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Closed loop analysis of a triangular wave generator

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In this paper an analysis has been given of a closed loop system having an integrator, an On–Off element with hysteresis and a multiplier. It has been shown that the output of the integrator will be a train of triangular waves. Practical implementation of such a system using integrated circuits has been given.

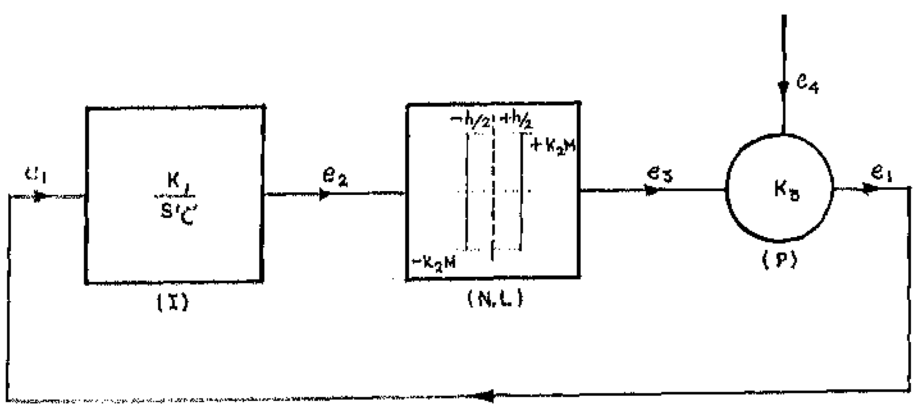
1. Introduction

Applications requiring a triangular wave generator that gives a symmetrical output, and the frequency of which can be varied over a wide range by an external input voltage, are many-fold. The theoretical basis for the design of such a system has been presented here, based on the closed loop analysis. A scheme for practical implementation that uses integrated circuit blocks, is also provided. The circuit described by Klein and Hagenbeuk (1907) for this purpose, however, uses only discrete components.

2. Analysis

In figure 1 is shown the schematic block diagram of the closed loop, that has an integrator (I), a non-linear element (N.L.), an On–Off element with

Fig. 1



Schematic of the closed loop.

hysteresis, and a multiplier (P). Much element has the respective transfer functions shown inside ench box. e_1, e_2, e_3 and e_4 are as follows :

e_1 = fed back voltage/output voltage of the multiplier,
e_2 = output voltage of the integrator,
e_3 = output voltage of the On–Off element,
e_4 = external voltage input to the multiplier.

Now

$$e_1 = \pm K_2 M K_3 e_4, \tag{1}$$

$\pm$ sign indicates : for $e_1 = \pm h/2$ switching takes place.

and

$$e_2 = \frac{K_1}{ST} e_1 \tag{2}$$

or

$$\frac{de_2}{dt} = \pm \frac{K_1 K_2 K_3 M e_4}{T}$$

or

$$e_2 = \pm \frac{K_1 K_2 K_3 M e_4}{T} t + C,$$

where C is a constant of integration.

At time $t = 0$; $e_2 = 0$;

