Available online at www.elixirpublishers.com (Elixir International Journal)

Electrical Engineering

Elixir Elec. Engg. 78 (2015) 29572-29574

ISSN: 2229-712X

Phase Sensitive Detector using Quadrature Oscillator

K.C.Selvam

Department of Electrical Engineering, Indian Institute of Technology, Madras, Chennai – 600036, India.

ARTICLE INFO

Article history:
Received: 12 November 2014;
Received in revised form:
21 December 2014;
Accepted: 2 January 2015;

Keywords
Sample and Hold,
Quadrature Oscillator,
Phase Detector,
Monostable Multivibrators,
Integrator.

ABSTRACT

A circuit which accepts two sinusoidal waveforms with phase difference Ø and provides two dc output voltages in which one dc output voltage is proportional to the quadrature component SinØ and the another is proportional to the in phase component CosØ, by position sampling of the reference quadrature waveforms, is described in this letter.

Introduction

The phase sensitive detector (PSD) plays an important role in instrumentation system particularly in (i) impedance measurement and (ii) power measurement. There are various types of phase sensitive detectors. The switching or synchronous type and the multiplier or homodyne type are described in [1]. Louis proposed a PSD [2] by using gating type detector that uses a diode half-bridge in conjunction with transformer. Cutkosky and Rober described a PSD [3] which features programmable gain, digital output and this instrument suppresses harmonic sensitivity through the use of analog circuitry which multiplies the signal by constant amplitude sine and cosine waves derived from an external reference of arbitrary voltage and frequency. Watnabe et all developed a PSD [4] which permits the realization of any phase response by means of many like stages in cascade or parallel. Chuanhong et all designed a PSD [5] based on matched filter principles and implemented using digital signal processing technology for electrical impedance tomography.

The phase difference between two sine waves is determined and converted in to a voltage V_θ. A constant sine wave of period T with peak value V_S is sampled by a sampling pulse whose position over the time period T is determined by the phase voltage V_θ. The sampled output is the quadrature component and is given by $V_Q = V_S \sin\theta$. A constant cosine wave of same period T with peak value of V_S is sampled by a sampling pulse whose position over the time period T is determined the same phase voltage V_θ. The sampled output is the in-phase component and is given by $V_I = V_S \cos\theta$. This type of PSD is called position sampled PSD and is described in this letter.

Circuit Analysis

The circuit diagram of the proposed PSD is shown in Fig. 1. The reference sine wave $V_1(t)$ and phase shifted sine wave $V_2(t)$ are given the phase detector [6] which consists of RS flip flops using NOR gates. The dc output voltage of this phase detector will be

$$V_\theta = \frac{V_{CC}}{360}\theta \qquad (1)$$

Where Vcc is the power supply voltage and θ is the phase difference between the input sine waves $V_1(t)$ and $V_2(t)$.

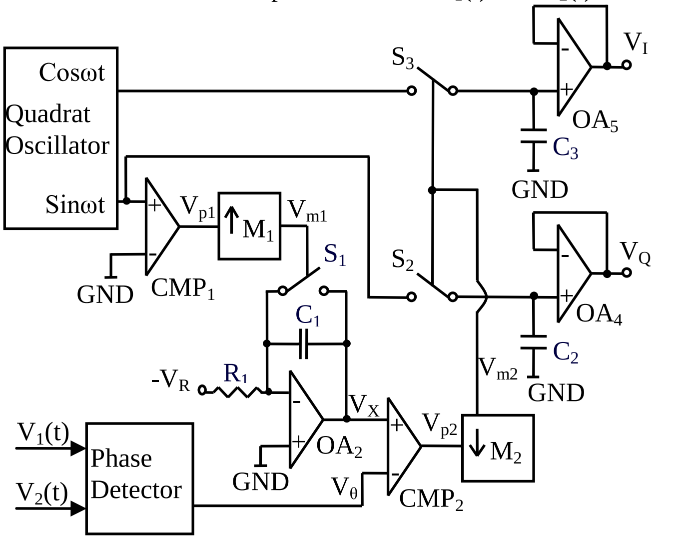

Fig. 1 Circuit diagram of proposed phase sensitive detector

From the equation (1) the phase voltage V_θ for different phase angles are given in Table I.

Table I Phase detector output for different phase angles

Sl.No	Phase difference θ	Phase detector output V_θ
1	90^o	Vcc/4
2	180^o	Vcc/2
3	270^o	3Vcc/4

The quadrature oscillator gives standard reference sine and cosine waves. The sine wave is converted in to a square wave V_{P1} by the comparator CMP_1. A short pulse V_{M1} is obtained during rising edge of this square wave V_{P1}. This short pulse V_{M1} shorts the capacitor C_1 in the integrator OA_2. A reference voltage $-V_R$ given to the integrator OA_2 and its output will be

$$V_X = \frac{1}{RC}\int V_R dt = \frac{V_R}{RC}t \qquad (2)$$

A saw tooth waveforms is generated at the output of integrator OA_2. The associated waveforms are shown in Fig. 2.

