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A REVIEW ON OP-AMP BASED FUNCTION GENERATOR: DESIGN AND SIMULATION

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ABSTRACT

In this research, different types of waveform such as sinusoidal, triangular and rectangular waves, with few electronic component and a wide frequency range was designed and generated. Operational amplifiers can be employed to perform such tasks through astable multivibrators as square wave generator. PROTO and MULTISM were used in simulating the circuits. The square wave can be integrated to form triangular wave and sine waves respectively. However, the operational amplifier operates under certain conditions. In this paper, the integration method is employed. It involves the generation of square wave which is then integrated to give triangular wave, as the square ramp integrate to triangular mathematical functions, the triangular wave is then integrated to give sinusoidal wave. Voltage comparator was used between the inverting and non-inverting inputs of the op-amp. A capacitor was placed at the inverting input of the op-amp. All the three waveform were generated using the overall circuit.

Keywords: Op-amp, Multivibrator, sinusoidal waveform, integrator, feedback

Introduction

The function generator generates the three wave forms (sine, triangular and square waves at the output) at certain frequency and amplitude. The primary wave form generated is the square wave, through which the rest could be obtained. This is the integration method used here is the integration method since a ramp integrates to triangular wave, which also integrates to sine wave respectively. Signals could also be generated through numerous methods, examples include audio frequency oscillator, radio frequency oscillator (RF) pulse generator and sweep frequency generators [1].

The audio frequency generators produce signals at the audio range of 20Hz to 20KHz They mostly use the Wien bridge oscillators. The radio frequency generators in contrast produces sinusoidal wave signals, modulated by an audio frequency signal at the frequency range of 33 to 300MHz, the pulse generators produced a rectangular output that have varying output frequency and duty cycle. The frequency range covers few Hertz to several mega Hertz (MHz), with a duty cycle range of five (5) to ninety-five percent (85%) [2]. The Radio frequency (RF) generator, also called the frequency sweep generator gives a radio frequency output of sinusoidal waveform [3]. A well-known method is to generated the square and triangular wave forms consecutively (Simultaneously) their rates are controlled by DC level, this is achieved by the use of the voltage controlled oscillator (VCO) The output of the VCO is clamped using diodes and resistor network to obtain the sine wave. Another perfect method is to generate clock pulse using the bi-stable multivibrators using op-amp (differentiators or integrators) [4].

Function generators are devices that use oscillation to generate mathematical functions; square, triangular and sinusoidal waveforms. The primary waveform is the square wave generated from an op-amp (astable multi-vibrator) [5]. The rectangular wave is generated from oscillation i.e. a process of generating periodic waveform at certain frequency at the output of the oscillator [6]. The square wave differs from the rectangular wave as the square wave is symmetrical in its functions parameters which include amplitude, period, pulse width and has a phase delay of zero degrees. The duty cycle is also 50% i.e. the off-time and the on-time are the same as shown in figure 1 [7].

$$Duty\ cycle\ = \frac{Pulse\ Width}{Period}\ x\ 100\%$$

The duty cycle of a square is 50% i.e. the pulse width is half of the period.

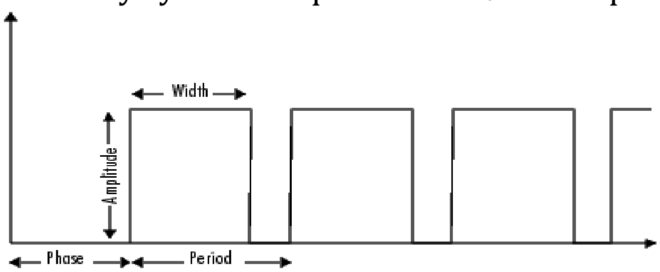

Fig. 1: Duty cycle of a square wave

The op-amp operates under certain conditions for oscillation such as:

i. The voltage gains at the feedback (positive feedback) greater than or equals to 1.0.
ii. The feedback returns part of the output to the input with no phase shift.
iii. The output is attenuated.
iv. The positive feedback is in-phase with the output, or sometimes shifts by 180 degrees which the inverting op-amp further shifts it by another 180 degrees to make it in-phase.
v. The closed-loop gain must be unity before oscillation and greater than unity to sustain any oscillation [8].

