A NEW DATA PROCESSING TECHNIQUE OF PPM/PPK WITHOUT THE REFERENCE PULSE

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ABSTRACT

This paper describes the technical principle that signals conversion, data-processing and data storage are directly carried out without fitting up with the reference pulse for PPM and PPK (pulse position keying). By means of analysis for typical frame structure of PPM/PPK signals, a variety of math models of signal time relationship of the system were found, and based on this, a engineering way and a principle block diagram for signals conversion, data processing and data storage were given out.

KEYWORDS

Pulse-position modulation without the reference pulse, Pulse-position keying without the reference pulse, signal conversion, data-processing, data-storage

PREFACE

Reference pulse which is called marker pulse or channel synchronizing pulse or channel sychronization is one of the most important elements of the whole frame structure in typical PPM and PPK systems. It is the time reference of each channel signal for demodulation, and the frame synchronization is chosen based on it. Existence and integrity of the marker pulse will decide whether the measured parameter value of each channel of whole frame signal is correctly demodulated or not. Therefore it is necessary to integrade the marker pulse before demodulation of a typical PPM/PPK signals, and this is our fundamental aim for researching principle of synchro patch marker and developing of synchro patch marker unit.

However, we have analyzed PPM signal frame structure again and found that it implied important information in developing PPM telemetry system without marker pulse. Several math expressions have been set up, and base on them, under some necessary conditions, the principle and method of signal conversion.

This technique will be realized by using either microcomputer or other hardware circuits.

1. SIGNAL FRAME STRUCTURE OF PPM/PPK WITHOUT REFERENCE AND DETECTIVE METHOD

1.1 Frame structure and parameter name

Fig.1 Shows frame structure of typical PPM/PPK without maker pulse system. $M_1, M_2, M_3 \cdots M_n$ in dashed line are reference pulses, they are called channel synchro pulse or channel synchronization. In the system without reference pulse, each M pulse is not transmitted and can not be received.

$D_1, D_2 \cdots D_n$ in real line are data pulses, they are called channel signal or channel pulse. They are corresponding one by one with reference pulses, theirs width τ_0 is generally less than $1\mu s$.

As shown in Fig.1, $t_1, t_1', t_2, t_2' \cdots t_n, t_n'$ indicate each reference pulse and channel pulse respectively, i.e.

position on time-axis. $t_1, t_2 \cdots\cdots t_n$ are only assumed because they haven't been in real.

The foot-note numeber N of the reference pulse M_n and the channel pulse D_n equals 32, 64, 128 or 256, it represents the maximum channel number of a certain PPM/PPK telemetry system, i.e. the amount of channel period T_0 of a complete frame structure.

To represents time between two near reference pulses, it is called channel period and it is a constant for a certain system. The unit of τ_0 is 1μs or $\triangle t$ which is a quantizing step, i.e. a period of the main clock.

T_F is a frame synchronization, usually it occupies 1, 2 or 3 T_0 periods. T_F represents a frame period, it is a constant for a certain system, for instance, it is usually 20ms.

As shown in Fig.1, t_{x1}, $t_{x2} \cdots\cdots t_{xn}$ indicate time values of the M reference pulses and the D channel pulse, they are variably and represente the value of the measured parameters. They are our briefly objects discussed, and shortly called pulse interval.

1.2 Reference intervals

There are several special signals to be set as reference and calibration signals for telemetry system. The minimum reference interval corresponding measured parameter value to be the lowest level (zero level) is t_{xmin}. The maximum reference interval corresponding the highest input level is t_{xmax}.

1.2.1 The minimum reference interval t_{xmin}

The selection of the t_{xmin} is determined in the following way for a certain system

$$0 \leq t_{xmin} < t_{xmax} \qquad (1)$$

for example, t_{xmin} =100μs when t_{xmax} =400μs; another example, t_{xmin} =0.$\triangle t$ when t_{xmax} =511$\triangle t$ ($\triangle t$ is an oscillation period of crystal oscillator or a qualizing step) .

1.2.2 The maximum reference interval t_{xmax}

The selection of the t_{xmax} is determined by the following formula

$$t_{xmin} < t_{xmax} < T_0 \qquad (2)$$

for example, t_{xmax}=400μs when T_0=680μs and t_{xmin} =100μs for a certain system; for another example, t_{xmax} =511$\triangle t$ when T =640$\triangle t$ and t_{xmin} =0.$\triangle t$. As selecting the two values of t_{xmin} and t_{xmax}, the precision demand of the system and the bit rate ect. have to be considered. After having selected them the two values are constant, C_{xmin} and C_{xmax} stand for them

$$\left.\begin{array}{l} t_{xmin} = C_{min} \\ t_{xmax} = C_{max} \end{array}\right\} \qquad (3)$$

1.3 A detective method of PPM/PPK signal without reference pulse

A basic task of the general detective unit is to accept the signals from the receiver, to transform it back to the PAM or PCM data. There is a general detective device in Fig.2. The synchronous timing circuit (i. e. filling up reference pulse circuit) provides two kind of timing pulse tranins. One of them is the reference pulse (a), representing the starting points in succesive channels. The other is the counting pulse (b) whose period is equal to the quantizing step $\triangle t$. When ever the reference pulse arrives, the gate is switched on to allow the following counting pulses to enter the counter. The counting pulse also makes the sampling switch on for a short time to determine whether the low-pass filter output u_j exceeds the threshold level u_0 or not. If $u_j < u_0$, all go on. If $u_j \geq u_0$ when $t = k\triangle t$, the gate will be switched off and no more counting pulses will enter the counter. In such way the counter will stop with binary state of K. Then the required PCM data can be obtained by serially or parallely this state out.
Obviously, the reference pulse (a) starts the counter (Q) is fundamental for the device. Therefore, filling up the reference pulse to PPM/PPK signals seems to be the only way for it.
However, this paper describes the technical principle that signal transformation, data-processing and data

storage are directly carried out without filling up the reference pulse for PPM PPK.

2 MATH MODEL OF MEASURED PULSE INTERVAL OF PPM/PPK SYSTEM

2.1 Channel correlation type of the measured pulse interval

In Fig.1, let us assume two conditions:
1. $M_1, M_2 \cdots\cdots M_n$ reference pulses in dashed line are considered real.
2. In the PPM/PPK system the 1st channel measured parameter is zero level as one of the reference of the system.