Tele:
E-mail addresses: kcselvam@ee.iitm.ac.in

From the waveforms shown and from the equation (2) at t = T, $V_X = V_T$ where V_T is the peak value of the saw tooth wave. Let V_T = Vcc and it is given by

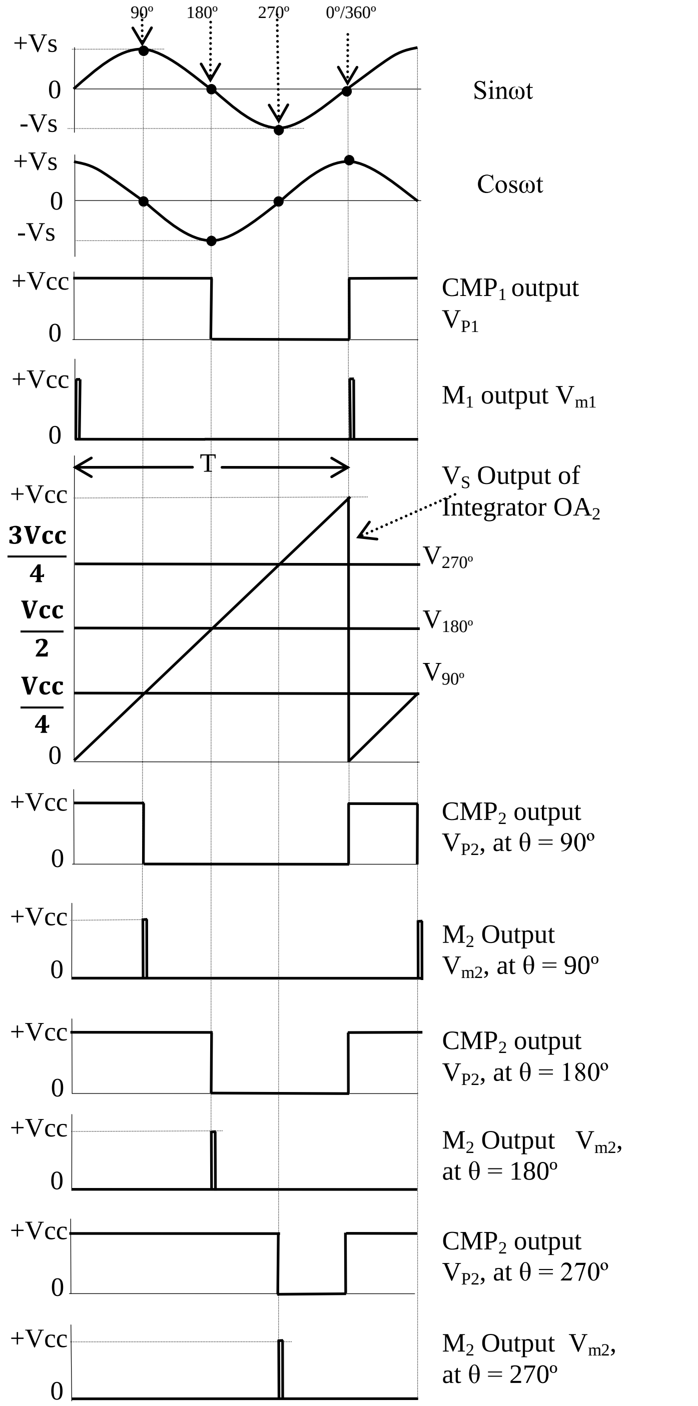

Fig. 2 Associated waveforms of Fig. 1

$$V_T = \frac{V_R}{RC}T = Vcc \quad (3)$$

The phase voltage V_θ is compared with this saw tooth waveform by the comparator CMP_2. A pulse waveform V_{P2} is generated at the output of CMP_2. A short pulse V_{M2} is generated during falling edge of this pulse train V_{P2}. The short pulse V_{M2} is acting as a sampling pulse to sample and hold circuits realized with op amps (OA_4 and OA_5), Capacitors (C_2 and C_3) and switches (S_2 and S_3). It samples sine wave for quadrature and cosine wave for in-phase components. It is observed from the waveforms of Fig. 2. for different phase angles of 90°. 180° and 270° that the output of OA_4 and OA_5 will be

$$V_Q = V_S Sin\theta \quad (4)$$

$$V_I = V_S Cos\theta \quad (5)$$

The observations are given in table II. V_S is the peak value of the quadrature oscillator output signals.

