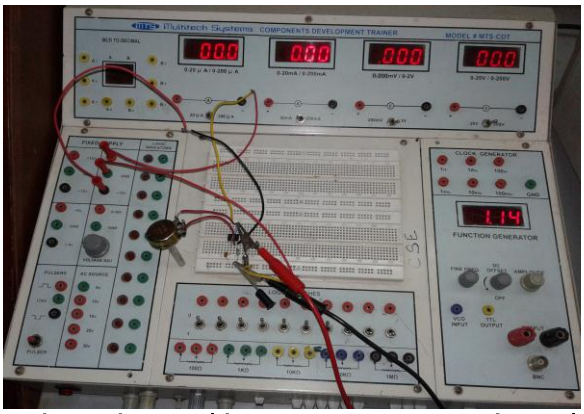

Fig. 5. Photographic view of the system to generate Rectangular waveform.

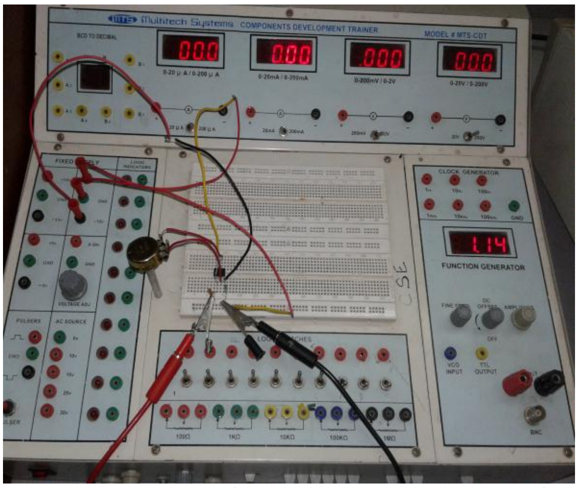

Fig. 6. Photographic view of the system to generate Ramp waveform.

IV. Experimental Results

A. *Hardware Results*

The output waveform in the form of a Rectangular wave was observed on the CRO when the positive probe from channel 2 was connected at output pin (pin number 6) of opamp IC and the negative probe connected to the ground. The capacitor voltage waveform in the form of Ramp wave was observed when the positive probe from channel 2 was connected to pin number 2 of the opamp IC and negative probe connected to the ground. A CRO has two channels namely channel 1 and channel 2. Since in the present case no input is required, hence any of the two channels can be used for seeing the output waveform. The output waveform and the voltage waveform across the capacitor are shown in figure 7 and 8 respectively.

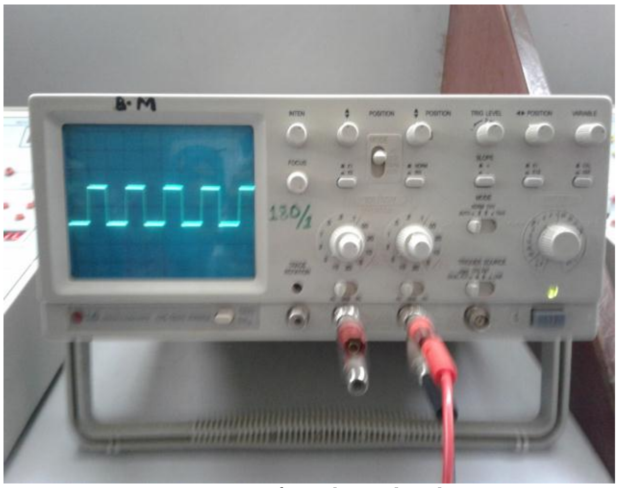

Fig. 7. Output waveform observed on the CRO.

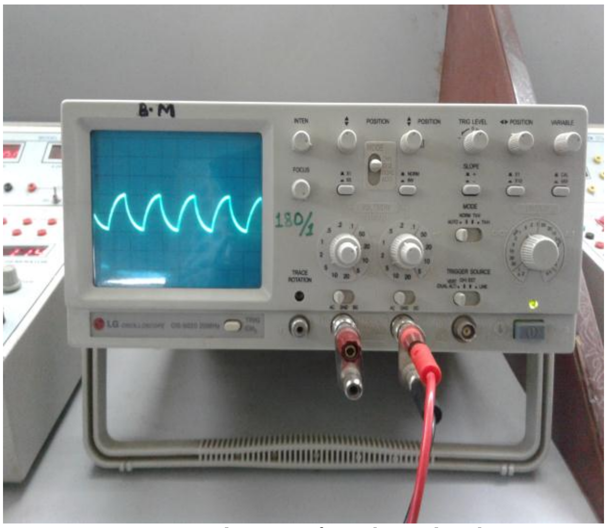

Fig. 8. Capacitor voltage waveform observed on the CRO.

The amplitude of the output waveform is noted down and calculated as follows

Amplitude = [Number of divisions covered by the wave along Y-axis (vertically) x Multiplying factor of channel 2]

Amplitude = [2x5]

= 10 V

Time Period T = [Number of divisions covered by the wave along X-axis (horizontally) x Time/division]

Time Period T = [2x 0.5 msec]

Hence, T = 1 msec.
Frequency F = [1/Time period]
F = [1/T]
F = [1/ (1x10^{-3})]
Therefore F = 1 KHz.

B. *Simulation Results*

The Opamp Relaxation oscillator (Rectangular waveform generator) is designed and implemented using Multisim Simulation package. The simulation circuit is shown in figure 9.