According to the above conditions, the 1st pulse interval t_{x1} is the minimum t_{xmin}.

$$t_{x1}=t_1 t_1'=t_{xmin} \quad (4)$$

The conditions are easily realized in engineering and have to be done. Therefore, (4) is in accord with engineering reality. Substitute (3) into (4) and obtain

$$t_{x1}=t_{xmin}=C_{min} \quad (5)$$

Let us observe the 2nd pulse interval t_{x2} in Fig.1, it's corresponding measured parameter is u_{x2}, u_{x2} is variation. According to the expression $t_{x2}=t_2 t_2'$ it is impossible to get measured interval because the reference pulse M_2 is only an imagination. It needs getting a new way to work out. As shown in Fig.1.

$$t_1' t_2'=t_1' t_2+t_2 t_2' \quad (6)$$

Suppose $\triangle Tx1$ equals $t_1' t_2$, then $t_1' t_2=\triangle Tx1=t_1 t_2-t_1 t_1'$. Substitute (4) into it, then obtain

$$t_1' t_2=\triangle Tx1=t_1 t_2-t_{x1} \quad (7)$$

The item $t_1 t_2$ of the expression (7) has been defined already in the begining of the paper, i.e.

$$t_1 t_2=T_0 \quad (8)$$

Substitute (8) into (7) and obtain

$$t_1' t_2=\triangle Tx1=T_0-t_{x1} \quad (9)$$

Substitute (9) into (6) and obtain

$$t_1' t_2'=T_0-t_{x1}+t_2 t_2' \quad (10)$$

In above section we have defined $t_2 t_2'=t_{x2}$, thus

$$t_{x2}=t_{x1}+t_1' t_2'-T_0 \quad (11)$$

t_{x1} of the above formula has been defined in (5). T_0 is a channel period of the system. $t_1' t_2'$ is the interval of really receivable channel pulses D_1 and D_2. From (11) it is concluded that the 2nd pulse interval t_{x2} can be obtain after having selected the frame synchronization and obtained the 1st pulse interval t_{x1}. By the same reason we can obtain.

$$t_2' t_3'=t_2' t_3+t_3 t_3'$$
$$t_2' t_3=\triangle Tx2=t_2 t_3-t_{x2}$$
$$t_2 t_3=T_0$$
$$t_3 t_3'=t_{x3}$$

the formula (12) can be obtained

$$t_{x3}=t_{x2}+t_2' t_3'-T_0 \quad (12)$$

Compare (12) with (11) it is concluded that the 3rd interval t_{x3} will be obtained if the 2nd t_{x2} is obtained. The rest may be deduced by analogy, thus

$$t_{x4}=t_{x3}+t_3' t_4'-T_0 \quad (13)$$
$$t_{x5}=t_{x4}+t_4' t_5'-T_0 \quad (14)$$

By the reason the general formula has been deduced

$$t_{xn}=t_{x(n-1)}+t_{n-1}' t_n'-T_0 \quad (15)$$

It is concluded that the whole measured pulse intervals t_{x2}, $t_{x3} \cdots\cdots t_{xn}$ including in a frame can be obtained based on the formula (15), provided that the frame synchronization can be chosen and the 1st pulse interval has been known or can be obtained. Obviously, the subtraction of the formula (15) can be done while getting the pulse interval $t_{n-1}' t_n'$. According to the commutative law the orders of the subtraction and the addition of (15) can be flexibly arranged. Based on the formula (15) the brief operation process can be produced.

1. Input the constants $t_{x1}=C_{min}$ and T_0 into the computer under the routine according to the formulas (11)~(15) having been inputed.
2. Input the accepted pulse interval $t_1' t_2'$ into the data memory of a computer after converting it into the ordinary digital quantity.
3. Run the above routine, complete the operation of the formula (11) and obtain t_{x2}.

4. Store the t_{x2} in the memory or register of μc for calculating next interval and other processing of t_{x2}.
5. Repeat 2 for $t_2't_3'$, convert $t_2't_3'$ into the digital quantity and input it into the computer. Then repeat 3 and obtain t_{x3} based on (12), and so on.
6. Reapet 2, 3, 4, 5 until n channel intervals of a frame have been calculated and the processing of t_{xn} is completed.
7. Choose the next frame synchronization and begin to process the frame signals. Repeat above steps until all the data have been processed.
Now this paper has to answer a practical problem that needs to be solved. If one pulse t_{xi} (1<i<n) or more

lose each pulse after it will be affected.

2.2 Channel non-correlation type of measured pulse interval

It should be pointed out, events shown in (15) are very much correlative. Only when the $t_{x(n-1)}$ and $t_{(n-1)}'t_n'$ have appeared, the event $t_{x(n-1)}$ will be formed. Obviously, it is impossible to form t_{xn} without anyone of the first two events. Say it in another way, either D_{i-1} or D_i of measured pulse interval t_{xi} had lost, it is impossible to acquire each channel datum after it till the next frame. This shortcoming should be overcomed by application of (15). Let us return to the calculation of t_{x2}. In above there are formulas (11),(12) indicating t_{x2} and t_{x3}

$$t_{x2}=t_{x1}+t_1't_2'-T_o$$
$$t_{x3}=t_{x2}+t_2't_3'-T_o$$

If substitute (11) indicating t_{x2} into (12), then

$$t_{x3}=t_{x1}+t_1't_2'-T_o+t_2't_3'-T_o$$

arrange and obtain

$$t_{x3}=t_{x1}+t_1't_2'+t_2't_3'-2T_o \qquad (16)$$

As shown in Fig.1, we have:

$$t_1't_2'+t_2't_3'=t_1't_3' \qquad (17)$$

Substitute (17) into (16) and obtain

$$t_{x3}=t_{x1}+t_1't_3'-(3-1)T_o \qquad (18)$$

The formula (18) means that the measured interval t_{x3} equals to the t_{x1} plus the interval $t_1't_3'$ between the 1st pulse D_1 and the 3rd pulse D_3 minus $(3-1)T_o$ before the pulse D_3. As T_o is a constant, the interval t_{x3} is only related to t_{x1} and the interval $t_1't_3'$, however, with no relation to the pulse D_2 and it's interval. Substitude (16) into (13), thus

$$t_{x4}=t_{x1}+t_1't_2'+t_2't_3'+t_3't_4'-(4-1)T_o \qquad (19)$$

as $t_1't_2'+t_2't_3'+t_3't_4'=t_1't_4'$, therefore (19) can be written as:

$$t_{x4}=t_{x1}+t_1't_4'-(4-1)T_o \qquad (20)$$

Obviously, (20) is similar to (18), the measured t_{x4} is only related to t_{x1} and the interval $t_1't_4'$, however, with no relation to the pulses D_2 and D_3. By the same reason, the general formula t_{xn} can be easily worked out

$$t_{xn}=t_{x1}+t_1't_2'+t_2't_3'+\cdots t_{n-1}'t_n'-(n-1)T_o\ ,\ n>2 \qquad (21)$$

or

$$t_{xn}=t_{x1}+\sum_{i=2}^{n} t_{i-1}'t_i'-(i-1)T_o$$

as

$$\sum_{i=2}^{n} t_{i-1}'t_i'=t_1't_n'\ ,\ \text{thus}$$

$$t_{xn}=t_{x1}+t_1't_n'-(n-1)T_o \qquad (n\geq 2) \qquad (22)$$

Substitute (5) into (22) and obtain

$$t_{xn}=C_{min}+t_1't_n'-(n-1)T_o \qquad (23)$$

The general formula (23) shows: in PPM/PPK system without reference, any measured interval t_{xn} is only related to the first interval t_{x1} and the interval $t_1't_n'$ between the 1st puls D_1 and the n-th D_n, however, with no relation to others pulses $D_2, D_3\cdots\cdots D_{n-1}$ between them, the coefficient of the constant item is forever (n-1).
Analyse the formular (23) and we can obtain
1. (23) is the fundamental of signal convertion and data processing of PPM/PPK system without reference pulse, it has overcome the shortcoming in formula (15).
2. In the system, as long as the system reference interval is set up in the period of the 1st channel, e.g.

