HUITIEME COLLOQUE SUR LE TRAITEMENT DU SIGNAL ET SES APPLICATIONS

NICE du 1er au 5 JUIN 1981

UTILIZATION POSSIBILITIES OF PCM LINKS FOR DIGITAL COMMUNICATION

Dr. Eng. M. Nagi El Yousfi & Dr. Eng. M. Moustfa Rateb

The George Washington University, Department of Electrical Engineering & Computer Science, Washington, DC 20052

RESUME

Resume:

Les systèmes MIC sont souvent utilisés pour la transmission numérique. Il a été prouvé que l'utilisation, sur ces systèmes MIC, de canaux numériques pour la communication numérique n'était pas rentable. Ce problème peut être résolu si on réussit à accéder ou à extraire les canaux numériques de ce système MIC pour les utiliser dans la communication numérique, sans conversion A/N et N/A devenue inutile.

Cette note suite cette idée et décrit les possibilités d'entrée de données dans le système MIC sans conversion inutile.
L'obtention de ces possibilités dépend de ce qui suit:
a) il existe en général deux possibilités d'insertion des données dans le MIC: soit directement ou par bourrage.
b) si des liaisons MIC existent, il est préférable d'utiliser le canal numérique de 64K bit/sec pour la communication numérique,

il faut à présent résoudre le problème d'insertion des données sur cette interface.
Pour arriver à cette interface, cette note propose d'introduire un extracteur de canal numérique afin de permettre l'entrée des données sur la partie numérique de la liaison MIC.
Cet extracteur numérique représente un élément externe supplémentaire du MIC et agit comme un adapteur fournissant des circuits numériques.

Avant d'analyser l'introduction de l'extracteur numérique, cette note montre les différentes possibilités d'entrée dans le MIC: le multiplexeur numérique TDM à faible vitesse, l'extrémité frontale de l'ordinateur, le raccordement direct au terminal, l'interupteur de circuit et de transmission, la grande bande passante et le trans-multiplexeur.
Pour chaque entrée dans le MIC, on analyse l'emplacement de l'extracteur et la vitesse d'entrée des données en association avec le timeur MIC et l'extracteur.
Trois cas sont analysés:
Quand le timeur pour le signal d'entrée a la même fréquence que le timeur MIC, ou s'il est plus lent ou si les données d'entrées arrivent à l'extracteur à une vitesse et un code irréguliers. Dans le dernier cas, la note indique une distortion maximum inhérente des données et détermine alors les taux de modulation correspondant des données transmises de cette facon sur le raccordement des données point par point (12800 Baud) et sur des interrupteurs (3200 Baud).
Enfin, pour compléter l'étude, cette note décrit les différentes façons de transmettre des signaux numériques sur des chaines MIC isochrones; le code et le taux de modulation opaques avec regénération; et le code et le taux de modulation sans regénération. Cette noet montre enfin que l'exemple codé est plus rentable.

SUMMARY

Abstract:

In many cases PCM systems had been used for telephone transmission. It proves to be uneconomical when one uses analog channels implemented on these PCM systems for digital communication. But if one succeeds in accessing or extracting the digital paths of this already in-service PCM system and use them for digital communication without unnecessary A/D and D/A conversions, this mentioned waste will be eliminated.

This paper utilizes the philosophy of this idea and illustrates the utilization possibilities of entering data into the PCM system without these unnecessary conversions.
But the provision of these possibilities depends on the following facts:
a) There exist in general two possibilities of inserting data into PCM system: either directly or with the use of stuffing.
b) Wherever PCM links exist, it is advisable to use the 64 K bit/sec digital channel for digital communication,

and now the problem of inserting data has to be solved on this interface basis.
But to attain this interface the paper proposes the introduction of digital channel extractor to enable the entrance of data into the digital part of a PCM link.
This digital extractor represents an additional external device to the PCM equipment and acts as an adaptive device providing digital circuits for digital communication.