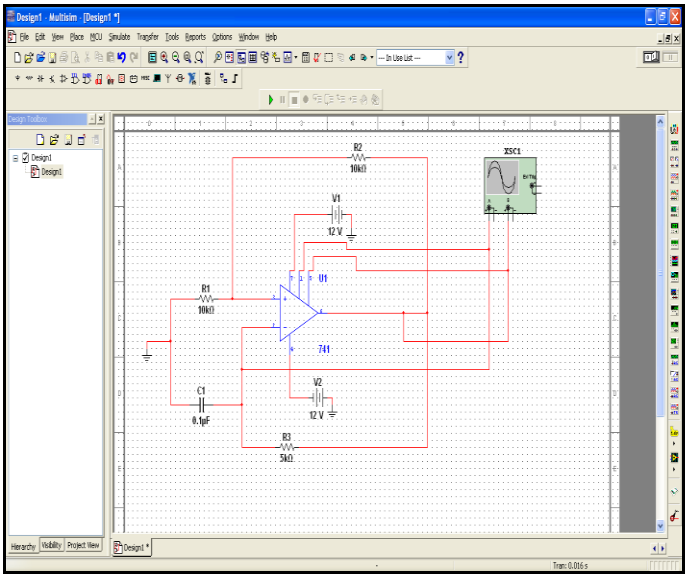

Fig. 9. Simulation circuit schematic.

The waveforms for the simulation circuit are shown in figure 10.

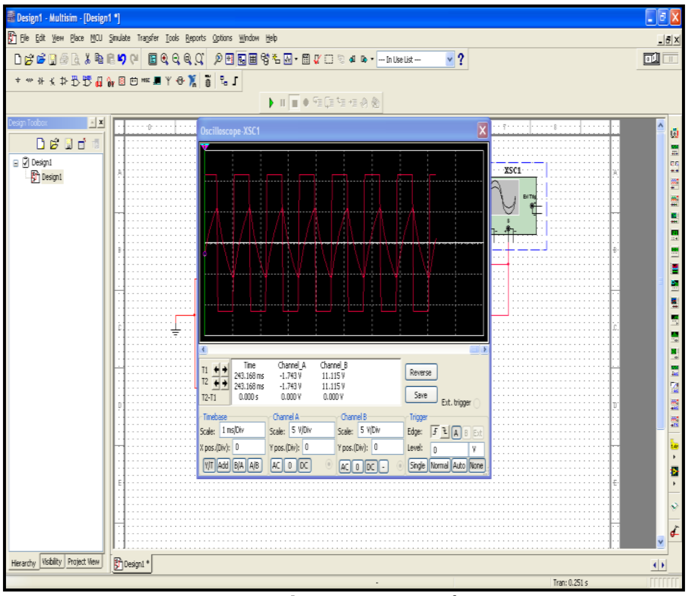

Fig. 10. Simulation circuit waveforms.

V. Conclusion

Opamp Relaxation oscillator circuit was designed and implemented. The designed system showed excellent characteristics and Precise Hardware and Simulation results were obtained. Opamp Relaxation oscillator circuit is very simple and easy to design requiring few components. In addition the system uses low power consumption through opamp. Furthermore, as opamp IC 741 is used, the designed system is very stable, reliable, easy to handle and requires less cost. Owing to these numerous advantages, it is used in a large number of applications such as controlling the timing of operations in digital systems, such as clock generators for microprocessors. They also find uses in analog circuits as simple lamp flashers to complex control systems such as Pulse width control systems for audio and radio applications.

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References

[1] A. K. Maini and V. Agarwal, Introduction to Operational amplifiers, *Electronic Devices and Circuits*, New Delhi: Wiley India Pvt. Ltd, pp. 627-629, 2009.

[2] A. Malvino and D. J. Bates, Nonlinear Opamp Circuits, *Electronic Principles*, New Delhi: Tata Mc Graw Hill, 7th Edition (Special Indian Edition), pp-869-871, 2007.

[3] A. K. Maini and V. Agarwal, Operational Amplifier Application Circuits, *Electronic Devices and Circuits*, New Delhi: Wiley India Pvt. Ltd, pp. 690-691, 2009.

[4] D. Liang Wang, Relaxation Oscillators and Networks, *Wiley Encyclopedia of Electrical and Electronics Engineering*, vol. 18, Wiley & Sons, pp. 396-405, 1999, Retrieved February 2, 2014.

[5] A. P. Godse and U. A. Godse, Operational Amplifier Application circuits, *Analog & Digital Electronics*, Pune: Technical publications (First edition), chapter 3, pp- 72-76, 2016.

[6] S. Varigonda and T. T. Georgiou, "Dynamics of relay relaxation oscillators," *IEEE Transactions on Automatic control, Institute of Electrical and Electronics Engineering*, January 2001, Retrieved February 22, 2014.

[7] C. R. Nave, "Relaxation oscillator concept," Hyper physics, Dept. of Physics and Astronomy, Georgia State University, February 2014.

[8] Opamp µA-741Data sheet, *Texas Instruments*, pp. 1-2, November 1970, revised January 2015.

[9] J. K. N. Shukla, "Discontinuous theory of Relaxation Oscillators," M.S Thesis, Department of Electrical Engineering, Kansas state university, 1965, Retrieved February 23, 2014.

[10] C. R. Nave, "Relaxation oscillator concept," Hyper physics, Dept. of Physics and Astronomy, Georgia State University, February 2014.

[11] R. P. Jain and M. M. S Anand, *Digital Electronics practice using Integrated circuits*, Tata Mc Graw Hill education, pp. 158-160, 1983.