$t_{x1}=C_{min}$ the n measured intervals t_{x2}, $t_{x3}\cdots\cdots t_{xn}$ will be obtained and processed individually base on (23), not be limited by the channel order.

3. If some pulses after D_1 are lost, the others won't be influenced.

4. It is greatly helpful to real-time processing of data and to quick look and report.

2.3 The type of accumulated difference of measured interval

The formula (23) had overcomed the shortcoming of (15), however, it included an item $t_1't_n'$. Its easily seen that sometime the word length of item $t_1't_n'$ is very long, especiely, even n can reach it's maxmum 15 bit. Therefore, it will be trouble to time-digit converter, data processing and data storage, this engineering problem will be solved in this section.

As mentioned above, in assumed PPM/PPK system without reference pulse the minumum reference pulse corresponding the lowest parameter is still put up in 1st channel (see Fig.1). Calculated formulas (5), (11), (12), (13), (14) and (15) are base.

Substitute (5) into (11) and obtain

$$t_{x2}=C_{min}+t_1't_2'-T_0$$

substitute above into (12) and obtain

$$t_{x3}=C_{min}+t_1't_2'-T_0+t_2't_3'-T_0$$

also arrange it into (24)

$$t_{x3}=C_{min}+(t_1't_2'-T_0)+(t_2't_3'-T_0) \qquad (24)$$

Obviously, the two items in parentheses are similar, they are all the expressions of the difference and then plused, and then plused, so that it was called the type of acculated diference. Put it in order

$$t_{x3}=C_{min}+\sum_{i=2}^{3}(t_{i-1}'\ t_i'-T_0) \qquad (25)$$

as shown in (25), each difference can be obtained meanwhile the intervals $t_1't_2'$, $t_2't_3'$, etc are forming. Substitute (24) into the (13) and obtain the t_{x4}

$$t_{x4}=C_{min}+(t_1't_2'-T_0)+(t_2't_3'-T_0)+(t_3't_4'-T_0) \qquad (26)$$

or

$$t_{x4}=C_{min}+\sum_{i=2}^{4}(t_{i-1}'\ t_i'-T_0) \qquad (27)$$

By the same reason, substitute (26) into (14), thus

$$t_{x5}=C_{min}+(t_1't_2'-T_0)+(t_2't_3'-T_0)+(t_3't_4'-T_0)+(t_4't_5'-T_0) \qquad (28)$$

It should be

$$t_{x5}=C_{min}+\sum_{i=2}^{5}(t_{i-1}'\ t_i'-T_0) \qquad (29)$$

Obviously, the structure of (27) and (29) is similar to (25), therefore, it has the same physical meaning with (24), both t_{x4} and t_{x5} are all accumulated value. Infer like this and we can obtain the general math formulas (30), (31)

$$t_{xn}=C_{min}+(t_1't_2'-T_0)+(t_2't_3'-T_0)+\cdots\cdots+(t_{n-1}'\ t_n'-T_0) \qquad (30)$$

$$t_{xn}=C_{min}+\sum_{i=2}^{n}(t_{i-1}'\ t_i'-T_0) \qquad (31)$$

The formula (31) means: in PPM/PPK system any measured interval t_{xn} equals the minimum reference interval C plus summation of all differences between each intervals and T_0 (the intervals are limited between the 1st pulse D_1 and D_n). Especialy, the difference between the interval and T_0 could be obtained while obtaining the interval. (23) differs from (22) by this. Obtain the deduction from (31) as following.

1. It had been solved that the digit of $t_1't_n'$ was too long.

2. In the course of apperance of interval $t_{i-1}'\ t_i'$ and subduction between $t_{i-1}'\ t_i'$ and T_0, even if one or more channel pulses are lost, neither digit of $t_1't_n'$ in (23) too long nor the measured interval strictly related will be caused, therefore, the formula not only is beneficial to the realization of engineering, but also won't affect the data processing of each accepted channel pulse.

3. Data processing of PPM/PPK system without reference pulse according to the formula (31) can utilize the constant C_{min}, T_0, etc, and software can be developed for (31) and data processing canbe completed by a computer. Especialy, the item $(t_{i-1}'\ t_i'-T_0)$ of (31) can be excutive out of computer, its accumulative value can be input into the computer as it is needed.

For instance, the arithmetic unit can be designed like a cycle counter which takes T_0 as a period, the accumulative value of all differences is just in it. When the i-th measured interval t_{xi} is needed, the present accumulativ value of cycle counter can be output only by using the i-th channel pulse D_i, i.e. the second item of formula (31) has been completed, then plus C_{min} in the computer and the value of t_{xi} has been obtained.

2.4 Effective interval type of measured parameter

While we analyze and deduce and discuss the formulas (15),(23) and (31), we all utilized the concept interval value which corresponds the measured parameter u_{xn}, it was indicated by t_{xn}. The chief feature of the concept and expression was that the value t_{xn} included the minimum interval C_{min} corresponding the lowest level (usually zero level) of measured parameter. C_{min} to be included in t_{xn} would bring some troubles which increased links and decreased speed for signal conversion and data processing. For this purpose, the measured effective interval concept had been put forward in this section, and several formulas had been established.

As shown in Fig.3, if we insert a pulse D' indicating in dashed line between the imaginary reference pulse M and channel pulse for each channel, i.e. there is always a pulse D' corresponding the minimum interval C_{min} after each reference pulse M, in that case, each measured interval t_{xn} can be expressed in another form, which measured effective interval is deduced from.

The following analyses and deduction began from the 2nd measured interval t_{x2}, and utilized the relation formulas esstablished before, $t_{x1}=t_{xmin}=C_{min}$, as there was a imaginary pulse D', the 2-nd measured interval t_{x2} could be written as: $t_{x2}=t_{x1}+(t_{x2}-t_{x1})$, or

$$t_{x2}=t_{x1}+\triangle t_{x2} \qquad (32)$$

Substitute (5) into (32), then

$$t_{x2}=C_{min}+\triangle t_{x2} \qquad (33)$$

arrange it again and obtain

$$\triangle t_{x2}=t_{x2}-C_{min} \qquad (34)$$

the $\triangle t_{x2}$ of (34) is called measured effective interval of the 2-nd channel, it is equal to the diference between the 2-nd measured interval t_{x2} and the minimum reference interval C_{min} of the system. As a imaginary pulse D' has been inserted after each reference pulse M, the 3-rd measured interval after the 2-rd channel as shown in Fig.3. It should be indicated

$$t_{x3}=t_{x1}+(t_{x3}-t_{x1})$$
$$=C_{min}+\triangle t_{x3}$$

or

$$\triangle t_{x3}=t_{x3}-C_{min} \qquad (35)$$

Obviously, (35) is similar to (34) in structure, $\triangle t_{x3}$ is called measured effective interval value of the 3-rd channel, it is equal to the difference between the measured interval value of the 3-rd channel and the minimum interval C_{min} of the system. On the analogy of this, the general formula of each measured effective interval for the PPM-PPK system can be obtained

$$\triangle t_{xn}=t_{xn}-C_{min} \qquad (36)$$

Beach effective interval $\triangle t_{xn}$ is equal to the difference between the measured interval t_{xn} and the minimum reference interval C_{min}. The formula (36) indicated that each measured effective interval $\triangle t_{xn}$' could be obtained subtraction through measuring interval t_{xn} and then subtracting the minimum reference interval C_{min}.