But before analyzing the introduction of the digital extractor, the paper illustrates the different input possibilities to the PCM which can be: Low-speed digital TDM multiplexer, computer front end, direct connection of data terminal equipment, or circuit and message switching, wideband modem, and trans-multiplexer.
For every input to the PCM systems is analyzed the place of the extractor and input bit rate in association with PCM closk and the extractor.
Then, the paper analyzes three cases:
When clock derived from the incoming signal has the same frequency as the PCM clock, lower or when the incoming data arrives to the extractor with random speed and code. For the last case, the paper formulates the maximum inherent data distortion, and then determines the corresponding modulation rates of data transmitted in this manner on point-to-point data link (which is of 12800 Baud) and on switched connections (which is of 3200 Baud).

Finally the paper as to complete the survey.

discusses the ways of transmitting digital signals over isochronous PCM link; code and modulation rate untransparent with regereration, and code and modulation rate without regeneration. Then it shows that coded sampling is more economic.

1. Principle of PCM Transmission:

It is known, that in PCM transmission a pulse coded speech is obtained by sampling the amplitude of the analog signal at a rate at least twice as high as the highest audio frequency to be transmitted, then encoding each sample into binary form. In a typical PCM system, voice waveforms are sampled at a rate of 8000 per second. Each sample is represented by an 8 bit binary number (one bit as a sign of the sample, six more bits for magnitude and one further bit providing synchronizing and signalling). This represents a time slot of 4 μ sec. The eight-bit sample at 8000 samples per second produces an 8 x 8 = 64 K bit/sec stream for each PCM speech channel.

In practice PCM systems group together 24 or 30 speech channels by a time-division multiplexing. In CCITT systems there are 30 channels in the group plus extra two channels to carry framing and signalling information. Thus, a complete frame contains 8x32 = 256 bits. These fall into 32 time slots of 8 bits each. The samples are taken at 8000 per sec for each channel. Each channel in its turn fills a time slot transmitted with a period of 125 μ sec, and thus the PCM system operates at output aggregate of 2048 K bit/sec.

2. Entering Data Signals to PCM Systems:

Generally, there are two possibilities of inserting data into PCM system (with output aggregate 2048 K bit/sec and input interfact of 64 K bit/sec).

a. Directly when the bit stream sequence to PCM multiplexer is independent and bit rate equals 64 K bit/sec.
b. With the use of stuffing when the bit rate of the incoming bit stream to the PCM multiplexer is less than 64 K bit/sec.

In fact, wherever PCM links exist, it is advisable to use 64 K bit/sec digital channels for data transmission. The question of inserting data into PCM systems is quite solved even directly or with the use of stuffing on the 64 K bit/sec interface basis. This 64 K bit/sec interface, corresponding to a time slot of the standard 32 channels PCM system can be attained either by entering into the PCM system between A/D convertors and time division multiplexor; or by using a digital channel extractor external to the PCM equipment. Consequently, the digital extractor can be connected to any of the inputs to the PCM systems: low-speed digital TDM multiplexer, computer front end, or direct connection of terminal equipment or a wide-band modem.

3. Inputs to PCM Multiplexer:

To attain this interface, the inputs to the PCM multiplexer can be one of the following alternatives:

a) Digital TDM multiplexer:

It yields digital subchannels of lower signalling rates on one hand and with an aggregate output of 64 K bit/sec interfacing a PCM multiplexer via an extractor on other hand. The 64 K bit/sec clock signals proceed in the direction opposite to data stream. This is one of the facilities for sharing a common transmission path by introduction this low-speed digital multiplexer. This multiplexer interfaces on one hand with a number of slow-speed channels, and on the other hand with a medium speed channel or a PCM multiplexer. With start-stop signals from terminals on the low-speed channels a slight difference in timing can be absorbed in the stop-element, otherwise all the aspects of this TDM multiplexer are the same as with a PCM multiplexer.

b) Direct connection of data terminal equipment to PCM multiplexer:

If the line terminal is directly connected, to PCM multiplexer, data can be extracted at bit rate given by the PCM clock. No stuffing is required, the signal at the output of the distant PCM equipment are without distortion.

The data terminal equipment DTE can be also replaced by a digital circuit-switching exchange or a message switching exchange or a message switching centre.

c) Computer front end:

A computer interface unit serves as an adapter between a computer channel on one hand and a digital extractor on the other hand.

