CAT. No. 74 CHO 859-9-CSCB

INTERNATIONAL CONFERENCE ON COMMUNICATIONS

ICC 74 – JUNE 17-19
MINNEAPOLIS, MINNESOTA

CONFERENCE RECORD

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

A DIGITAL STANDARDS-CONVERTER FOR TELEVISION USING INTRA-FRAME LINE INTERPOLATION TECHNIQUES

K. Kinuhata, H. Sasaki, H. Yamamoto and K. Amano

Research and Development Laboratory,
Kokusai Denshin Denwa Co., Ltd.
2-1-23 Nakameguro, Meguro-ku, Tokyo, JAPAN

SUMMARY

Exchange of television programs between two countries that have adopted different standard systems requires standards conversion. This paper reports the features, construction and performance of a new digitalized standards converter. The converter possesses a digital storage device large enough to store three fields of television signals in order to realize a new sophisticated signal processing for scanning systems conversion, and can remove almost all the shortcomings inherent in the analogue converters.

1. INTRODUCTION

Since satellite communications were introduced in the field of global communication, international exchange of television programs has been practiced frequently. Although there are many television systems in the world, three standard systems, NTSC, PAL and SECAM are used in almost all international networks. Exchanging programs between two countries that have adopted different standard systems require standards conversion. There are two kinds of standards conversion, one for color systems and the other for scanning systems. Greater difficulty exists in the latter. The former can easily be achieved by conventional video processing techniques, however, the latter is accompanied with a different problem, the necessity of large storage or delay of video signals.(1)

The earliest converters consisted of a camera operated in the desired standard system and a picture monitor operated in the original standard system. Improved models of this type of converter are now used in West Germany.(2) On the other hand, all-electronic converters were developed in England(3) and also in Japan.(4), (5) They are constructed by using sophisticated analogue techniques of electronics and depend on the availability of ultrasonic delay lines. Although they are fully operational at present, they still have some inherent shortcomings, for example, geometric distortion, jerky movement, low signal to noise ratio, the necessity of delicate adjustment, large size and high cost.

Recently, remarkable developments have been achieved in digital electronics, especially, high-speed and high-density memory devices. Now it has become possible to make use of digital memory devices to store picture signals and to carry out the conversion by means of digital signal processing. These digital techniques can remove most of the aforementioned shortcomings in the analogue converters. Some experimental results of such digitalized converters have been already been reported.(6) The authors have also studied a digitalized converter.(7), (8), (9), (10)

This paper presents the features, construction and performance of the converter recently developed in which a three-field storage is installed to achieve more advanced scanning systems conversion.

In the following, line and field interpolation methods, which are basic problems of the scanning systems conversion, are discussed first, and a new line interpolation method, we call intra-frame line interpolation, is proposed. Then, the organization of the present digitalized converter using the new line interpolation method is described. Finally, performances of the converter are shown.

2. INTERPOLATION

The scanning system conversion consists of line conversion and field conversion. These processes have particular problems with distortion of output pictures individually. The line conversion causes geometric distortion in the form of a serrated appearance particularly noticeable on sloping edges in a picture, and the field conversion causes a jerky appearance of a moving object in a picture. To overcome these problems, interpolation techniques are utilized.

2.1 Line Interpolation

If some sequencies of input lines are used directly as output lines in the conversion from 625 to 525 lines, an input line is omitted approximately every six lines. Because of this omission, the diagonal edge which is straight in an input picture takes on a serrated appearance in an output picture. The similar appearance is caused by duplicating the input lines in the reverse conversion. Fig. 1 shows an example of a diagonal edge in a 625 line picture derived from a 525 line picture by duplicating certain lines. This serrated appearance, called geometric distortion, can be visually lightened by line interpolation. In the conventional line interpolation process, the video signals of successive lines in an input field are weighted in proportion to their relative positions to a resultant output line and mixed to produce the output line.(4), (5) Although geometric distortion can be largely avoided by this process, considerable loss of sharpness and appearance of spurious movements result.

