iJRASET
International Journal For Research in Applied Science and Engineering Technology



# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 7 **Issue:** VI **Month of publication:** June 2019

**DOI:** http://doi.org/10.22214/ijraset.2019.6238

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177*
*Volume 7 Issue VI, June 2019- Available at www.ijraset.com*

# Fuzzy Logic Control on Ancient Indian Mathematically Derived SPWM

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***Abstract:*** ***With a prolonged work on porting of SPWM waves for various applications like Inverters, UPS and Static change over solutions using digital methods where Sine weighted data put in memory as look up table has been a glitch in the thought to minimise the memory space occupied. Speed of the microcontroller would never support to calculate the sine weighted data using any conventional methods. Apart from that correction of amplitude having feedback across the load would never have time in conventional mathematical methods implemented in the microcontroller. Ancient Indian mathematical methods find way producing the results in short time. Calculation of sine of an angle and for 10mS of 180$^o$ is possible by sine approximation of Bhaskara I (600 – 680 AD). Fuzzy logic implemented to derive amplitude regulation across load forms a combination of smooth control over effective sine wave produced across the load.***

***Keywords*****:** ***SPWM, Sine Approximation, Bhaskara's Sine Approximation formula, Digital to Analogue Converter, Fuzzy Logic.***

## I. INTRODUCTION

Conventional way of generation of SPWM is either by microcontroller or a DSP Controller. Both types bear a look up table of Sine weighted Amplitudes or Pulse Width data which is ported out for switching the power devices. Sine wave smoothness depends on SPWM pulses in 10mS of time. Generally, it is fixed to 256 steps or it could be defined as 8-bit rate. These 256 steps are burnt into the microcontroller as look up table occupying memory locations and ported out in sequence. An attempt to calculate sine of 256 angle points in 10mS with a conventional mathematical method leaves a complication. A Microcontroller by its architecture is a more logical processor than a mathematical one. It could do arithmetic functions and when forced with logics to perform mathematical functions certainly does it with a compromise in time and memory space. Ancient Indian Mathematical methods have given way to a logical solution embedded in the form of algorithms for each function. One such suitable function is work of Bhaskar I on Sine Approximation. This is embedded into a low-end microcontroller which is enough to perform giving out sine value amplitudes of each part of the 256 points along 180$^o$.

A unique combination of Ancient Indian Mathematics and Fuzzy Logic has resulted out a long-awaited solution for calculated sine weighted amplitude generation and regulation with respect to load and line conditions. Error correction of the signal generation is brought in reading the voltage across the load and difference is calculated. The error in the difference is fuzzified. This is tabulated using Mamdani method. The defuzzified value defines the multiplication factor for the Sine Approximated digital value for SPWM. Since fuzzy logic decision takes place very fast, regulation of the system remains tight.

## II. BHASKARA'S APPROXIMATION

Bhaskara I in his work Mahabhaskariya has given a Sanskrit text which stands an algorithm [1] for calculating sine of a degree. The expression gives trigonometric sine function [1].

G

According to work of dedicated works it is briefed to state a rule. For finding the Bhujaphala and the Kotiphala, substract the degree of Bhuja from the degree of half the circle. Multiply the reminder by degrees of Bhuja and put the result in two places. In first place substract the result from 40500. By one fourth the reminder, devide the result in the other place as multiplied by the antyaphala. Thus, obtained is the the Bhujaphala.

Bhaskara's Sine Approximation is put in conventional mathematical way as [2]:

$$\text{Sine } \theta = \frac{4\theta\,(180 - \theta)}{40500 - \theta\,(180 - \theta)}$$

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## III. SINE WEIGHTED DATA USING BHASKARA'S APPROXIMATION

From Bhaskara's formula all the 256 values from 0° to 180° are calculated.
Each part angle = 180°/ 256 = 0.703125°
Maximum amplitude of the waveform Vm = 5V
Generally, V = Vm ( sine Θ )
Amplitude at Θ = 0.703125° will be V = Vm ( sine Θ )
V = 5 ( sine 0.703125 )

$$\text{Sine } 0.703125 = \frac{4 \times 0.703125\,(180 - 0.703125)}{40500 - 0.703125\,(180 - 0.703125)}$$

$$= 0.01249$$

V = 5(0.01249)
V = 0.06245 V
5V max corresponds to HEX value 0FFH
0.06245V corresponds to HEX data = ( 0.06245 X 256 ) / 5
= 3.1974
= 003H

Next the Θ value is multiplied by 2 to calculate the next step value of sine weighted data. A counter running from 0 to 256 as a multiplier relives the memory space [3]. A low-end microcontroller can perform this function in less than 25µSec off 39µSec of allotted time for one off 256 steps in 10mSec of time for one ½ cycle of 50Hz of frequency [3].

