SEQUENTIAL SYMBOL SYNCHRONIZERS BASED ON PULSE COMPARATION

Antonio D. Reis[1,2], Jose F. Rocha[1], Atilio S. Gameiro[1] and Jose P. Carvalho[2]

[1]*Dep. de Electrónica e Telecomunicações / Instituto de Telecomunicações, Universidade de Aveiro, 3810 Aveiro, Portugal*
[2]*Dep. de Fisica / U. D. Remota, Universidade da Beira Interior Covilhã, 6200 Covilhã, Portugal*

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Abstract: This work presents a sequential symbol synchronizer, that is based on a pulse comparation, between a phase variable pulse and a reference fixed pulse. This synchronizer has two types namely the both data transitions and the positive data transitions. Each type has two versions which are the manual and the automatic. The objective is to study the synchronizers and evaluate the output jitter UIRMS (Unit Interval Root Mean Square) versus the input SNR (Signal Noise Ratio).

1   INTRODUCTION

This work studies a sequential symbol synchronizer, based on pulse comparation, between a phase variable pulse and a reference fixed pulse.

The input data transitions and the clock positive transitions produces between them, a variable pulse Pv. The input data transitions with the help of a T/2 delay or clock provides a fixed pulse Pf (Imbeaux, 1983), (Rosenkranz, 1982), (Witte, 1983), (Hogge, 1985), (Simon and Lindsey, 1977).

If the clock is delayed, Pv is greater than Pf, and then is applied a positive pulse Pe (Pv-Pf) that advances it. On the other hand, if the clock is advanced, Pv is lesser than Pf, and then is applied a negative pulse Pe (Pv-Pf) that delays it (Carruthers, Falconer, Sandler and Strawczynski, 1990), (Huber and Liu, 1992), (D'Amico, D'Andrea and Regianni, 2001), (Dobkin, Ginosar and Sotiriou, 2004), (Noels, Steendam and Moeneclaey, 2006).

The clock positive transition samples the data symbols at the maximum opening eye diagram.

Fig.1 shows the functioning principle of the referred synchronizer.

Kf is the phase comparator gain, F(s) is the loop filter, Ko is the VCO (Voltage Controlled Oscillator) gain and Ka is the loop amplification that controls the root locus and then the loop desired characteristics.

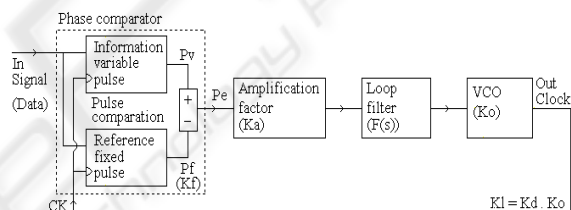Following, we present the both transitions synchronizer with its versions manual and automatic.

Figure 1: Aspect of synchronizers based on pulse comparation.

Next, we present the positive transitions synchronizer with its versions manual and automatic.

After, we present the design and tests.

Then, we present the results.

Finally, we present the conclusions.

2   BOTH TRANSITIONS SYNCHRONIZERS

The both transitions synchronizer takes synchronism information of the both data transitions (positive and negative). This synchronizer has the following versions manual and automatic.

The variable pulse Pv is similar in the two versions, but the difference is in the fixed pulse Pf) (Reis, Rocha, Gameiro and Pacheco, 2008).

2.1 Both Transitions and Manual Version

The manual version uses a fixed pulse, based on an exor with delay $\Delta t = T/2$, previously adjusted by the manufacturer, that produces the fixed pulse Pf (Fig.2).
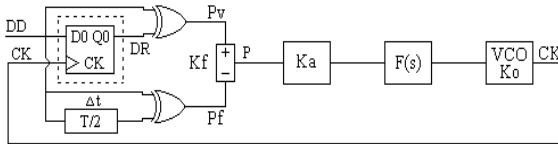

Figure 2: Synchronizer both transitions and manual (b-m).

The delay $\Delta t = T/2$ with exor produces a fixed pulse Pf that determines the rhythm of charge.