Table II: Outputs for different phase angles

Sl.No	Phase θ	V_S Cosθ	V_S Sinθ
1	90°	0	V_S
2	180°	$-V_S$	0
3	270°	0	$-V_S$

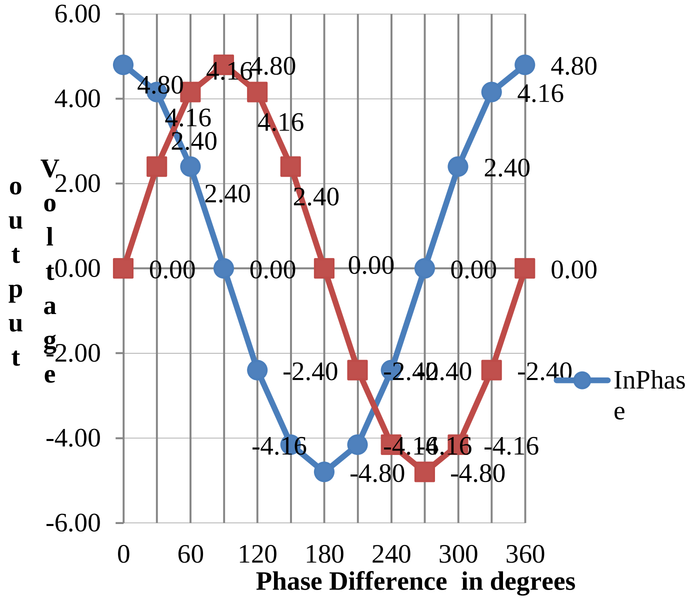

Fig 3. Test results of the sampling type PSD

Experimental Results And Conclusion

The proposed circuit of Fig. 1 is tested in our laboratory. LM 324 IC is used for all the op amps. CD 4066 IC is used for all the switches. CD 4528 IC is used for the monostable multivibrators. Conventional quadrature oscillator circuit given in [7] is used for the experiment. Reference and phase shifted signals of 5V peak, are obtained from the HP 203A variable phase function generator. The phase difference between the input waveforms are varied from 0° to 360° in steps of 30° and the output voltages are measured and plotted in the graphs of Fig. 3. A new type of phase sensitive detector is described. The proposed PSD can be used for (1) Impedance measurement in polar and rectangular forms and (2) Active and reactive power measurement.

Acknowledgement

The author is highly indebted to his loving wife Mrs. S. Latha for circuit drawing, waveforms drawing, proof reading and discussions. He also thanks Prof. Dr. V.Jagadeesh Kumar, Prof. Dr. Hari Shankar Ramachandran, Prof. Dr. Sridharan, Dr. Arun Mahindrakar, Dr. Bharath Bhikkaji and Dr. Ramakrishna Pasumarthi, Department of Electrical Engineering, Indian Institute of Technology, Madras, for their constant encouragement throughout the work.

References:

[1] H.O Modi, V.Jagadeesh Kumar and P.Sankaran, "Feed back compensated synchronous and multiplier type phase sensitive detectors", IEEE Transactions on Instrumentation and measurement, Vol.40, Issue:3 pages: 646-649 1997.

[2] Marzetta, A Louis, "A high performance phase sensitive detector" IEEE Transactions on Instrumentation and Measurement, Vol.IM, -20, Issue:4, Pages:296-301, 1971.

[3] Cutkosky, D.Rober, "A Programmable phase sensitive detector for automatic bridge applications", IEEE Transactions on Instrumentation and Measurement, Vol.27, Issue: 4, pages:401-402, 1978
[4] Watnabe, Kenzo, Madihian,Mohamed, Yamoto, Tatsuo, "A Cascade phase sensitive detector-phase response", IEEE Transactions on Instrumentation and Measurement, Vol.29, Issue:1, pages:3-6, 1980
[5] Chuanhong he, Lizhang, Bin Liu, Zhen xu, zhanlorg zhang, "A Digital phase sensitive detector for electrical impedance tomography" Automation Congress, WAC 2008, pages: 1-4 2008.
[6] U.A. Bakshi, A.P. Godse and A.V. Bakshi, Linear Integrated Circuits, Technical publications pune, pp:7.19 to 7.20, fifth edition 2010.
[7] Sergio Franco, Design with operational amplifiers and analog integrated circuits, TATA McGraw-Hill Edition, third edition, pp:456-457, 2002.

K.C. Selvam was born on 2nd April 1968 in Krishnagiri District of Tamil Nadu State, India. He was graduated by the Institution of Electronics and Telecommunication Engineers, New Delhi, in the year 1994. He has published 26 research papers in various national and international journals. He got best paper award by IETE in the year 1996. At present he is working as Technical Staff in the Department of Electrical Engineering, Indian Institute of Technology, Madras, India. He developed interest in design and development of function circuits to find their applications in modern measurements and instrumentation systems.