The canonical requirements (simplest form) for oscillation can be demonstrated using the transfer function as shown in figure 2 [9].

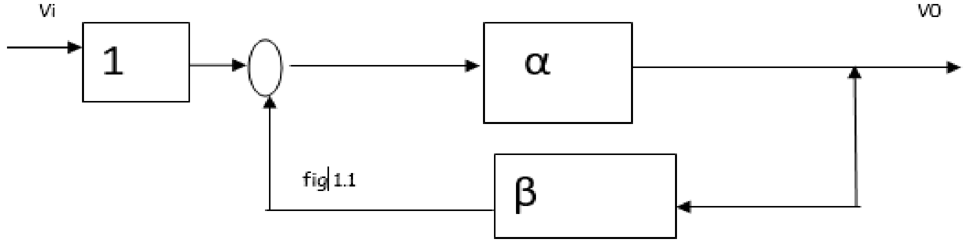

Fig. 2: Transfer function block diagram

Where Vi = input voltage, Vo = output voltage, α = op-amp gain and β = feedback factor.

$$\frac{Vi}{Vo} = \frac{\alpha}{1 + \alpha\beta}$$

The above equation is called Barkheusen Creterion .

i. Design Configuration

The function generator generates the three waveforms; sine waveform, triangular waveform and square waveform at the output.

Square Waveform

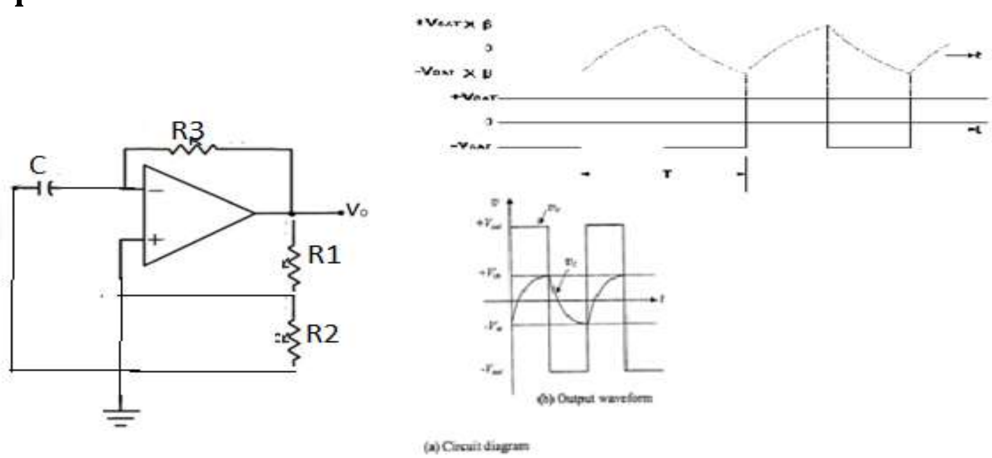

Fig. 3: Square wave generator circuit

From the fig 3 above, it is assumed that the positive output is initially saturated; the voltage at the non-inverting input of op-amp is given by;

$$+\text{Vsat}\left(\frac{\text{R1}}{\text{R1+R2}}\right) \qquad \ldots\ldots\ (1)$$

Thereby making the output remained in the positive saturation level as the capacitor C is initially in fully discharged stage. Then C begins to charge towards the positive value the saturation voltage +Vsat through the feedback resistance R. As the voltage of capacitor, exceeds the voltage at the non-inverting input of the op-amp, then output now becomes the negative saturation voltage –Vsat. Therefore, the voltage at the non-inverting input of the op-amp changes to;

$$-\mathrm{Vsat}\left(\frac{R1}{R1+R2}\right) \qquad \ldots\ldots\ (2)$$

Now the capacitor begins to discharge and after reaching zero, it begins to discharge to –Vsat value. If the value exceeds the negative threshold value in the non-inverting input of the op-amp, the output becomes +Vsat again, this process makes the cycle repeats itself, these results into a rectangular waveform at the output. The equation for the time period output waveform is given;

$$T = 2RCIn\frac{1+\beta}{1-\beta} \qquad \ldots\ldots\ (3)$$

The feedback factor;

$$\beta = \frac{R1}{R1+R2} \qquad \ldots\ldots\ (4)$$

$If \quad R1 = R2$ $\qquad \mathrm{T} = 2\mathrm{RC}\ln 3 \qquad \ldots\ldots\ (5)$