## IV. FUZZY LOGIC CONTROL

Sine weighted data ported out from the controller is applied on to a DAC where it gets formed into a corresponding sine wave. In later stages it gets into switching power devices to form a sine wave across AC load [3]. A sample of this power is fed back to controller to form a closed loop for regulating the power across the load. To make it a tight regulation along with undistorted sine wave with a THD within limits, fuzzy logic plays a role in correction speed with accuracy. Error is detected and is usually positive. Correction factor is calculated and is applied on to the Vm, where V = Vm ( sine Θ ) which is considered to be 5V without a control [3]. This takes less than 12 µSec complying to the requirement and able to perform within 39 µSec.

1) Sine wave signal Amplitude
SS – Small
MS – Medium
LS – Large
{SS, MS, LS}

Feedback Amplitude
SR – Small RPM
MR – Medium RPM
LR – Large RPM
{SR, MR, LR}

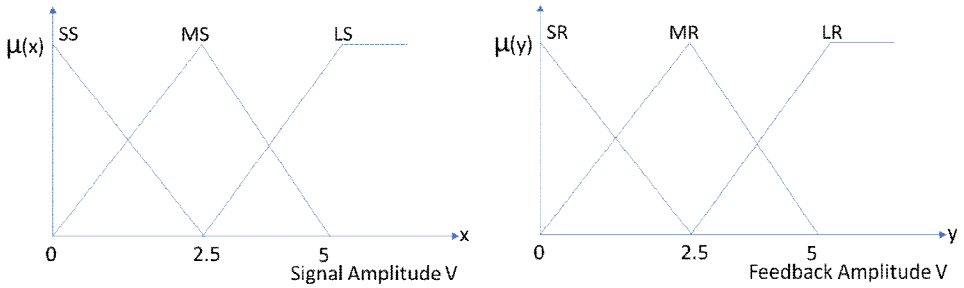
2) Governor Voltage
VS – Very Small
S – Small
M – Medium
L – Large
VL – Very Large
{VS, S, M, L, VL}

Define range of Signal Amplitude and Feedback Amplitude, Membership Function of the input and output variables. We use Triangular Membership Functions.

Range for Signal Amplitude (0 to 5):
SS: 0 to 2.5
MS: 0 to 5
LS: 2.5 to 5

Range for Feedback Amplitude (0 to 5):
SR: 0 to 2.5
MR: 0 to 5
LR: 2.5 to 5

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$\mu_{SS}(x) = 2.5 - x/2.5 - 0$

$\mu_{MS}(x) = x - 0/2.5 - 0$ || $\mu_{MS}(x) = 20 - x/20 - 10$

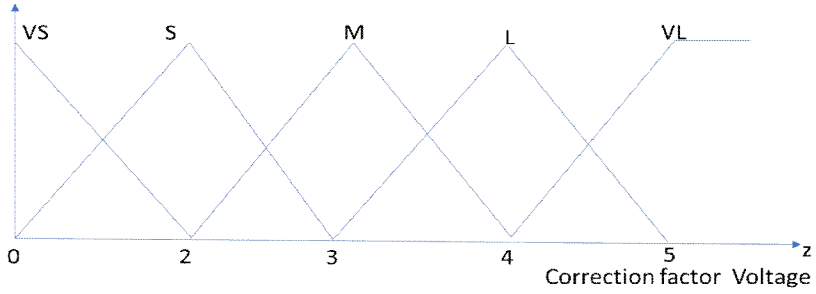
$\mu_{LS}(x) = x - 2.5/5 - 2.5$

$\mu_{SR}(y) = 2.5 - y/2.5 - 0$

$\mu_{MR}(y) = y - 0/2.5 - 0$ || $\mu_{MR}(y) = 5 - y/5 - 2.5$

$\mu_{LR}(y) = y - 2.5/5 - 2.5$

Membership function for Correction factor Voltage:
VS: 0 to 2
S: 0 to 3
M: 2 to 4
L: 3 to 5
VL: 4 to 5




$\mu_{VS}(z) = 2 - z/2 - 0$

$\mu_{S}(z) = z - 0/2 - 0$ , $\mu_{S}(z) = 3 - z/3 - 2$

$\mu_{M}(z) = z - 2/3 - 2$ , $\mu_{M}(z) = 4 - z/4 - 3$

$\mu_{L}(z) = z - 3/4 - 3$ , $\mu_{L}(z) = 5 - z/5 - 4$

$\mu_{VL}(z) = z - 4/5 - 4$

*A. Rule Base For Correction Factor Voltage*

| Signal \ Feedback | SR | MR | LR |
|---|---|---|---|
| SS | VL | S | VS |
| MS | VL | M | VS |
| LS | VL | L | VS |

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Thus generated fuzzy logic decision in the form of a numerical value to alter the multiplication value Vm in V = Vm ( sine Θ ) gives an immediate change in the amplitude of the signal. Correction speed is faster resulting a tight regulation without affecting the sine waveform.

## V. CONCLUSION

Digitally produced SPWM anyhow needs an external hardware to regulate the load power [4]. In digital method and Microcontroller method generally, a negative supply is required to bias the triangular wave to shift it down to ground. To overcome this employing a DSP Microcontroller is the traditional method [5]. A combination of Bhaskara's Sine approximation formula to deliver sine weighted SPWM and Fuzzy Logic to control the Load voltage forms a closed loop giving low THD sine wave.