Effective interval $\triangle t_{xn}$ had not referred to the minimum reference interval $t_{xmin}=C_{min}$ which responded the zero level value of measured parameter, however, only reflected the increment of measured parameter U_{xn} in relation to zero level. In other words, effective interval $\triangle t_{xn}$ had not included the interval $t_{xmin}=C_{min}$ which corresponded zero level of U_{xn}, i.e. the minimum reference interval C_{min} was equal to zero.

Although the introduction and definition of the effective interval $\triangle t_{xn}$ were based on measured interval t_{xn}, this did imply that the interval t_{xn} should not be obtained at first in engineering. Exactly the reverse, signal convertion and data processing of the system were simplified because of introduction of $\triangle t_{xn}$ concept. Deduction as following the math model (15) esstablished in 2.1 section

$$t_{xn}=t_{x(n-1)}+t_{n-1}'-t_n'-T_0$$

Substitute (15) into (36) and obtain

$$\triangle t_{xn}=t_{x(n-1)}+t_{n-1}'-t_n'-T_0-C_{min}$$

simplify and obtain

$$\triangle t_{xn}=\triangle t_{x(n-1)}+t_{n-1}'-t_n'-T_0 \qquad (37)$$

The math model (23) was esstablished in 2.2 section

$$t_{xn} = C_{min} + t_1' t_n' - (n-1)T_0$$

substitute (23) into (36) and obtain

$$\Delta t_{xn} = t_1' t_n' - (n-1)T_0 \qquad (38)$$

The math model (31) was esstablished in 2.3 section

$$t_{xn} = C_{min} + \sum_{i=2}^{n} (t_{i-1}' \; t_i' - T_0)$$

Substitute (31) into (36) and obtain

$$\Delta t_{xn} = \sum_{i=2}^{n} (t_{i-1}' \; t_i' - T_0) \qquad (39)$$

As shown in (37),(38) and (39), calculation of an effective interval Δt_{xn} needn't begin from calulating the measured interval t_{xn}, and it is simplier than the calculation of t_{xn}. Obviously, having chosen frame synchronization each measured interval Δt_{xn} which is located after the 1-st channel pulse D_1 is immediately calculated for the PPM/PPK signals. It should be pointed out, the final formulas (37),(38) and (39) of the effective interval were deducted from (15),(23),(31) and (36), therefor, (37),(38) and (39) did not include the minimum reference interval C_{min} and were more simplier, still, they had individually physical mean and feature of each deduction of (15),(23) and (31).

Therefore, the physical mean and deduction in above sections were still adapted for all math model of Δt_{xn}. The effective interval Δt_{xn} not only is the simplist former of the techniqual princilpe, but also provides convenient condition for adapting to the some former of final processing result in the data processing of each model realized this principle. Actually, calculation of interval t_{xn} and effective interval Δt_{xn} were not the final result of signal conversion and data processing. In most cases, the final target is restoration of measured parameter U_{xn}, sometimes, the ratio of each measured parameter U_{xn} over the maximum reference interval C_{max}, as following

$$U_{xn} = \Delta t_{xn} \cdot K_{xn} \qquad (40)$$

$$\delta_{xn} = \frac{\Delta t_{xn}}{C_{max}} \cdot 100\% \qquad (41)$$

Where, C_{max} is one of the constants of PPM/PPK system, i.e. the maximum reference interval at the beginning of the paper; K_{xn} is a ratio of measured parameter level increment over pulse interval increment, delda, it is a constant for a certain system, it's unit is V/μs or V/Δt.

Obviously, each math model of the principle using effective pulse interval' Δt_{xn} possesses practicability in telemetry data processing.

3. Data processing engineering of PPM/PPK system without reference pulse

3.1 General of data processing engineering

3.1.1 Data processing foundmental

1. Data processing content

The signal convertion of PPM/PPK without reference pulse, data operation and data storage and output.

2. Data processing base

The math models established in the above sections are a base of the data processing for PPM/PPK system without reference pulse. Four types are channel correlation type, channel no correlation type difference accumulate type and effective interval type.

3.1.2 Data processing accurary and main clock frequency

The key to satisfy the request of the telemetry system for the data processing accuracy lies in chosing the main clock.

The main clock of the data processing unit should match the main frequency of the video unit of the transmitting end. The match was demanded to guarantee the accuracy, and never implied to have the same frequency. Higher main clock frequency than that of the transmitting end was requested in the data processing engineering.

It can be demonstrated: While the main clock frequency both is high enough and possesses certain stability, the unit can be operating in close loop state of data processing after once entering a synchro state, until having finished all the tasks in limited time.

3.1.3 Choicing and filling up frame synchronization

The frame synchronizion is a base of a telemetry demodutater and data processing unit. On the other hand, the miss and error pulse caused by radio wave's fading can bring a trouble for choising frame synchronization. Therefore, filling up the miss frame synchronization or reject the error frame synchronization which i.e. filling up the frame synchronization is important. The filling up frame synchronization which was solved years ago can be utilized in the engineering. By the above reason, it is not discussed.

3.1.4 Data processing steps of engineering

1. Signal convertion and time-digital (T/D) convertion

Signal convertion using math models is the brief condition for the data processing engineering of PPM/PPK system without reference pulse, it's aim is to acquire data to input it into computer, and satisfies all requirment of data processing.

2. Choising and filling up frame synchronization
3. Input system constants into a computer

The system constants which are inputted into computer are:(a). the minimum reference interval C_{min}. (b). themaximum reference interval C_{max}. (c). the channel period T_o. (d). the frame sync marker interval t_F. (e). the frame period T_F.

4. Establish the channel pulse D_1.

As shown in math models it is very important to recognize and establish the channel pulse D_1 which is the starting point of data operation of the data processing unit and the entering pulse to enter the sync state.

5. Establish data processing pattern and design software

Following contents are mainly contained: (a). choosing math modeles of data processing for the system;(b). define t_{xn} or $\triangle t_{xn}$; (c). define output pattern: δ_{xn}, U_{xn} or else; (d). input channel ordinals for quick-look and report; (e). output: print, plot and store.

6. Operation

3.1.5 Engineering

The data processing engineering of PPM/PPK system is roughly classfied as three types: general hardware which is called a special computer also; general computer; and mixer which has both hardware and μc.

3.2. General hardware engineering

Let us discuss the instance, relation channel type of measured interval. Refer to (15): $t_{xn} = t_{x(n-1)} + t_{n-1}' \; t_n' - T_o$

3.2.1 Assume discussed format of the PPM/PPK signal has following features:

(1). format in Fig.3; (2). frame synchronization is a long interval, it's width is t_F; (3). channel period is T_o; (4). the minimum reference interval of the system is C_{min}, and locates at 1-st channel; (5). the maximum reference interval of the system is C_{max}; (6).the ratio of voltage increment to interval increment is K_n ($V/\triangle t$); (7). form of output data is δ_{xn} or U_{xn}.

