Wave Form Generator

1.0 Abstract

The aim was to analyze and implement a standard time-base wave generator that would produce 0 to 10 volts sawtooth and operate within the frequency of 100 to 1000 Hz. Also, 14 V p-p pulse waveform was required as an output. The circuit mainly consisted of hysteresis, which switched according to input from an integrator. The integrator was intern fed an adjusted output from the hysteresis. After analyzing systematically, the component values were determined and the circuit was implemented and tested part by part. The circuit operated as expected for the frequency range of 100 to 312 Hz, however, failed to behave properly for higher frequencies. It might be due to unaccounted capacitance effect; thus by adjusting the capacitor values of the integrator the circuit could be modified to meet the exact requirements.

2.0 Introduction

2.1 Objective

Output	Voltabe Range (v)	Frequency (Hz)	Notes
Linear sawtooth	0 min to 10 max	100 to 1000	9/10 T rise, 1/10 fall
Pulse	-14 min to 14 max	100 to 1000	9/10 -ve, 1/10 +ve
Pulse	0 min to 2 max	100 to 1000	

The aim was to analyze a standard time base sawtooth generator circuit based on the understanding of the behavior and interconnections of the components. In addition, the component values were to be determined for given specifications. Refer to Table I for the specifications.

2.2 Background

Pulses and triangular waveforms are common components in large circuits. Clocks, resets, and testing circuit are few examples where they are employed. Various IC based implementation means exist; and designer must select or construct according to his needs.

2.3 Theory

Bistable multivibrator, op-amp integrator, and summer circuits were employed in constructing time-base sawtooth generating circuit. First, the operations of circuits will be discussed separately and later it will be shown how different parts combined to produce the desired output.

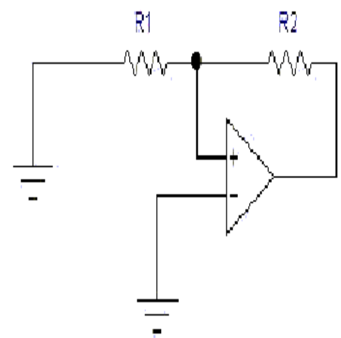

Figure 1: Bistable Multivibrator

Bistable Multivibrator

Bistable multivibrator is an op-amp configuration where the feedback is received by the positive terminal. Consider the circuit in Figure I, if a small positive voltage is applied the output will eventually saturate to L^+ due to the gain of the op-amp. The voltage at the positive terminal would be $V^+ = \frac{R1}{R1+R2}V_o$. If you apply a voltage higher than this at the negative terminal the output will switch to negative saturation. The ratios of the R1, and R2 can be adjusted to determine the switching voltages or V_{TH}, V_{TL}.

Integrtor

The op-amp configuration of Figure II produces an output Vo = -(Vin/RC)t. Refer to Appendix for the derivation of the formula. Here t is time and RC=t is the integrator time constant. For constant input the output is a linear slant. Also, by adjusting R or C one can alter the frequency of the waveform.

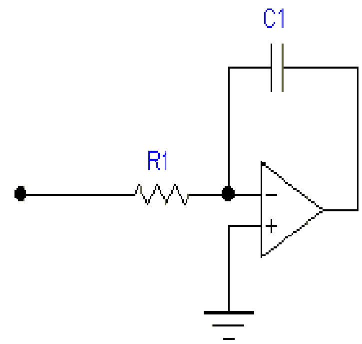

Figure 2: Integrator

Summer Circuit

A summer circuit produces an output Vo = -(R1/R2)V1-(R1/R3)Vin. Assuming that op-amp operates under linear conditions, above result could be derived by using superposition. The gain due to V1 and Vin were determined separately and added.

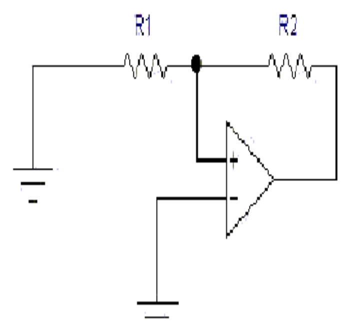

Figure 3: Summer Circuit

(The following is the theoretical analysis of the standard circuit. The component names were from the Figure P1.2 of the Lab Manual.)