Today, the interlace scanning method in which the lines are interlaced with each other on two successive fields is used in all television standard systems. Therefore, a complete picture is formed by two successive fields, called a frame. In other words, each picture is sampled by every line on a frame in the vertical direction. Thus, the line conversion can be regarded as a process of resampling to change the rate of sampling in the vertical direction. From this point of view, the conventional line interpolation methods are equivalent to performing the resampling of a frame by mixing its every other lines. Thus, we can expect that more accurate resampling will be achieved by making use of every line of an input frame. We call the line interpolation for such resampling "intra-frame line interpolation", and on the other hand, the conventional one "intra-field line interpolation". It is expected that the output degradation of still pictures under the present intra-frame interpolation will be half that of the conventional one.[8]

Here, examine the equivalent transfer function of the line interpolation for the diagonal edge, denoted $H(\omega)$, to clarify the differences between those two line interpolation methods. This function is given as follows :

$$H(\omega) = \frac{F_o(\omega)}{F_i(\omega)} = \sum_{r=0}^{n} c_r e^{jr\omega\tau}$$

where

$$F_i(\omega) = \int_{-\infty}^{\infty} f_i(t) e^{-j\omega t} dt$$

$$F_o(\omega) = \int_{-\infty}^{\infty} f_o(t) e^{-j\omega t} dt$$

$$= \sum_{r=0}^{n} f_i(t) c_r e^{-j\omega(t-r\tau)} dt$$

$f_i(t)$; input original signal of a scanning line
$f_o(t)$; interpolated signal
τ ; equivalent time interval in horizontal direction between adjacent scanning lines
c_r ; weighting factor .

For interpolation using only two adjacent lines in a field or in a frame, we obtain;

$$H(\omega) = c_o + c_1 e^{j\omega\tau} = A(\omega) \cdot e^{j\varphi(\omega)}$$

where

$$A(\omega) = (c_o^2 + c_1^2 + 2c_o c_1 \cos\omega\tau)^{\frac{1}{2}}$$

$$\varphi(\omega) = \frac{\omega\tau}{2} + \tan^{-1}\left\{(c_o - c_1)\tan\frac{\omega\tau}{2}\right\}.$$

From the above equations, it is apparent that the equivalent pass-band-width (from DC to cut-off frequency) of the intra-frame interpolation becomes twice that of the intra-field interpolation because the value of τ in the former is reduced to half of that in the latter.

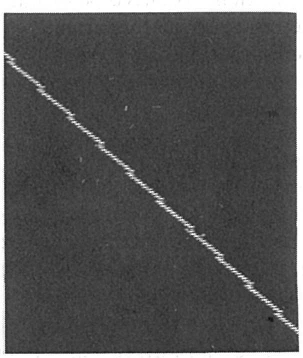


Fig. 1 A serrated appearance caused by duplicating the input lines

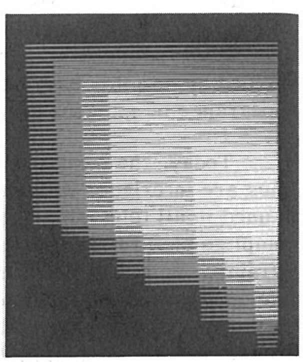


Fig. 2 A jerky movement caused by omitting the input fields

Now, consider how many adjacent input lines for each output line should be mixed to produce a satisfactory output picture. According to the sampling theorem, the exact value of each resampled point can be obtained by summing all the original samples, weighted by their respective impulse functions. Of course, such perfect resampling is impractical, and usually several original samples, adjacent to a desired resampling point, weighted by suitable weighting functions, are summed to reproduce a satisfactory value for the resampling point. Simple calculations performed,[8] for example, concerning a diagonal white line inclined at forty-five degrees in a picture indicate that the peak level of an output line reproduced by using four or eight adjacent input lines decreases to about eighty percent of the original when its undershoot is suppressed within four or five percent. On the other hand, the output peak level reproduced by using only two adjacent lines is restored to seventy-five percent of the original without any undershoot. The difference is trivial. Thus, considering that the circuitry for the reproduction is much simpler in the latter case, we can conclude that the intra-frame interpolation using two lines is most practical. To adopt this method, two lines from present and previous fields must be utilized simultaneously and so the signal storage for at least one field is required. The memory system for field conversion described in the following is also used for this purpose.

2. 2 Field Interpolation

The field conversion is also regarded as a resampling problem to change a sampling rate of movement. An input field must be duplicated every five or six fields for conversion from 625/50 to 525/60 system, and be omitted similarly for the reverse conversion. A moving object in an output picture appears to move smoothly in successive fields, but to jerk to an unexpected position when field duplication or omission occurs. Fig. 2 shows an example of this jerky movement caused by field omission. To reduce this jerkiness, interpolation between successive fields is employed as well as interpolation between successive lines employed for the line conversion. Experiments show that interpolation of two or three successive fields reproduces a satisfactorily smoothed movement in a converted picture. In relation to this field interpolation, intra-frame line interpolation has the advantage over conventional line interpolation. For no particular degradation appears in the interpolated pictures in which intra-frame line interpolation is utilized, while a decrease in sharpness and a spurious movement are observed owing to field setting and interlace interpolation[4] in the interpolated pictures in which intra-field line interpolation is utilized.