3.2.2 The principle block diagram is shown in Fig.4, it is really a special computer. It corresponda with (15)

3.2.3 Brief operating process

(1). In Fig.4, whenever the PPM/PPK signal reaches the frame sync recognization circuit, choice the frame synchronization from it, and complete filling up the frame sync at the same time.

(2). The frame sync opens the strobing gate of D_1 which selects the pulse D_1. Coming on time of pulse D_1 demostrates the truthfulness of the selected frame sync and makes the data processing unit into synchro state. For this purpose, the channel pulse D_1 directly completes three operations:(a).open channel pulse gate: (b). clear 'm bit counter' ; (c). open 'read C_{min} control gate' , input C_{min} into 'm bit accumulator' therefore the datum of accumulator should be $t_{x1} = t_{xmin} = C_{min}$

(3). Channel pulse D_2 completes the following operations. (a). open m bit data transmission gate, make m bit parallel data which correspondes to interval $t_1' t_2'$ into the accumulator, and then complete the add

operation in the accumulator: $t_{x1}+t_1't_2'=C_{min}+t_1't_2'$; (b). then clear the m bit counter, make it restart.
(4). Complete the addition in m bit data accumulator, then input the sum into the m bit data subtractor and output a pulse which opens read T_o control gate, at last, input T_o into the subtractor.
(5). m bit data subtractor completes the following operations: (a). finish the subtraction and obtain from it, $t_{x2}=C_{min}+t_1't_2'-T_o$; (b). sent t_{x2} back into the accumulator and get ready for the next channel; (c). send t_{x2} into the m bit data divider/multiplier; (d). give a control pulse to open the read C_{max} control gate, input the C_{max} or K_n into the divider/multiplier; (e). when it is needed the t_{x2} can be given into a terminal or other peripheral.
(6). m bit data divider/multiplier completes the following operations. (a). finish the divider (multiplier) operation and obtain: $\delta_{x2}=\triangle t_{x2}/C_{max}$ or $U_{x2}=K_n\cdot\triangle t_{x2}$; (b). give the parallel data δ_{x2} (U_{x2}) and handshaking signals to the peripheral to print and to plot.
(7) . When the channel pulse D_3 comes, the above process begins with (3) again. Notice the following difference: (a). in this time the data t_{x2} has been in accumulator. Complete the addition $t_{x2}+t_2't_3'$ while the pulse D_3 comes; (b). not input C_{min} into the accumulator because the pulse D_1 has not been; (c). complete the subtraction and obtain: $t_{x3}=t_{x2}+t_2't_3'-T_o$ send the t_{x3} back into the accumulator for the next.
(8). Repeat from (1) to (7) until each data pulse of the frame has been processed, then process the data of the next frame and go on.

3.2.4 The principle block diagram II
The process has been described in above section, now the concept of the effective interval $\triangle t_{xn}$ is used. The formula (37) is: $\triangle t_{xn}=\triangle t_{x(n-1)}+t_{n-1}'t_n'-T_o$, also:

$$\triangle t_{x1}\equiv 0$$
$$\triangle t_{x2}=\triangle t_{x1}+t_1't_2'-T_o$$
$$=t_1't_2'-T_o$$
$$\triangle t_{x3}=\triangle t_{x2}+t_2't_3'-T_o$$
$$\triangle t_{x4}=\triangle t_{x3}+t_3't_4'-T_o$$

As mentioned in the above section, the formula (37) is similar to (15) except for C_{min}. The order of the addition and subtraction of the formula (37) can be arranged at will. The subtraction ($t_{n-1}'t_n'-T_o$) can be completed with the form of $t_{n-1}'t_n'$ at the same time, as T_o is a constant, when the mode of the m bits parallel counter in Fig.4 equals T_o , the operation of subtracting T_o can be realized automatically because the counter will be reset.
Obviously, the above operation $\triangle t_{x2}=t_1't_2'-T_o$ has been completed in the counter. After getting $\triangle t_{x2}$ the counter does not yet stop, and go on. In reality, it equals to execute the addition ($\triangle t_{x2}+t_2't_3'$).
In the process, the counter certainly reset. It equals to complete the operation $\triangle t_{x3}=\triangle t_{x2}+t_2't_3'-T_o$, the value $\triangle t_{x3}$ is remained in the counter. By the same reason, $\triangle t_{x4}$, $\triangle t_{x5}\cdots\cdots\triangle t_{xn}$ can be obtained.
Therefore, as mentioned in the above section, m bits data accumulator and m bit data subtraction in Fig. 4 can be replaced with m bits parallel T_o counter, thus, obtain the Fig.5 principle block diagram II. Fig. 5 deffers from Fig.4 in which addition and subtraction are completed by T_o counter. Therefore, when the pulse D_2 passes through 'data pulse input gate' and reaches the 'm bits data transmission gate' the data inputed into 'm bits data divider/multiplier' through the transmission gate are $\triangle t_{x2}$. When the pulse D_3 comes the $\triangle t_{x3}$ is inputed, until $\triangle t_{xn}$ is inputed. They have no other difference.

3.2.5 A few explanations
(1) . t_{xn} and $\triangle t_{xn}$ in (15) and (37) have calculated already in Fig.4 and Fig.5 . For the Fig. 4, to calculate t_{xn} from $\triangle t_{xn}$: (a). when $C_{min}=0$ we can treat (15) as (37), and $t_{xn}=\triangle t_{xn}$; (b). as $C_{min}\neq 0$, if we require the data processing result to be the form of t_{xn}, it corresponds to the hardware principle block diagram I. If we require the form of $\triangle t_{xn}$ and it is completed by the hardware principle block diagram I, it only requres to preset the C_{min} register with C_{min} 0. This equals to complete the subtraction $\triangle t_{xn}=t_{x(n-1)}-C_{min}$.
(2). output data
The data output to the peripheral equitments, whichever t_{xn}, $\triangle t_{xn}$, δ_{xn} or U_{xn}, both parallely and seriesly, it is determined by the peripheral.

3.3 The engineering which combines hardware and software----the general computer
In the discussion of the hardware engineering----the special microprocessor, it is very clear to realize the signals conversion and the data processing of the PPM/PPK system using the technical principle of this

paper. The general computer type is similar to that, therefore, only summarise it as following.
The difference accumulate type of the measured interval is discuse based on the formulas (23) and (39), and give an example of the data processing.

$$t_{xn} = C_{min} + \sum_{i=2}^{n} (t_{i-1}' \; t_i' - T_o)$$

$$\triangle t_{xn} = \sum_{i=2}^{n} (t_{i-1}' \; t_i' - T_o)$$

3.3.1 About the format and system state of the system without reference pulse
In order to easily compare them, assume the format and the system state the same as the condition of the hardware engineering. In addition, increase the requisition of the data storage, quick--report and quick--look: (1). The format is shown in Fig.3; (2). The frame synchronization is a long interval which equals $t_F \cdot \triangle t$; (3). The channel period is $T_o \cdot \triangle t$; (4). The minimum reference interval $C_{min} \cdot \triangle t$ of the system lies on the 1-st channel; (5). The maximum reference interval $C_{max} \cdot \triangle t$ of the system; (6). The voltage increment—to—interval increment ratio is K_n (V/$\triangle$t) ;(7). Some measured data output, quick--look; (8). The final results are expressed by the form of δ_{xn} or U_{xn}; (9). Print and plot the final results; (10). Storage all the final results of the data processing.