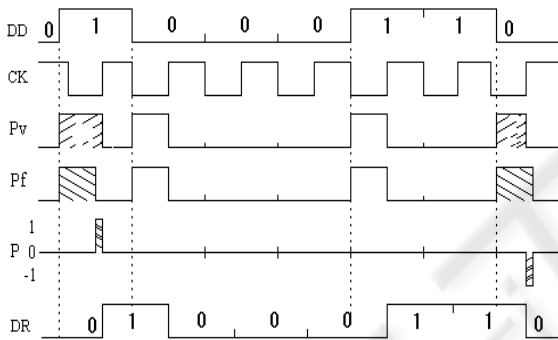Fig.3 shows the waveforms of the synchronizer both transitions and manual.

Figure 3: Waveforms of the synchronizer both transitions manual.

The error pulse Pe diminishes and disappear at the equilibrium point.

2.2 Both Transitions and Automatic Version

The automatic version uses a fixed pulse, based on an exor with flip flop 1, automatically adjusted, that produces the fixed pulse Pf (Fig.4).
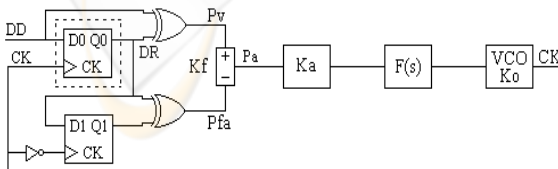

Figure 4: Synchronizer both transitions and automatic (b-a).

The flip flop1 with exor produces a fixed pulse

Pf that determines the rhythm of charge.

Fig.5 shows the waveforms of the synchronizer both transitions and automatic.
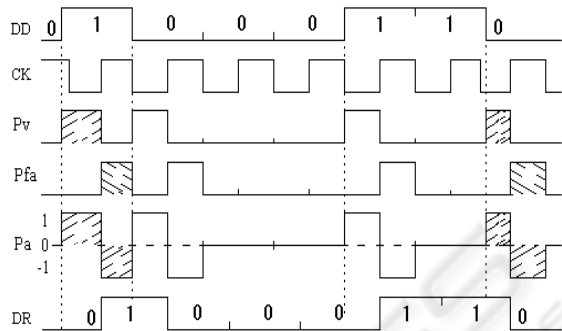

Figure 5: Waveforms of the synchronizer both transitions automatic.

The error pulse Pe don't disappear, but the positive area is equal to the negative at the equilibrium point.

3 POSITIVE TRANSITIONS SYNCHRONIZERS

The positive transitions synchronizer takes synchronism information only of the positive data transitions. Can be useful in nonlinear systems where the period multiplicity is guaranteed only between positive transitions. This synchronizer has the following versions manual and automatic. The variable pulse Pv is similar in the two versions, but the difference is in the fixed pulse Pf (Reis, Rocha, Gameiro and Pacheco, 2008).

3.1 Positive Transitions and Manual Version

The manual version uses a fixed pulse, based on an AND with delay $\Delta t = T/2$, previously adjusted by the manufacturer, that produces the fixed pulse Pf (Fig.6).
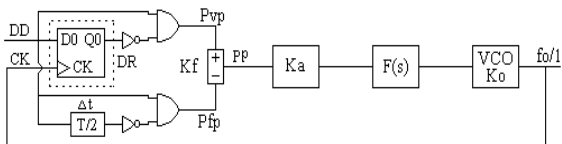

Figure 6: Synchronizer positive transitions and manual (p-m).

The delay $\Delta t = T/2$ with AND produces a fixed

pulse Pf that determines the rhythm of charge.

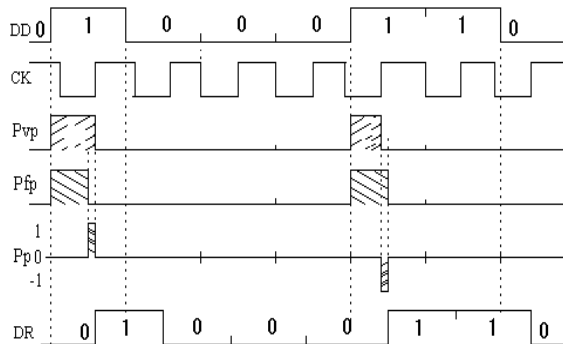Fig.7 shows the waveforms of the synchronizer positive transitions and manual.

Figure 7: Waveforms of the synchronizer positive transitions manual.