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## ACKNOWLEDGEMENT

While working on a paper which got published recently gave way into this exclusive out of the box thinking to combine Ancient Indian mathematics to generate sine wave and using fuzzy logic to control the output voltage. Extensive work on generation of sine wave from over 20 years and embedding into my designs has developed a desire to calculate sine of the angle rather to use a lookup table.

Myself and my son P.Surya Narayana Reddy dedicate this technique to my Father Late Prof P.Surya Narayana Reddy who has incepted technical thoughts in me. And dedicate to my first schoolteacher Late S.S.Betgeri who has carved my technical thoughts to realization.

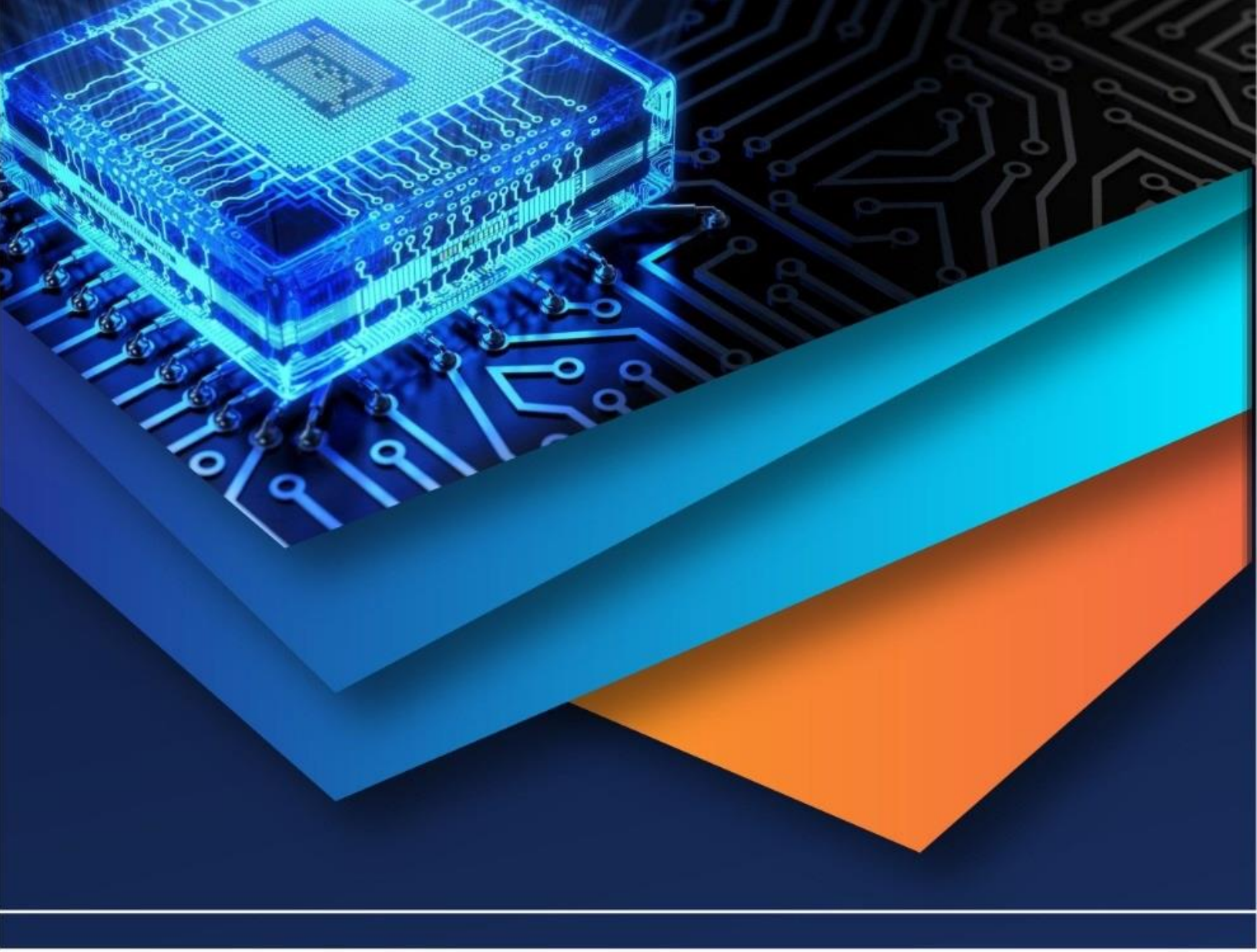
## OBEISANCE

I wish to convey obeisance to my teachers who have continually updated me at various levels of my education and trends in the technology with a right stroke and chisel over my technical skills.

*1)* B.B. Nagnur
*2)* Dr. M.B. Kothle
*3)* Prof. Kudleppanavar
*4)* Dr. P.P. Shaha
*5)* Dr. R.R. Mudholkar
*6)* Dr. R.K. Kamath
*7)* Dr. S.A. Deoskar
*8)* Dr. S.S. Ghaisas

In chronological order of seeking their blessings.

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