3.3.2 The principle block diagram I
The frame selection and filling up and the 1st pulse D_1 selection are necessary for the data processing engineering which is based on the formulas (23) and (39) and by the instrument of the general computer. These operations are all completed by it, the complex software development is refered. As shown in Fig.6, the frame selection and the pulse D_1 selection circuit are added to the computer.

3.3.3 The operating procedure
The principle block diagram is based on the formulas (23) and (39), its procedure as following: (1). After selecting the frame sync and pulse D_1 the constant T_o is inputed into timer/counter of the computer by the frame sync pulse, then the pulse D_1 starts the timer/counter which cycle counts, and makes the device into synchro--state; (2). The timer/counter which is started by the pulse D_1 cycle counts itself, and produces t_{x2} or $\triangle t_{x2}$ at that moment when the pulse D_2 reaches it, has completed the signal convertion; (3). The pulse D_2 opens the interrupt at the same time or is given as a acknowledgement signal making the computer to execute t_{x2} or $\triangle t_{x2}$ data processing routine; (4). When the pulse D_3 comes the above steps repeat until each measured channel of a frame has been completed. It still starts from the frame selection and compensation for the next frame; (5). It is of a great importance to develop the software containing the above steps, quick output and show of the data and the data storage.

3.3.4 The software development flow process
The software which includes the print, plot and display function and the data storage can be developed on the basis of the formulas (23),(39),(40) and (41) and other requirements. The development flow—process shows as folloing:

power—on reset the computer and peripheral
↓
computer self—checking
↓
input C_{min}
↓
input T_o
↓
input C_{max}
↓
input the measured channel number n
↓
input the channel numbers for quick report and look
↓
→ wait for the frame sync pulse
↓

put T_0 into timer/counter by the frame sync pulse

wait for the pulse D_1

start the timer/counter by D_1

reset T_0 counter itself

wait for the channel pulse

the pulse D_2 appears (then $D_3, D_4 \cdots\cdots D_n$)

read the timer/counter

obtain t_{x2} ($\triangle t_{x2}$) on the basis of (27) and (43)

reset T_0 counter itself

obtain δ_{xn} (U_{xn}) on the basis of (44) or (45)

save both the result and it's channel number

check the channel to be a quick report and look or not

give both the result and it's channel number

print, plot

check the channel to be the last one or not

jump the frame selection and compensation

It should be shown, the final accuracy of the data processing results is mainly determined by the main clock of the computer and the computer itself, containing it's operation speed. Although the operation read the counter can bring a little error, but a high speed computer satisfies for the demand of the data processing accuracy, even using a low grade computer, it is possible to satisfy the request of the processing accuracy by correctly modifying based on the constant C_{min}, C_{max} and etc.

3.3.5 Principle block diagram II

There is a example in Fig.7, using some hardware and a low grade computer to complete the data processing task and satisfy the request of the accuracy. It differs from the diagram I in Fig.6 in following

(1). use external 'm bits parallel T_0 counter' and 'm bits data latch' as a substitute for a timer counter and the corresponding software function of the computer, directly complete the calculation of $\triangle t_{xn}$ in (43), then input it into the computer to complete the other processing.

(2). the data, each $\triangle t_x$ can be read by the pulses $D_1, D_2, \cdots\cdots D_n$ from the 'm bits T_0 counter'.

The operating program and process are similar to that of the principle block diagram in Fig.6 and it's explanation when $\triangle t_x$ enters into the computer.

Conclusion

By means of the analyses and research of the signal frame structure for the typical PPM system and the PPM without reference pulse system, we obtain the principles of the entering in sync state and the data processing. It can be seen that the signal frame structure carries a large quantity of information. Therefor, keeping up researching the system and obtaining a great achievement are hoped.

REFERENCES

[1] Li You-Ping, 'A PPM/PPK TELEMETRY SYSTEM', ITC. 1980 Vol.16, P609~P615.