If design frequency of 1 kHz, $\mathrm{T} = \frac{1}{f} = \frac{1}{103} = 1mSec$

PARAMETRIC DESIGN

The components of all the sub-sectors of the square wave and the integrators are calculated using the above assumptions:

SQUARE WAVE GENERATOR

$If\ R1 = R2 = 10\ K\Omega$

Choosing a value of R, the value of C can be calculated from equation 5, Since $R << R1\ \&\ R2$

Let R= 4KΩ, then; $\mathrm{C} = \frac{\mathrm{T}}{2\mathrm{RIn}3} = \frac{1msec}{2.2R} = 8.9\mu f$

The values of the components across the op-amp are; R= 4 KΩ, $R_1 = R_2$ = 10 KΩ and

$C = 8.9\ \mu F$

INTEGRATOR

Figure 4 is the basic integrator, an inverting op-amp with a capacitor at the feedback. The output is proportional to the integral of the input [10].

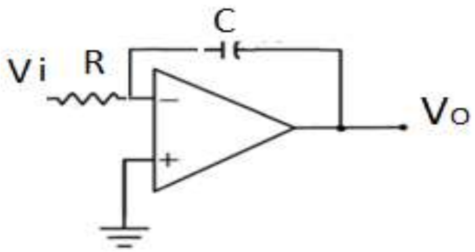

Fig. 4: Integrator circuit
The transfer function can be derived as

$$\frac{Vo}{Vi} = \frac{1}{RC}$$

$$Vo(t) = \frac{1}{RC}\int_{-\infty}^{\infty} Vi(t)dt$$

$$\frac{\Delta V0}{\Delta Vi} = -\frac{Vi}{RC}$$

From the fig 1.1 above

IR=$\frac{Vi}{R} = \frac{0-V0}{1/jwC}$, $-\frac{Vi}{R} = \frac{V0}{\frac{1}{jwC}}$, $\frac{V0}{Vi} = \frac{1}{jwRC}$

$$\frac{V0}{Vi} = \frac{1}{2\pi fRC} \qquad \text{……………7}$$

If the design frequency is 1KHz and the op-amp gain A ≥ 1, then;

$\frac{V0}{Vi} = \frac{1}{2\pi fRC}$ = A, $1 = \frac{1}{2\pi fRC} == \frac{1}{2\pi * 1000 * RC}$

If $R = 10K\Omega$, from Equation 7

$$C = \frac{1}{2\pi fR}$$

C = 1.9 X 10^{-9}F =1.9 nF

RESULTS AND DISCUSSION

The circuit above was simulated using PROTO and MULTISIM. The various results obtained were not clear, this was because the designed amplifier gain were set at unity A≥1. Another possible cause is due to the sweep time of the oscilloscope of the software it was set at 501µS, making the frequency 2KHz, the circuit was modified with some of the parameters changed as shown below.