It was noted early that hysteresis output fed into integrator will produce the

sawtooth waveform. Based on the required a 5V p-p integrator output, the values of R109, R108 were determined as follows:
$V_{th} = L^{+}\left(\frac{R108}{R108+R109}\right) = 5 = 14\left(\frac{R108}{R108+R109}\right)\ R109 = R108\frac{9}{5}$

Then, the capacitor value was assumed to be 1mF, and the relation wint = 1/RC was used to determine the (R100 + R101) as 159 W for 1000HZ and 1.59KW for 100Hz. Further, the relation Vo = -(Vin/RC) t was used to calculate the integrator input to be -0.88 and 8 volts.

The integrator input must switch from -0.88 to 8 volts, thus the 14V p-p must be attenuated by a factor of 3.15 to give a 8.88 V p-p. Assuming R102 =10KW lead R105 to be 31.5KW.

To achieve -0.88 V, the -4.44 V p-p must be offset by 3.56 V DC. In order to do so the summer circuit must provide 3.56 = (R102/R103 + R104)15, which yielded R103 + R104 = 42.1 KW.

The values of R114 and R115 were found by noting that the current through the diode and both resistor were same. Thus $i = \frac{2-0}{R115} = \frac{14-0.7-2}{R114}\ R115 = R114\frac{2}{11.3}$
let R114 = 10 KW then R115 = 1.8KW

To shift the 5V p-p to 0 to 10 V output required no gain, thus R113=R112=10K was chosen. To achieve 5 volt DC offset R110 + R111 was ac 30K gave a (1/3)15 V superposition addition. The theoretical values are summarized in the Table II:

Component	Value
Resistors	Kohm
R100	0.16 to 1.6
R101(adjustable)	0.16 to 1.6
R102	10
R103	42.1
R104(adjustable)	42.1
R105	31.5
R106	1
R107	Not Applicable
R108	10
R109	18
R110	30
R111(adjustable)	30
R112	10
R113	10
R114	10
Capacitor	1F
Diode(0.7 Voltage Drop)	

3.0 Procedure

The standard circuit was implemented using the off the shelf components into a breadboard. The MC1741 op-amp, resistors with 5Mini-pots, and 1N4148 didode were used in the implementation. Diagram I was used as a guide in the implementation.

First, the operation of integrator, and the hysteresis were implemented and

their operation principals were verified. In implementing the hysteresis R107 was not used and the arbitrary value of 1KW was used to protect the op-amp from any rapid current inflow. Then the duty cycle adjusting summer circuit was added and the values were adjusted as seen fit. The theoretical value of R105 = 31.5 KW was unavailable and thus R105 = 33KW was used. At last, the offset adjuster summer circuit and the scope blank component were added. R115=2KW was used rather than the theoretical value of 1.8KW due to unavailability of the required resistor.

4.0 Results

In general, the expected waveforms were produced. However, there was an important shortcoming. The sawtooth waveform was disturbed above the frequency of 312 Hz. The behavior was recorded in Graph I. The circuit behaved more abnormally as frequency further increased. Perhaps, capacitance leakage (Diagram II) was the phenomena that was observed. Moreover, the value R100 + R101=1.3 KW was used at 98.0 Hz rather than the theoratical1.6 KW.

The Graph II, and Graph III records the results at the frequency of 100 Hz. R103 + R104 was adjusted to 30.2 KW to achieve the required slants of the output.

Increasing the resistor R111 increased the DC offset in directly proportional manner. Similar result was achieved by adjusting R104. Moreover, increasing R101 value showed an inversely proportional relation to the frequency; as expected.

5.0 Conclusion and Recommendations

The operation principals and interconnections must be fundamentally correct, however the frequency limitation was a failure to meet the requirement. The hysteresis output attenuated and shifted fed into an integrator can produce a sawtooth output which in turn can be fed into hysteresis. The values at the integrator output determined the switching parameters of the hysteresis.

The capacitor and resistive elements of the integrator determined the frequency of a time-base generator. Thus, the frequency limitation could be corrected by adjusting or altering those elements.