Investigation of the phase-voltage responses of digital phase detectors

Aleksandar H. Yordanov, Georgy P. Kachakov, Georgy S. Mihov

Abstract – **The paper deals to investigate some features of digital phase detectors and especially the range and the linearity of phase-to-voltage conversion. A specific method for simulation of digital phase detectors is examined. The analysis is done using transient analysis. The investigation demonstrates the simulations of most used digital phase detectors in Phase and Frequency Locked Loops.**

Keywords – **Digital phase detector, Simulation of phase - voltage response**

I. Advantages and Disadvantages of the Method for Simulation Analysis for Phase Detectors with Low-pass Filter

The main purpose of this paper is to investigate and enhance the methods for phase detectors simulation and particularly their conversion gain. In the previous research - [1] a method for simulation investigation of frequency sensitive digital phase detectors was presented. It was shown the phase-to-voltage response by using transient analysis and input sequences with two different frequencies. The outputs of the simulation give good results, which is very close to the mathematical expectations [2] and [3]. However there is a strong relation between smoothness and start and stop value of the conversion gain from the low-pass filter. The first order low-pass filter was used in the simulation of the scheme of common phase detector (Fig. 2) and the phase-to-voltage response is shown on figure 1.

Simulation on figure 1 shows the importance of low-pass filtering in this method and dependence of output from resistor R7. First characteristic ‘vout_p1’ use R7 = 1k, second ‘vout_p2’ - R7 = 2k and third ‘vout_p3’ - R7 = 3k.

To achieve smoother characteristic with this method, a higher order low-pass filter or lower phase change step has to be used. This means, it will take more time to determine the output voltage and increase the calculation points. Lower phase change step can be done by using input sequences with lower frequency difference – for more details see [1].

Using this method for simulation investigation leads to higher resolution of analysis, which in general is positive, but in some cases it is pointless or impossible to achieve. If the common phase detector shown on figure 2 is examined, higher resolution does not give more information about conversion gain, which in this case is linear from -2π to +2π. However higher resolution leads to:

- Transient analysis with very low time step;
- More processor time and memory to calculate the analysis;
- Probability of suspending the analysis because of low time step.

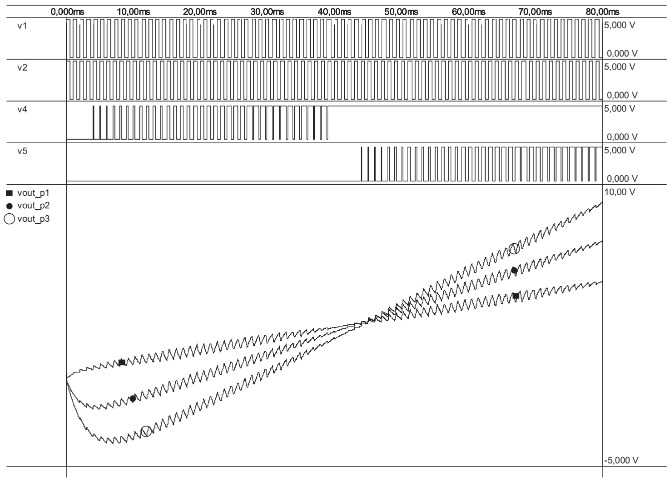

Fig. 1 Transient analysis of common phase detector

That is why, simulation investigations of phase detector with low-pass filter are not always practical. The phase-to-voltage response characteristics obtained by this method, gives information on both phase detector and low-pass filter and the connection between them. If we need to examine only the phase detector in some cases, influence of low-pass filter will be undesirable.

II. Method for Simulation Investigation of Phase Detectors with and without Low-Pass Filter and Average Function

The conversion gain shown on fig. 1 displays the behavior of the phase detector. For fast reaction of the scheme, insufficient filtration is used, which results in high frequency remains in the output signal. This high frequency remains can be removed by applying a mathematical function “average”.

The conversion gain of the same type phase detector is shown on fig. 3. The mathematical function “average” is applied on conversion gain from fig. 1.

[1]Aleksandar H. Yordanov is with the Faculty of Electronic Engineering and Technologies – Technical University of Sofia E-mail: yordanoval@abv.bg

[2]Georgy P. Kachakov is with the Faculty of Electronic Engineering and Technologies – Technical University of Sofia

[3]Georgy S. Mihov is with the Faculty of Electronic Engineering and Technologies – Technical University of Sofia, E-mail: gsm@tu-sofia.bg

