Sinewave Generation using analog Mux, Counter, and Op-amp

Anjali Chauhan
Electronics and Communication Engineering Department, Sardar Vallabhbhai National Institute of Technology
Surat, India
u21ec096@eced.svnit.ac.in

Shivang Sharma
Electronics and Communication Engineering Department, Sardar Vallabhbhai National Institute of Technology
Surat, India
u21ec097@eced.svnit.ac.in

Harshit Pathak
Electronics and Communication Engineering Department, Sardar Vallabhbhai National Institute of Technology
Surat, India
u21ec165@eced.svnit.ac.in

Anagha Mathkari
Electronics and Communication Engineering Department, Sardar Vallabhbhai National Institute of Technology
Surat, India
u21ec168@eced.svnit.ac.in

Abstract

The sinewave generation circuit incorporates an analog multiplexer (mux), a counter, and an operational amplifier (op-amp) to generate a sinusoidal waveform with a digitally controlled frequency. A counter is used in the circuit to generate a digital signal, which is then fed into an analog mux to generate a series of analog voltage levels. To generate a clean and reliable output signal, an op-amp is utilized as a buffer and amplifier. The output frequency of the circuit can be varied by adjusting the frequency of the counter. This approach offers a low-cost and straightforward solution for creating a sinusoidal waveform with exact frequency control.

I. INTRODUCTION

The generation of a sinusoidal waveform is a fundamental necessity in many electronic applications, including audio signal generation, waveform generation for testing and calibration, and frequency synthesis in communication systems.

An analog multiplexer (mux), counter, and operational amplifier (op-amp) circuit can also be used to generate a sinusoidal waveform. This method offers a simple and cost-effective solution with high accuracy and stability. The circuit works by using a counter to generate a digital signal, which is then translated to a series of analogue voltage levels by the analog mux. To provide a clean and reliable output signal, the op-amp buffers and amplifies the signal.

The frequency of the output signal can be readily changed using this method by modifying the frequency of the counter. This provides a versatile and adaptable technique for producing sinusoidal waveforms with exact frequency control. In this report, we will look at the design and operation of a sinewave generator circuit that makes use of an analog mux, a counter, and an op-amp.

II. BASIC THEORY

To generate a clean and stable sinewave output signal, a counter generates a digital signal, an analog mux converts it to an analog voltage signal, and an op-amp buffers and amplifies the signal.

The counter generates a digital signal with a square wave output waveform consisting of alternating high and low voltage values. The frequency of an external clock signal determines the frequency of the square wave. The frequency of the output sinewave is determined by the frequency of the clock signal.

The analog mux converts a digital signal into a series of analog voltage levels that resemble a staircase waveform. The resolution of the analog mux, which is based on the number of digital inputs to the mux, determines the number of steps in the staircase waveform.

The op-amp buffers and amplifies the staircase waveform signal produced by the analog mux. The op-amp delivers the signal with a high input impedance, a low output impedance, and gain. The feedback resistor network determines the gain of the op-amp, which can be changed to get the appropriate output amplitude of the sinewave.

The frequency of the output sinewave can be varied by modifying the frequency of the counter. This method is easy and inexpensive for creating a sinewave with exact frequency control. The op-amp provides the signal conditioning required to ensure that the output sinewave is clean, stable, and free of harmonic distortion and noise.

III. Design

CD74HC93

It acts as 4-bit triple counter. It has 4 outputs Q0, Q1, Q2, Q3 which counts from 0 to 15 repeatedly.

Pin connections:

It has 14 pins. Pin 1 is connected to pin 12(CLK). Pin 2 and pin 3 are grounded (GND). Pin 5 is connected to a +5V supply. Pin 8 is Q2 and pin 9 is Q1. Pin 10 is GND. Pin 11 is Q3 and pin 12 is Q0. Pin 14 is CLK

We will use outputs of counter Q0, Q1, Q2, Q3 and provide it in a combinational circuit that will give output C, B and A as 000,001,010,011,011,010,001,000,100,101,110,111,111,110,101,100.Using K-map it was concluded that

A = Q0 XOR Q2

B = Q1 XOR Q2

C = Q3

A, B, C will be used as select inputs to MUX.

74HC86

It consists of 4 XOR gates

Pin 14 is +5V and pin 7 is GND. Q0 is connected to pin 13 and Q2 is connected to pin 12 and output is taken from pin 11(A). Q1 is connected to pin 10 and Q2 is connected to pin 9 and output is taken from pin 8(B).

CD4051B

It is an 8x1 MUX.

Pin 1 is I4, pin 2 is I6, pin 3 is OUTPUT, pin 4 is I7 and pin 5 is I5. Pin 7 is Vee which is connected to-5V. Pin 8 is Vss which is GND. Pin 9 is C (SI). Pin 10 is B (SI). Pin 11 is A (SI). Pin 12 is I3. Pin 13 is I0. Pin 14 is I1. Pin 15 is I2. Pin 16 is Vdd which is connected to +5V

IC741

It is an op-amp. Its pin 2 is inverting input from MUX and pin 3 is non-inverting input and is GND. Pin 4 is -Vcc which is connected to -15V. Pin 6 is output. Pin 7 is +Vcc and pin 8 is GND.

SINE WAVE GENERATION

4-bit counter has been used which will give 16 different outputs so 1 cycle of sine wave has been divided into 16 parts which makes each part of 22.5 degree. Each phase amplitude was then calculated and op amp was used to amplify Vref differently according to previous amplitude calculations to generate sine wave.