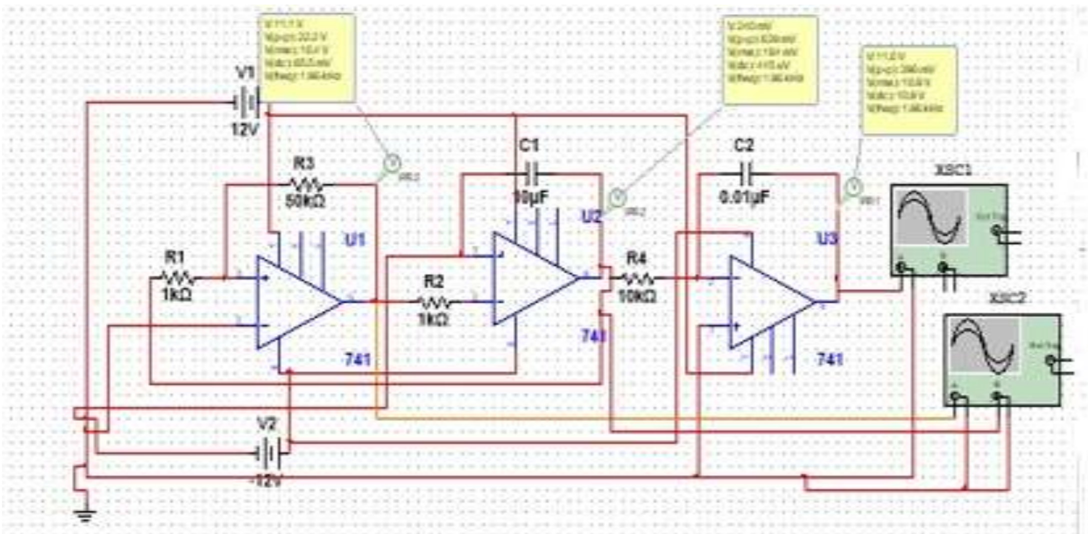

Fig. 5: Overall Circuit Diagram

The corresponding circuit was connected and simulated as shown in the figures below;

$C_1 = C_2 = 129nF$, $C_3 = 2pF$, $R_1 = R_4 = 4k\Omega$, $R_2 = R_3 = 10K\Omega$, $R_5 = 32K\Omega$

A_1 = Op-amp 1 = 1M **A_2 = Op-amp 2 = 406** **A_3 = Op-amp 3 = 2**

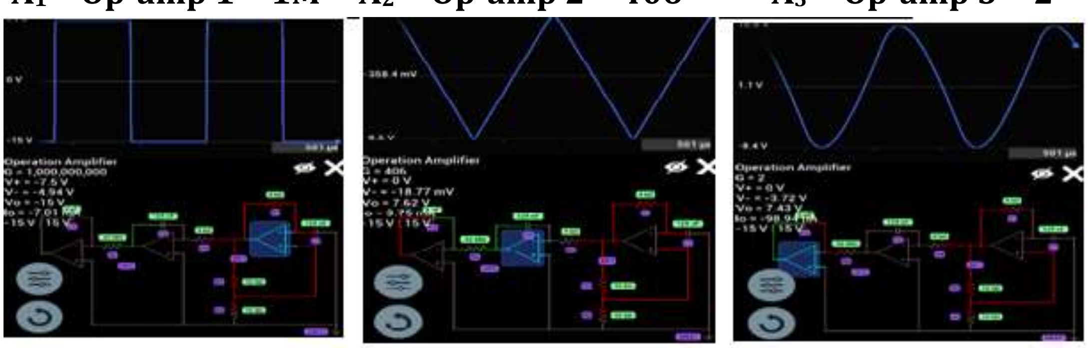

Fig. 6: Simulated Triangular, Square and Sinusoidal Wave

Figure 6 shows the entire circuit and the various waveforms displayed, the square waveform from the yellow amlifier, the triangular waveform from the blue op-amp (integrator1) and the sinusoidal waveform from the second integrator. The gains of the amplifiers differ due to attenuation experienced at each step, Sometimes a forth op-amp is introduce as the amplifier, which comprises of an op-amp with resistor at the inverting input and the feedback. The resistor at the feedback is far bigger than the inverting inputs, which gives an output with bigger amplitude. This is refered to as voltage amplifier.

Conclusion

The various waveforms were generated from the circuit realized. As the method implored is called the integration method. The overall circuits were realized, starting with the square wave, that was integrated to form the triangular wave, and the triangular wave to sine wave. The overall result can be seen from fig 3.8. The components can be varied to generate higher frequencies in Giga Hertz (GHz).

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