3. DESCRIPTION OF PRACTICAL EQUIPMENT

In making standards converter, the most important problem is how to construct a storage device large enough to store more than one field of television signals. It has been shown that the simplest field conversion in which no field interpolation is made needs at least $1 + |V_1 - V_2|/V_1$ field storage, where V_1 and V_2 are input and output field periods respectively.[9] The more sophisticated the field interpolation desired, the more storage capacity required. Hereafter, we will refer to the storage device which can store an input field signal as a "field memory". A storage device for line conversion is also required, but the field memory can also be employed for this purpose. The present digital converter has three field memories for both line and field conversions.

3.1 Detailed Description of the Equipment

A simplified block diagram of the converter is shown in Fig. 3. The incoming composite color television signal is decoded by the color decoder into a luminance signal Y and two color difference signals R-Y (or I) and B-Y (or Q). These three signals are digitalized individually by A-D converters. The sampling rate chosen for Y is 9.0 MHz and 3.0 MHz for each of R-Y and B-Y. Their phases are locked with input synchronizing pulses. These signals so sampled are converted into binary coded pulse train (eight bits for Y and six bits for each of R-Y and B-Y). The reason that the present way of digitalizing was chosen is its easy adaptability to two way conversion, from PAL or SECAM to NTSC and vice versa. These three digitalized signals are multiplexed into a word and written on the field memories cyclically. Once written, these signals are retained on the memories until they are rewritten by new signals. Each signal of the three stored fields, A, B and C, is read out simultaneously line by line, being locked with the output synchronizing pulses. The read-out signals are fed to two line interpolaters, each of which gives an interpolated output line.

As shown in Fig. 4, the line interpolater produces six lines of an output field from fourteen interlaced input lines in the conversion from 625 to 525 lines. In the reverse case six lines are produced from ten interlaced lines. The output lines from two line interpolaters form two intermediate fields D and E respectively, as shown in Fig. 5. Then, the two intermediate fields are combined by the field interpolater to give a final output field. The above description holds true except during the special period where writing and reading addresses happen to intersect each other in one of three field memories. During this special case, the output from that field memory, consequently an element which constructs the intermediate field D or E, must be inhibited. Because, the output field read out from that field memory is made from a combination of the upper part of one input field and the lower part of another input field, and it will cause unacceptable unnatural movement of objects in an output picture. This special period inevitably occurs because of the difference between the reading and writing speeds on the field memories. This special period, which occurs approximately every six output fields in the conversion from 625/50 to 525/60 systems and approximately every five fields in the reverse direction, can be predicted by measuring the interval of input and output vertical synchronization pulses. Thus, a final output field is usually formed from two intermediate fields, and formed from only one intermediate field during the special field period in which the intersection occurs. These intermediate fields are combined by the field interpolater to smooth a movement in a picture as shown in Fig. 6. The output signals of the field interpolater, which are multiplexed signals, are separated by the demultiplexer into three parallel signals, Y, R-Y (or I) and B Y (or Q), and are converted individually to analogue signals by the D-A converters. Finally, they are coded into the desired composite color television signal.

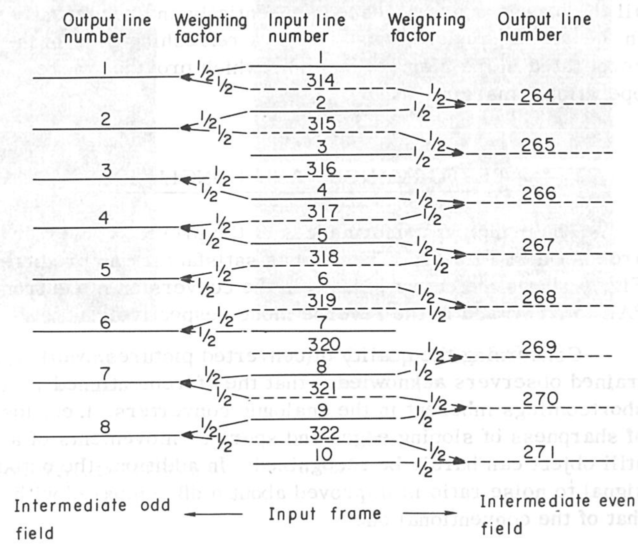


Fig. 4 Reproduction of intermediate field by intra-frame line interpolation from 625 to 525 lines