RESISTORS

Different resistors were used to produce different gains for op amp which were selected by the mux

V0=-(RF/R1 + RF/R2 + RF/R3 + RF/R4)*Vref

RF/R1 = sin (22.5) = 0.38

RF/R2 = sin (45) = 0.70

RF/R3 = sin (67.5) = 0.92

RF/R4 = sin (90) = 1

RF/R5 = sin (112.5) = |0.38|

RF/R6 = sin (135) = |0.70|

RF/R7 = sin (157.5) = |0.92|

RF/R8 = sin (180) = |1|

For RF=10k

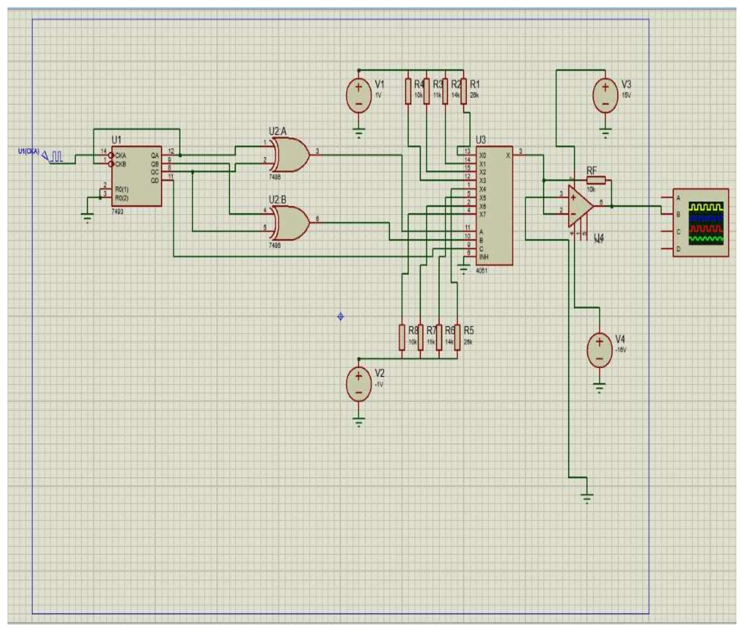
R1=R5=26k

R2=R6=14k

R3=R7=11k

R4=R8=10k

CIRCUIT DIAGRAM



A. *Abbreviations and Acronyms*

V = Voltage
CLK= Clock
GND = Ground
XOR = Exclusive OR
MUX = Multiplexer
SI = Select Input
IC = Integrated Circuit

B. *Units*

- Voltage was measured in volts.
- Theta was measured in degrees.
- Resistors were measured in kiloohm.

C. Equations

TRUTH TABLE

Q0	Q1	Q2	Q3	C	B	A	
0	0	0	0	0	0	0	0
0	0	0	1	0	0	1	1
0	0	1	0	0	1	0	2
0	0	1	1	0	1	1	3
0	1	0	0	0	1	1	4
0	1	0	1	0	1	0	5
0	1	1	0	0	0	1	6
0	1	1	1	0	0	0	7
1	0	0	0	1	0	0	8
1	0	0	1	1	0	1	9
1	0	1	0	1	1	0	10
1	0	1	1	1	1	1	11
1	1	0	0	1	1	1	12
1	1	0	1	1	1	0	13
1	1	1	0	1	0	1	14
1	1	1	1	1	0	0	15

- K-Map for A

Q3Q2/Q1Q0	00	01	11	10
00	0	1	1	0
01	1	0	0	1
11	1	0	0	1
10	0	1	1	0

$A = Q0 \oplus Q1$

- K-Map for B

Q3Q2/Q1Q0	00	01	11	10
00	0	0	1	1
01	1	1	0	0
11	1	1	0	0
10	0	0	1	1

$B = Q0 \oplus Q2$

- K-Map for C

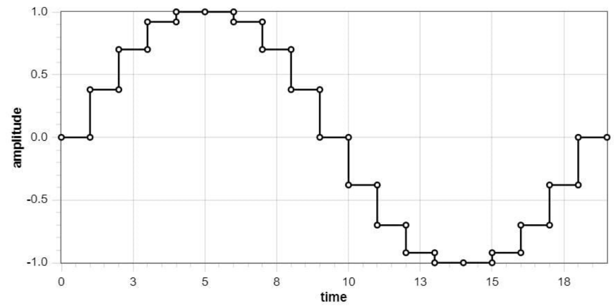
Q3Q2/Q1Q0	00	01	11	10
00	0	0	0	0
01	0	0	0	0
11	1	1	1	1
10	1	1	1	1

$C = Q3$

D. Some Common Mistakes

- Calculations to find the value of resistors can be wrong.
- Components used might be defected.
- Pin connections can be wrong.
- Short circuiting between the connections of the breadboard.

E. Result



Output Waveform

Output waveform was measured using DSO which provided us with a rough sine like wave which was a periodic step like wave with different voltage levels.

ACKNOWLEDGMENT

There are several individuals and sources that deserve acknowledgement for their contribution to the development and understanding of sinewave generation using analog mux, counter, and op-amp circuits.
Firstly, the use of analog muxes in waveform generation circuits has been widely explored and discussed in the academic and engineering communities. The work of researchers such as Dr. Jignesh Sarvaiya has contributed significantly to the understanding and development of analog mux-based waveform generation circuits.
Secondly, the development of operational amplifier technology has been instrumental in the success of this type of circuit have been crucial in the development of op-amp-based circuits for signal conditioning and waveform generation.
Finally, I would like to acknowledge the numerous engineering and academic sources that have contributed to my understanding of this topic, including textbooks, research papers, and online resources. Without these resources, this explanation of sinewave generation using analog mux, counter, and op-amp would not have been possible.

REFERENCES

[1] Mano Morris, "Digital Logic and Computer Design", 4th Ed., Pearson Education, 2006.

[2] Texas Instruments Datasheet

[3] GeeksforGeeks.com