In this case the extractor interfaces the computer on an on-line basis. Necessary signal adaptations can be performed by line control protocal.

d) Wide band modem interfacing a PCM:

Wide band modem enables interconnection of primary group channels adapted for digital transmission and PCM link. If the clock of a synchronous modem and PCM clock are not synchronized or if assynchronous modems are used, stuffing has to be applied.

A synchronizing channel can be run with considerable lower signalling rate compared with that of the clock being synchronized by this channel.

This synchronizing channel can be used for transmission synchronizing and signalling signals for more than one channel.

e) Trans-multiplexor directly interfacing PCM:

A trans-multiplexor acting as a code convertor can convert an aggregate FDM signal into an aggregate TDM signal. This TDM signal can enter the PCM interface.

By using trans-multiplexors, saving may be achieved in concentrating the function of the conventional FD demultiplexer (analogue to digital convertors and time division multiplexor) into one functional analog aggregate to digital aggregate conversion unit working with a prescribed algorithm.

4. Necessity of a digital extractor for data transmission possibilities on PCM links:

For the purpose of attaining 64 K bit/sec interface of PCM multiplexor to digital channels, a digital extractor is introduced. A digital extractor yields a single digital (data) channel of bit stream equal or less than 64 K bit/sec. It is an adaptive device which enables binary data signals to enter the digital section of PCM system.

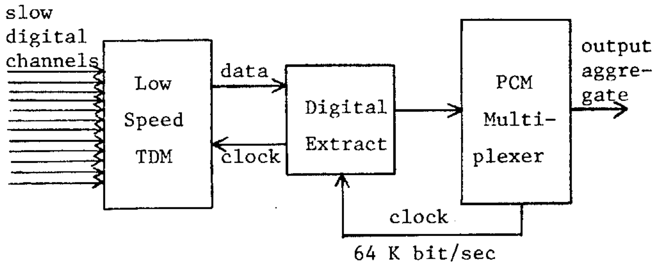

Fig. 1: TDM multiplexor yielding slow digital channel interfaces PCM multiplexor via digital extractor.

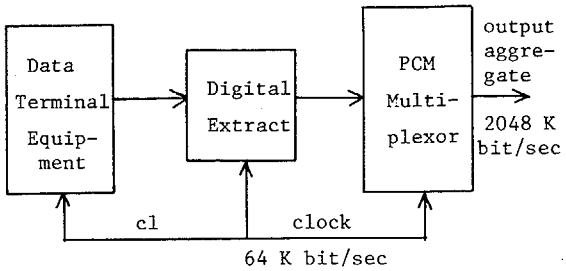

Fig. 2: Data terminal equipment DTE is directly connected to PCM multiplexor via digital extractor.

N.B. DTE can be replaced by digital circuit switching exchange or a message switching centre.

Thus, digital extractor provides digital circuits for data transmission possibilities on PCM systems.

With respect to input data to digital extractor, there exist three cases to be considered:

Case (1) The clock derived from the incoming signal (or delivered by a seperate channel) has the same mean frequency as the PCM clock:
In this case, only an elastic store is needed to overcome transient differences between clocks--caused by variable phase shift of synchronizing signal during transmission).
The signal is regenerated.

Case (2) The clock derived from the incoming signal has a slightly lower frequency than the PCM clock:
In this case, elastic store and stuffing have to be used, i.e., stuffing bits being generated are to be added.
The equipment on the opposite side has to recognize these stuffing bits from data bits. This can be realized either from information carried by the stuffing bits themselves or marking them by their transmission on extra channel.
Isochronous signals are not regenerated, the degree of telegraph distortion is altered. While start-stop signal can be generated.

Case (3) Incoming binary signal arrives to data extractor with random modulation rate and random code:
In this case, no clock frequency is needed. The signal is sampled by a sampling rate of 6400 samples per second controlled by PCM clock. Ths signal is reproduced with a telegraph distortion exceeding that of the input signal by maximally the the amount $\frac{125\ \mu\,\text{sec.}}{8\ \text{a sec}} \cdot 100$.