The error pulse Pe diminishes and disappear at the equilibrium point

3.2 Positive Transitions and Automatic Version

The automatic version uses a fixed pulse, based on an AND with flip flop 1, automatically adjusted, that produces the fixed pulse Pf (Fig.8).
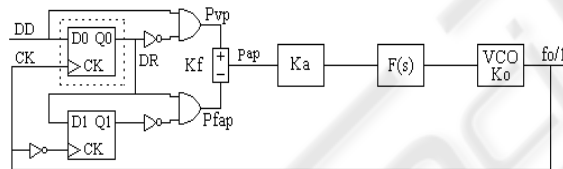

Figure 8: Synchronizer positive transitions and automatic (p-a).

The flip flop1 with AND produces a fixed pulse Pf that determines the rhythm of charge.

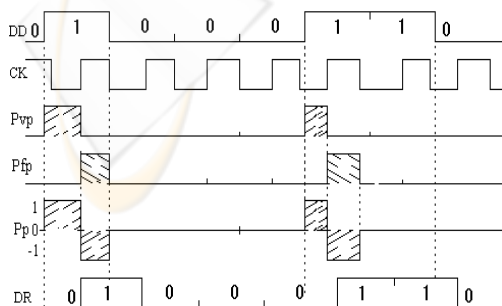Fig.9 shows the waveforms of the synchronizer positive transitions and automatic.

Figure 9: Waveforms of the synchronizer positive transitions automatic.

The error pulse Pe don't disappear but the positive area is equal to the negative at the equilibrium point.

4 DESIGN, TESTS AND RESULTS

We will present the design, tests and results of the referred synchronizers (Reis, Rocha, Gameiro and Pacheco, 2001).

4.1 Design

To get guaranteed results, it is necessary to dimension all the synchronizers with equal conditions. Then it is necessary to design all the loops with identical linearized transfer functions.

The general loop gain is Kl=Kd.Ko=Ka.Kf.Ko where Kf is the phase comparator gain, Ko is the VCO gain and Ka is the control amplification factor that permits the desired characteristics.

For analysis facilities, we use a normalized transmission rate tx=1baud, what implies also normalized values for the others dependent parameters. So, the normalized clock frequency is fCK=1Hz.

We choose a normalized external noise bandwidth Bn = 5Hz and a normalized loop noise bandwidth Bl = 0.02Hz. Later, we can disnormalize these values to the appropriated transmission rate tx.

Now, we will apply a signal with noise ratio SNR given by the signal amplitude Aef, noise spectral density No and external noise bandwidth Bn, so the SNR = A^2_{ef}/(No.Bn). But, No can be related with the noise variance σn and inverse sampling $\Delta\tau$=1/Samp, then No=$2\sigma n^2.\Delta\tau$, so SNR=A^2_{ef}/($2\sigma n^2.\Delta\tau$.Bn) = 0.5^2/($2\sigma n^2*10^{-3}*5$)= 25/σn^2.

After, we observe the output jitter UI as function of the input signal with noise SNR. The dimension of the loops is

- 1st order loop:

The loop filter F(s)=1 with cutoff frequency 0.5Hz (Bp=0.5 Hz is 25 times bigger than Bl=0.02Hz) eliminates only the high frequency, but maintain the loop characteristics.
The transfer function is

$$H(s)=\frac{G(s)}{1+G(s)}=\frac{KdKoF(s)}{s+KdKoF(s)}=\frac{KdKo}{s+KdKo} \qquad (1)$$

the loop noise bandwidth is

$$Bl = \frac{KdKo}{4} = Ka\,\frac{KfKo}{4} = 0.02Hz \qquad (2)$$

Then, for the analog synchronizers, the loop bandwidth is

$Bl=0.02=(Ka.Kf.Ko)/4$ with (Km=1, A=1/2, B=1/2; Ko=2π)

$$(Ka.Km.A.B.Ko)/4 = 0.02 \rightarrow Ka=0.08*2/\pi \qquad (3)$$

For the hybrid synchronizers, the loop bandwidth is:

$Bl=0.02=(Ka.Kf.Ko)/4$ with (Km=1, A=1/2, B=0.45; Ko=2π)

$$(Ka.Km.A.B.Ko)/4 = 0.02 \rightarrow Ka=0.08*2.2/\pi \qquad (4)$$

For the combinational synchronizers, the loop bandwidth is:

$Bl=0.02=(Ka.Kf.Ko)/4$ with (Kf=$1/\pi$; Ko=2π)

$$(Ka*1/\pi*2\pi)/4 = 0.02 \rightarrow Ka=0.04 \qquad (5)$$

For the sequential synchronizers, the loop bandwidth is:

$Bl=0.02=(Ka.Kf.Ko)/4$ with (Kf=$1/2\pi$; Ko=2π)

$$(Ka*1/2\pi*2\pi)/4 =0.02 \rightarrow Ka=0.08 \qquad (6)$$

The jitter depends on the RMS signal Aef, on the power spectral density No and on the loop noise bandwidth Bl.