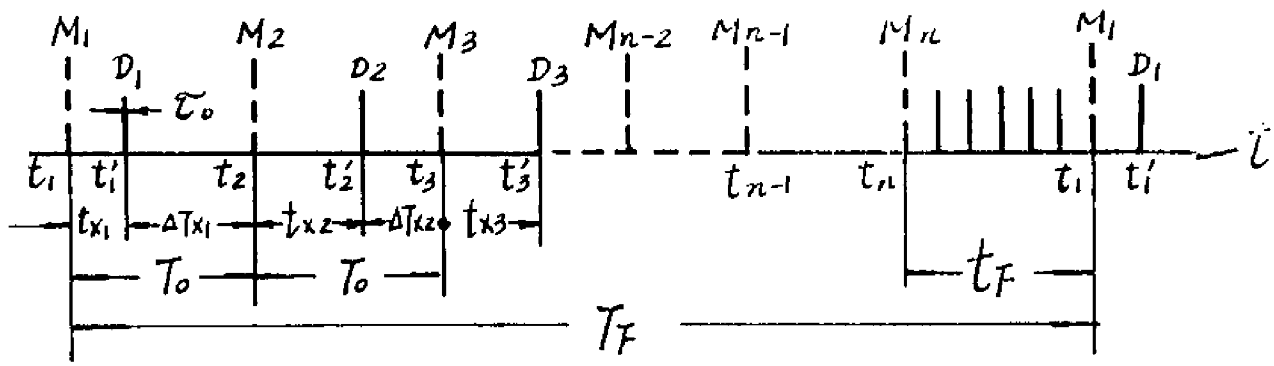

Fig.1. typical format of PPM(PPK) without reference pulses

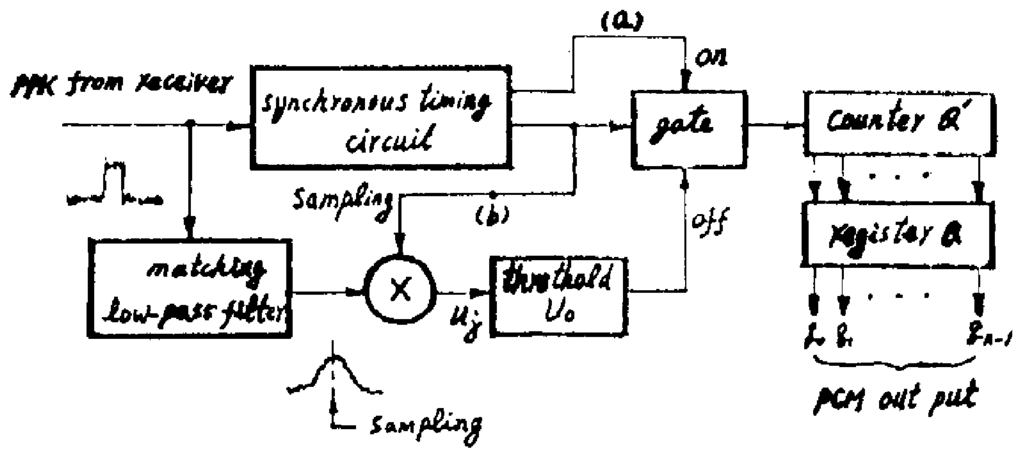

Fig.2 Detection device

(a) marker pulse (b) Count pulse

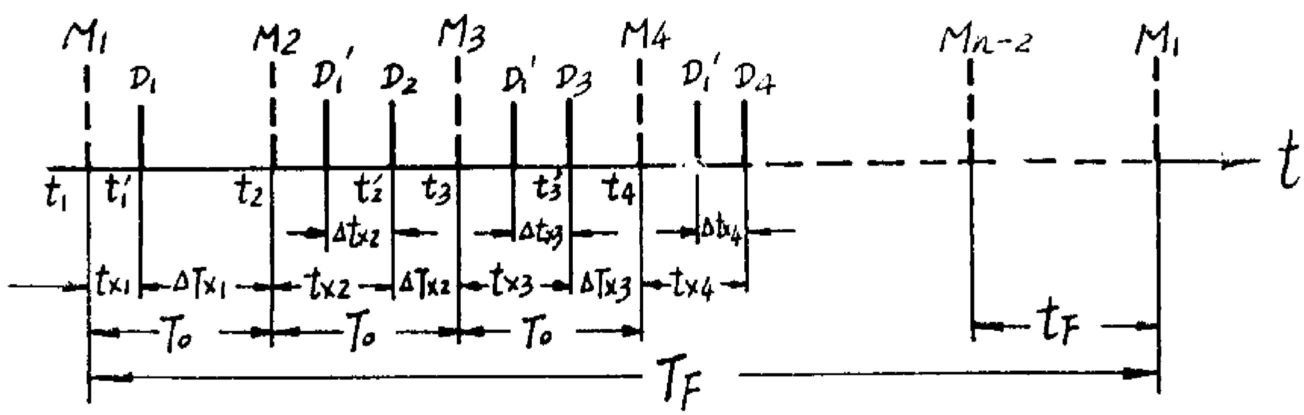

Fig.3. signal frame struction to possess imaginary data pulses D_1'