Generally since sampling frequency fs is defined by the reciprical of the sampling interval as, Δs, and the nominal modulation rate v is defined by the reciprical of the unit interval of data signla a, then the maximum inherent telegraph distortion of digital links equals:

$$\delta_{max} = \frac{\Delta s}{a} \cdot 100 = \frac{v}{f_s} \cdot 100\ \%$$

where it is necessary to choose $f_s >> v$ in order to keep distortion low.

- In point-to-point data link, we could tolerate 20% inherent distortion. Then a maximum modulation rate of the transmitted data signal is:

$$v_{max} = \frac{\delta_{max}\, f_s}{100} = \frac{20.64000}{100} = 12800\ \text{Bd}$$

without regeneration.

-for switched connections an inherent distortion of only 5% can be tolerated (because of the possibility of addition of distortion in tandem connected links).

Then, the maximum modulation rate of the transmitted data signal on switched network is:

$$v_{max} = \frac{5.64000}{100} = 3200\ \text{Bd without regeneration}$$

5. Methods of data transmission over PCM links:

As to the way of transmitting digital binary signals over a given data isochronous link (the 64 K bit/sec PCM digital link or channels of a TDM multiplexer), there exist two alternatives:

1 - Code and modulation rate transparent method without regeneration.

2 - Code and modulation rate untransparent method with regeneration.

Transparency limits the maximum modulation rate of input signal (with respect to the maximum tolerable inherent distortion) to 5 or 20% of that achievable with an untransparent system depending on whether the channels should work in tandem or not. Tandem connections are to be expected especially in switched networks. Besides, code and speed, transparency without regeneration is further subdivided into two methods:

- simple sampling;
- coded sampling.

Better utilization of code transparent system could be achieved by means of the coded sampling method. The economy of the coded sampling can be compared with the simple sampling as the difference of expressing a "number" by a number of dashes (case of simple sampling) and expressing the same number in a binary code (case of coded sampling 2n). The increase in sampling rate by coded sampling as compared with simple sampling is $2^n/n$, where n is the number of samples in one unit interval of signal carrying the sampling information. In this way, it is possible:

- either to decrease inherent distortion for a fixed modulation rate of the sampled signal and a fixed modulation rate of the signal on the transmission path over the digital links;
- or with the same inherent distortion of the transmission link and of the signal on the transmission path to increase modulation rate of the sampled signal.

Although it is economically advantageous to increase n, it cannot be increased to such an amount as to disable transmission of the shortest incoming significant interval (i.e. unit interval possibly shortened by telegraph distortion). Another disadvantage of the coded sampling method is that an error in one transmitted bit can cause distrotion as large as one half of the investigated period, whereas with simple detection it is only in one sampling period.

Lastly we can conclude:

- code and speed untransparency with regeneration posses the property of elimination of distrotion due to regeneration;
- with the use of coded sampling better utilization (more economical) of code transparent systems could be acheived. But it imposes restriction on the shortest characteristic interval to be transmitted and tends to increase telegraph distrotion considerably.

For these reasons, such coded sampling method is not suitable for channels having inferior transmission quality including those affected by noise (e.g., radio relay link).

Conclusions:

The paper illustrates the different input possibilities to PCM system it proposes the introduction of a digital extractor for handling digital communications and enabling the entrance of data in the digital part of the primary PCM system without unnecessary A/D or D/A conversions. The behavior of data inpur to PCM is analysed and the corresponding modulation rates and distortion are assessed (the modulation rate of data on point-to-point data link is of 12800 Baud and on switched connections of 3200 Baud).

With respect to the ways of transmitting digital binary signals over a given for example 64K bit/sec PCM digital link, there are two ways of communication:

- code and modulation rate untransparent method with regeneration. It possesses the property of elimination of distortion due to regeneration;
- code and modulation rate transparent method without regeneration (which is divided into simple sampling and coded sampling). The coded sampling is more economical but on the other hand is tending to increase telegraph distrotion. Thus its application is limited to channels having higher transmission quality.

References:

Bennett and Davey: Data Transmission, McGraw-Hill, 1965.

J. Martin: Teleprocessing Network Organization, Prentice-Hall, 1970.

Davies Barber: Communivation Networks for Computer, Wiley, 1973.