For analog PLL the jitter is:

$\sigma\phi^2=Bl.No/Aef^2=Bl.2.\sigma n^2.\Delta\tau=0.02*10^{-3}*2\sigma n^2/0.5^2=16*10^{-5}.\sigma n^2$

For the others PLLs the jitter formula is more complicated.

- 2nd order loop:

The second order loop is not shown here, but the results are identical to the ones obtained above for the first order loop.

4.2 Tests

The following figure (Fig.10) shows the setup that was used to test the various synchronizers.
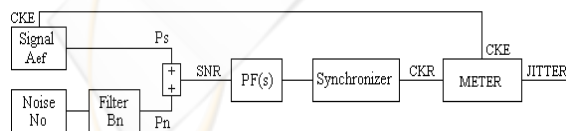

Figure 10: Block diagram of the test setup.

The receiver recovered clock with jitter is compared with the emitter original clock without jitter, the difference is the jitter of the received clock.

4.3 Jitter Measurer (Meter)

The jitter measurer (Meter) consists of a RS flip flop, which detects the random variable phase of the recovered clock (CKR), relatively to the fixed phase of the emitter clock (CKE). This relative random phase variation is the recovered clock jitter (Fig.11).
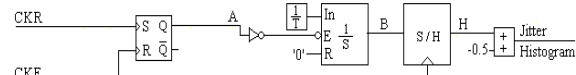

Figure 11: The jitter measurer (Meter).

The other blocks convert this random phase variation into a random amplitude variation, which is the jitter histogram.

Then, the jitter histogram is sampled and processed by an appropriate program, providing the RMS jitter and the peak to peak jitter.

4.4 Results

We will present the results (output jitter UIRMS versus input SNR) for the four synchronizers.

Fig.12 shows the jitter-SNR curves of the four synchronizers: both transitions and manual (b-m), both transitions and automatic (b-a), positive transitions and manual (p-m), positive transitions and automatic (p-a).
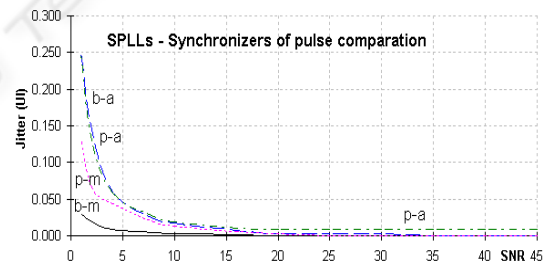

Figure 12: Jitter-SNR curves of the four synchronizers(b-m,b-a,p-m,p-a).

We verify, that generally the output jitter UIRMS diminishes exponentially with the input SNR increasing.

For high SNR, the four curves tend to be similar although with a slight disadvantage of the positive transitions automatic (p-a). However, for low SNR the both transitions manual (b-m) is the best, followed of the positive transitions manual (p-m). The both transitions automatic (b-a) and the positive transitions automatic (p-a) are the worst and similar.

5 CONCLUSIONS

We studied four synchronizers, namely the both transitions manual (b-m), the both transitions automatic (b-a), the positive transitions manual (p-m) and the positive transitions automatic (p-a). Then, we tested their output jitter UIRMS versus input SNR.

We observed that, generally, the jitter diminishes almost exponentially with the SNR increasing.

We verified, that for high SNR, the jitter of the four synchronizers are similar, although with a little disadvantage of the positive transitions automatic (p-a), this is comprehensible since it has two flip flops and stays more time in the error state until the next correction transition.

However, for low SNR, the both transitions manual (b-m) is the best since only one flip flop contributes to the error state and the time in the error state is lesser. After is the positive transitions manual (p-m) since only one flip flop contributes to the jitter but the time in the error state is greater (two times). In last, are the two automatic versions (b-a and p-a) since they have two flip flops that contributes to the jitter and are similar. Anyway, the last case is still aggravated by the greater time in the error state.

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