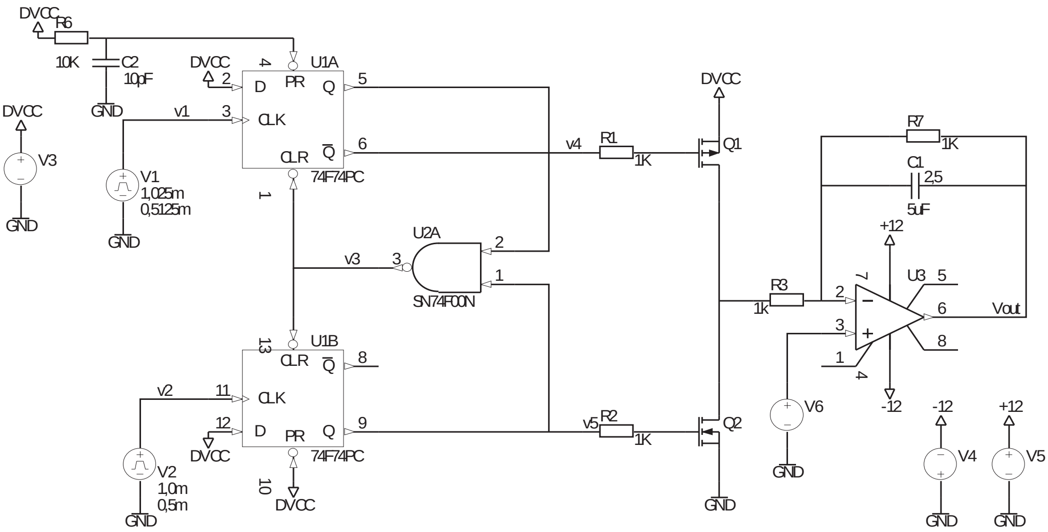

Fig. 2. Scheme of common phase detector

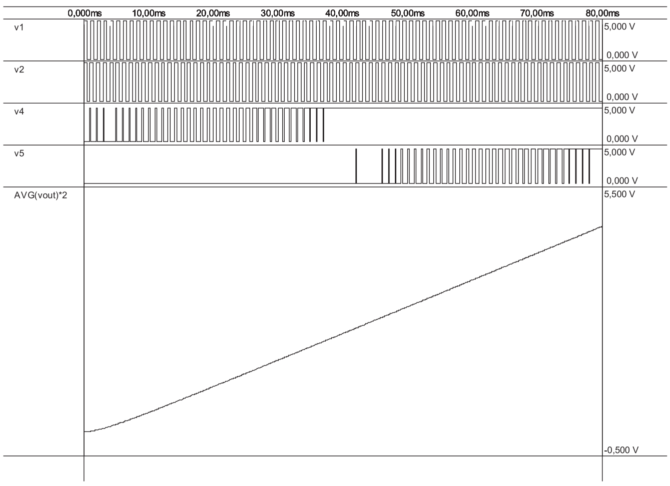

Fig. 3 Conversion gain of common phase detector with average function applied

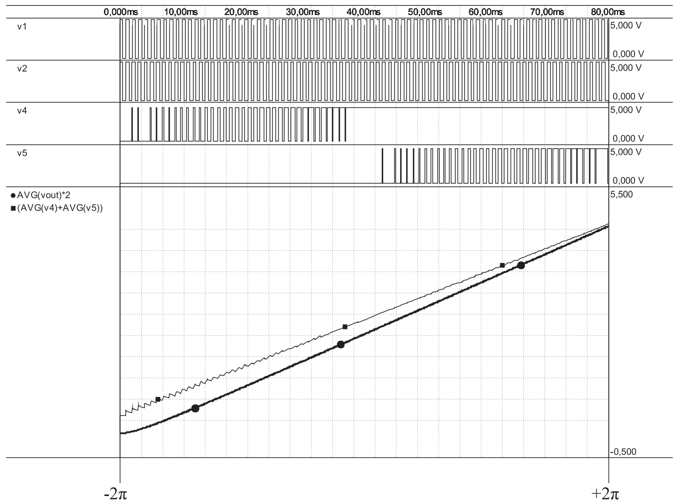

Fig. 4 Conversion gain of common phase detector with average function applied

Good linearity and smoothness of phase-to-voltage response is obtained for relatively low resolution of the input signal – 80 points. In this case the influence of the low-pass filter is extremely reduced, but it is not completely eliminated. This is clearly visible at the beginning of the conversion gain, where is a slight nonlinearity (fig. 3). This nonlinearity emerges because of real time delays of the filter, calculated by the simulator. This nonlinearity resembles the time reaction of the scheme, but does not exist in real conversion gain, neither of the phase detector nor of the low-pass filter.

Another approach to obtain better linearity of conversion gain is applying the function “average” to the digital output signal from phase detector. By this method there is no influence from the low-pass filter to the phase-to-voltage response.

On fig.4 is shown conversion gain by the two methods, with and without low-pass filter and the applied mathematical function “average”.

The chart marked with squares, shown on fig. 4, is the conversion gain of the common phase detector shown on fig. 2, obtained by applying the “average” method upon the sum of both of the digital outputs of the phase detector.

This conversion gain matches the mathematical expected one - [3]. The error is equivalent to one discrete of phase difference and it is influenced only by the deference between the two input frequencies and the mathematical function “average” applied. This method has largest diversion at the beginning of the computations (around -2π), because of lack of preliminary data.

REFERENCES

[1] Yordanov Al, Simulation Investigation of Frequency Sensitive Digital Phase Detectors, ICEST 2007 book 2, p. 773.

[2] Mihov G. A Digital Phase Synchronisation of Counters. The fifth National Scientific Conference ELECTRONICS ’96. Bulgaria, Sozopol, 1996.

[3] Willams A. Designer’s Handbook of Integrated Circuits. Mc Graw Hill Inc., 198’.