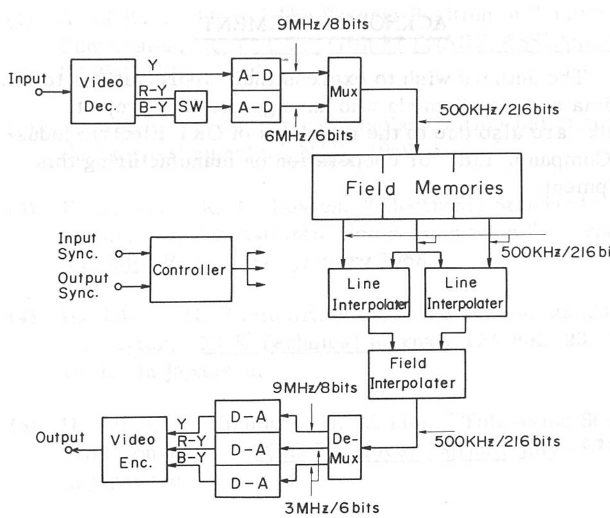


Fig. 3 Simplified block diagram

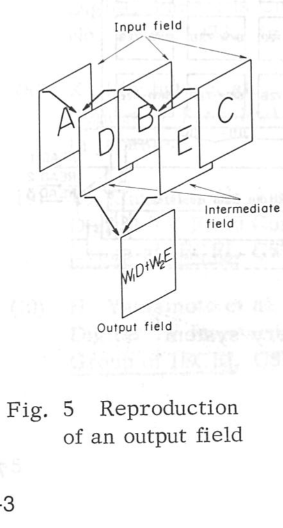


Fig. 5 Reproduction of an output field

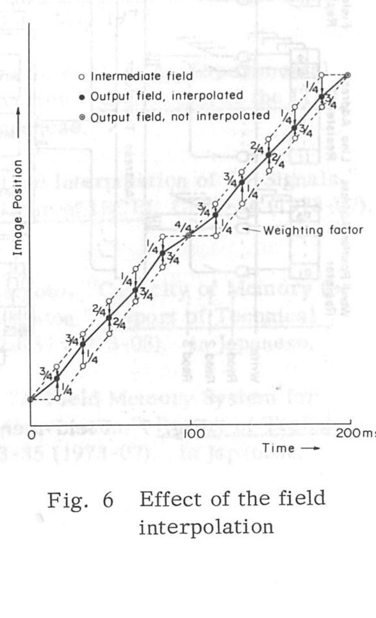


Fig. 6 Effect of the field interpolation

3.2 Assembly of the Field Memory System[10]

Fig. 7 shows the assembly of the memory system for field memories of the present converter. The memory system has one data register and one address register for writing, and three data registers and three address registers for reading. Read or write data consist of 216 bits, which correspond to 18 picture elements. Dynamic MOS-RAM is used for memory elements. Nine basic memory systems (8 kW - 72 bits each) form the present memory device, so it is a memory system of 24 kW - 216 bits. This capacity is a little more than three fields. The main clock frequency is 500 kHz, which is one eighteenth of the sampling frequency of A-D conversion for Y signal. One memory cycle, which is 2 micro seconds, is divided to 4 phases, and they are assigned to one writing and three readings respectively. Write or read cycle time of the present MOS-RAM is nominally 350 nano seconds.

In using dynamic MOS-RAM there is a problem of memory refreshing. It was settled by arranging the address connection such that the writing access alone is sufficient to maintain data in this case because, in the memory system all the locations are accessed sequentially and recurrently in the writing mode. Thus, no extra refreshing time is incorporated in the memory system, which provides more operational margin.

4. PERFORMANCES AND CONCLUSIONS

The principal performances of the present converter are shown in Table 1. They are as satisfactory as predicted. Fig. 8 shows the output signals in the conversion mode from PAL to NTSC and in the reverse mode respectively.

Concerning the quality of converted pictures, well-trained observers acknowledge that the aforementioned shortcomings inherent in the analogue converters, i.e., loss of sharpness of sloping edges and spurious movements of a still object can hardly be recognized. In addition, the output signal to noise ratio is improved about 6 dB compared with that of the conventional one.