$$\therefore \quad C = 0,$$

and calling

$$\frac{K_1 K_2 K_3 M e_4}{T} = \lambda ; \tag{3}$$

$$\therefore \quad e_2 = \pm \lambda t. \tag{4}$$

3. Discussion

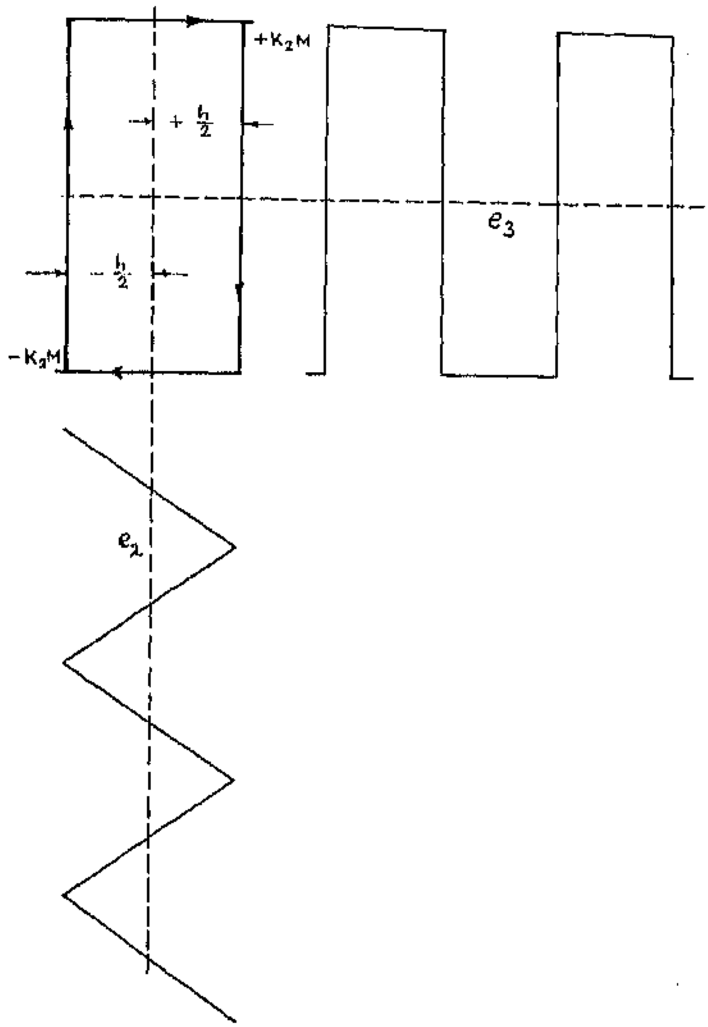
Figure 2 shows the process of switching. The output of the integrator is a ramp function. No switching takes place, until the value of e_2 reaches $h/2$. When $e_2 > +h/2$, switching takes place. When switching has occurred the slope of e_2 changes from $+\lambda$ to $-\lambda$ and the next switching takes place only when $e/2 = -h/2$. The time T taken to complete one cycle is, therefore the time taken for e_2 to change from $e_2 = -h/2$ to $e_2 = +h/2$ and back to $e_2 = -h/2$, i.e. through h. Since λ is the slope,

$$T = \frac{2h}{\lambda}. \tag{5}$$

Thus the frequency of the generated triangular waves in

$$f = \frac{\lambda}{2h}. \tag{6}$$

Fig. 2

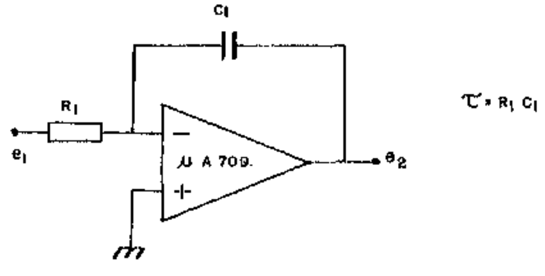


Hence, by varying A or h, it is possible to vary the frequency of the generated triangular waves. For a given value of T, K_1 and K_3e_4, either by setting the value of K_2M by the use of a potentiometer at the output of the On–Off element, or by setting the value of h, it is possible to make the system oscillate at the required frequency. And now, if e_4 is varied, f changes linearly. Thus the system can be used as a linear voltage controlled oscillator. In addition to the triangular waves, the output of the On–Off element is a train of square waves. It is also possible to produce sine waves by properly shaping the triangular waves with diodes.

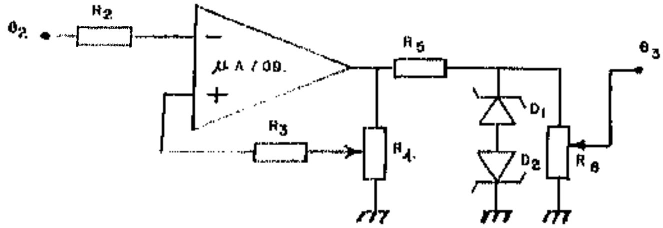
4, Conclusions

It is not difficult to realize these elements electronically by using operational amplifiers. Figure 3 shows the operational integrator and the Ou-Off element. P can be an integrated chip multiplier. M is maintained constant by the

Fig. 3



(*a*)



(*b*)

(*a*) Integrator. (*b*) On–Off element.

use of zener diodes at the output of the On–Off element. K_2 denotes the function of the potentiometer across these zener diodes. K_3 is the constant of the multiplier.

In this paper only the basic theoretical aspects of a triangular wave generator based on the closed loop analysis has been given. However, practical implementation of this scheme using operational amplifiers as circuit blocks is not difficult.

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