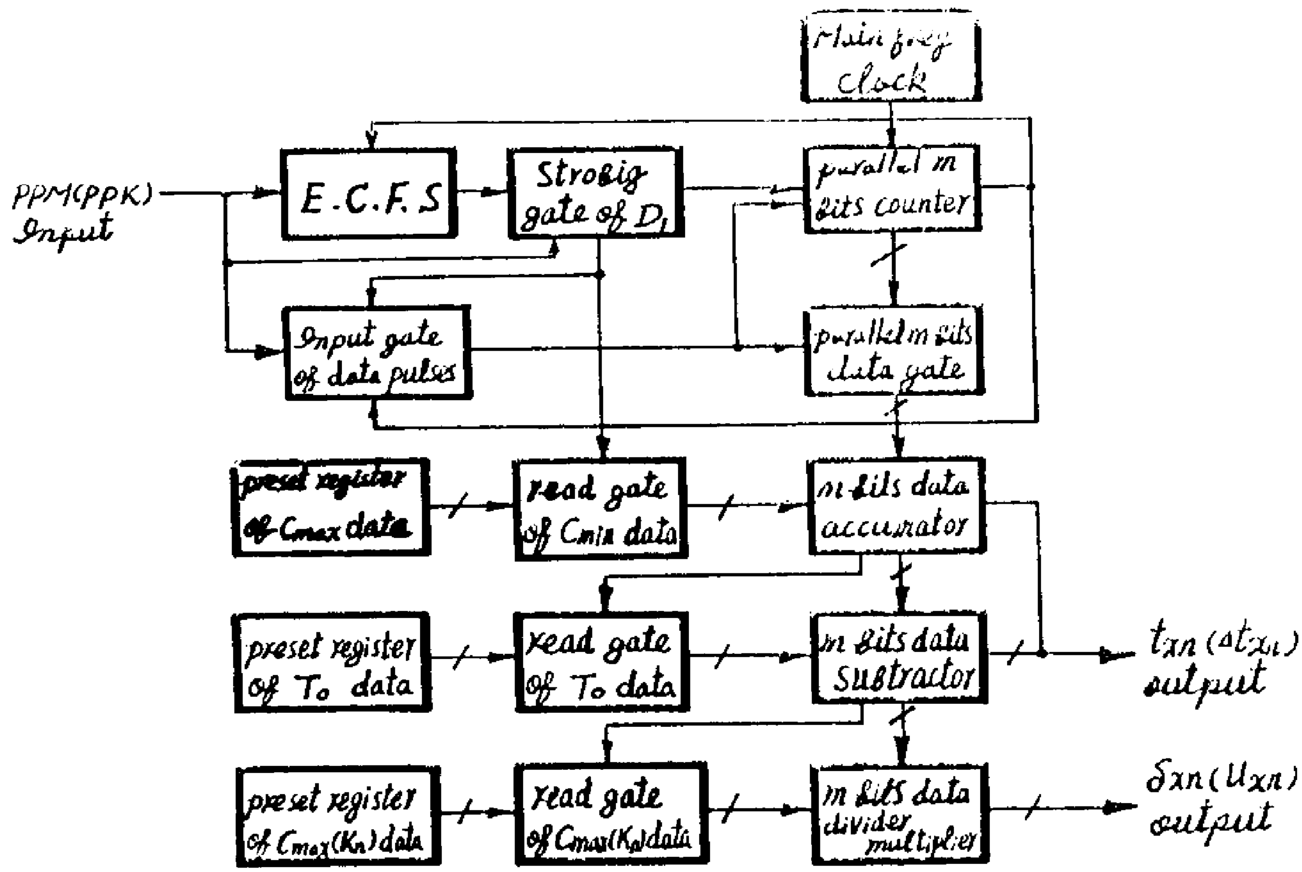

Fig.4. principle block diagrim I of hardware way

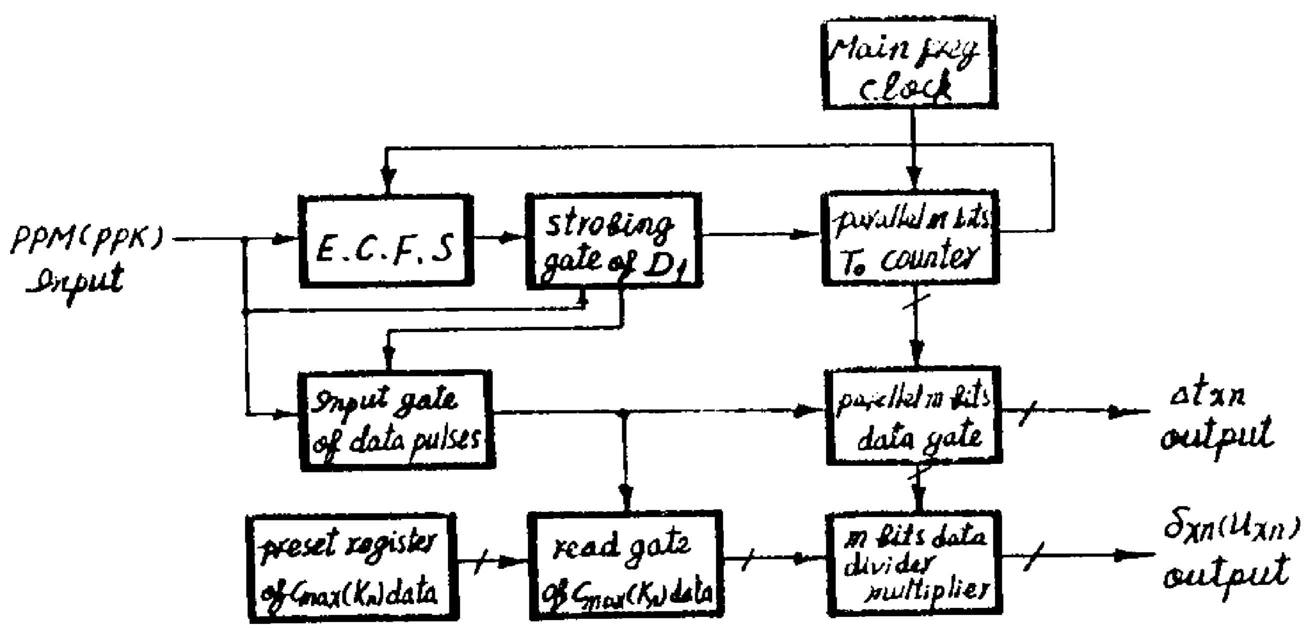

Fig.5. principle block diagrim II of hardware way

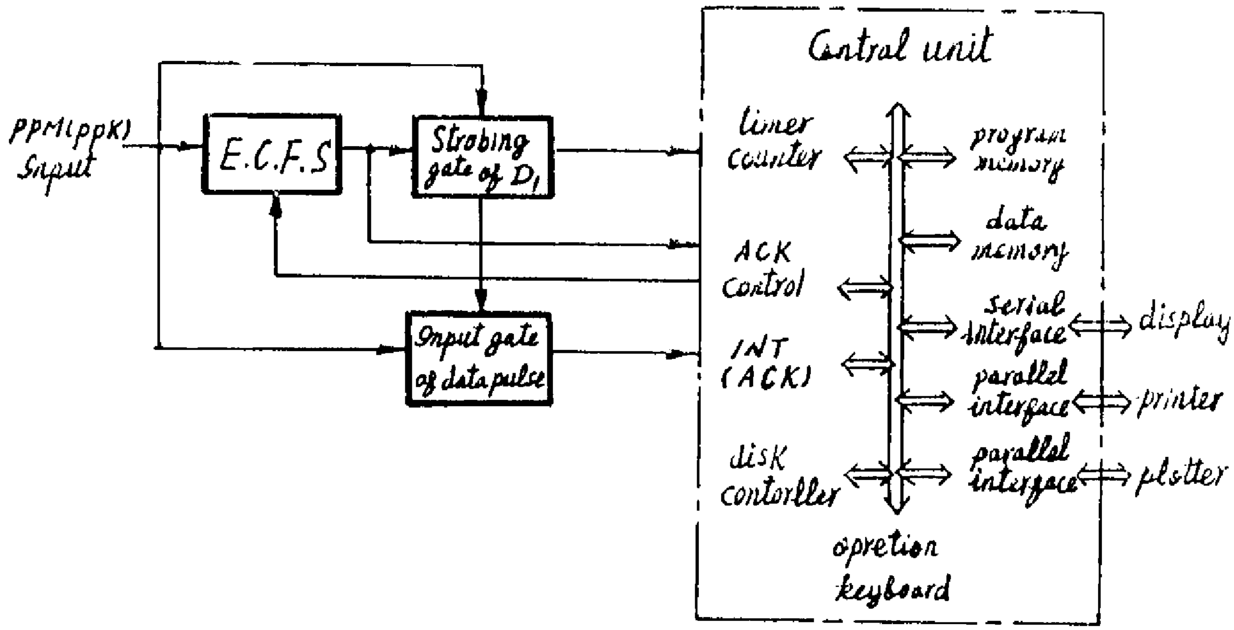

Fig. 6. principle block diagrim I of software and hardware way

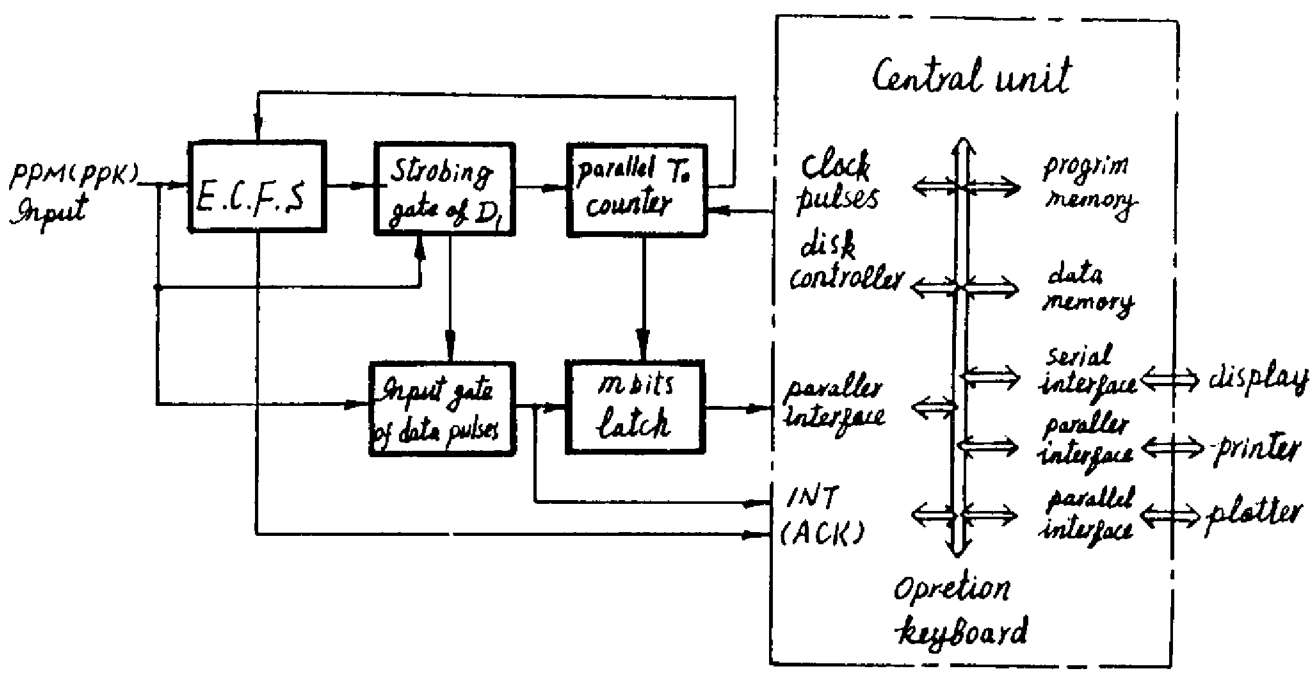

Fig. 7. principle block diagrim II of software and hardware way