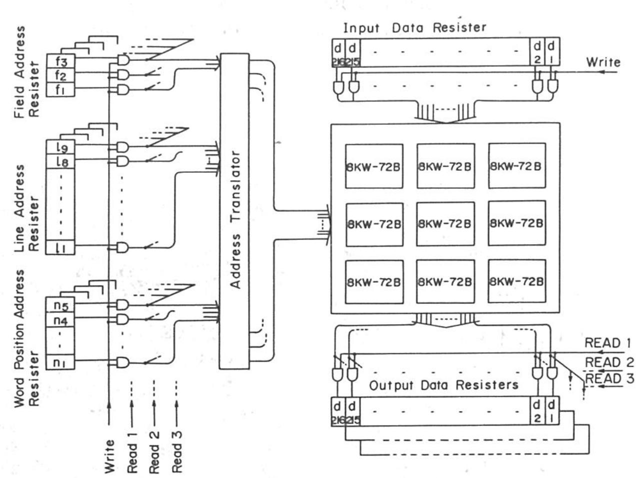


Fig. 7 Field memory system

The present converter is assembled into only two bays: a signal process and control bay (570W × 450D × 2000H in mm) and a field-memory bay (750W × 700D × 1700H in mm). They do not require most of those critical adjustments which the analogue ones do, and can start working perfectly at the instance when switched on. Moreover, its cost is expected to be reduced to about half of that of the analogue converters on the commercial base. Thus, the digital converter with the intra-frame line interpolation can remove almost all the problems related to the analogue converters.

As discussed above, three field memories are incorporated in the converter, however, this capacity of field storage is not essential. The necessary capacity depends on a method of interpolation. Almost the same performances as the present one can be expected for a converter with approximately 2.5 fields memories, which is now under estimation.

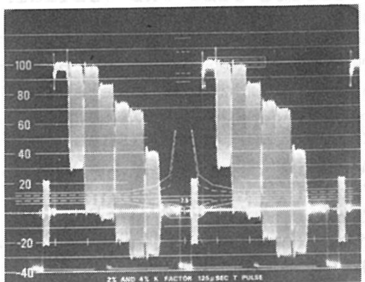
A digitalized standards converter will be well adopted to expected digital transmission systems of television signals in the future. In digital transmission, bit rate reduction is another important problems. The authors consider that such a digital signal processing as frame-to-frame coding can be effectively integrated in standards conversion using field memories in common.

Table 1. Performances of the equipment

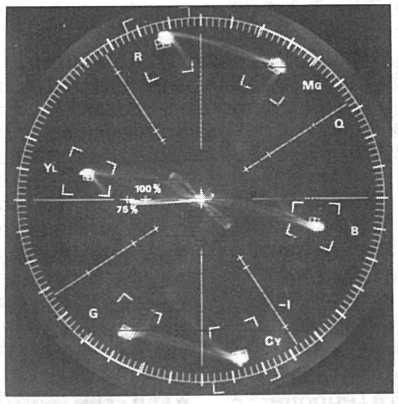
		PAL → NTSC	NTSC → PAL
S/N	Y channel	60 dB b-w/rms (weighted)	
	R-Y, B-Y channels	60 dB b-w/rms (weighted)	
DG		2 %	
DP		2°	
Line-time distortion		1 %	2 %
Field-time distortion		2 %	2 %

ACKNOWLEDGEMENT

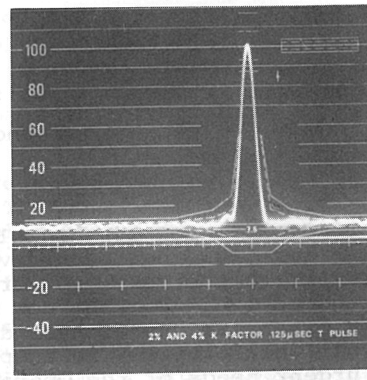
The authors wish to express their appreciations to Dr. Oshima and Dr. Kameda who have guided this project. Thanks are also due to the members of OKI Electric Industry Company, Ltd. for cooperation on manufacturing this equipment.



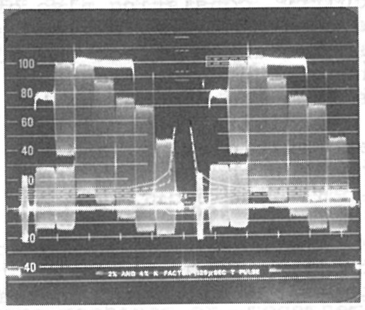
(a) NTSC output for PAL color bars input



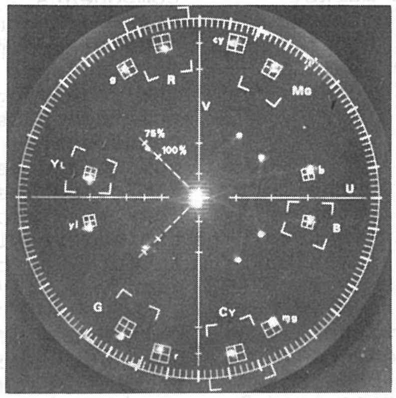
(b) NTSC output color vectors for PAL color bars input



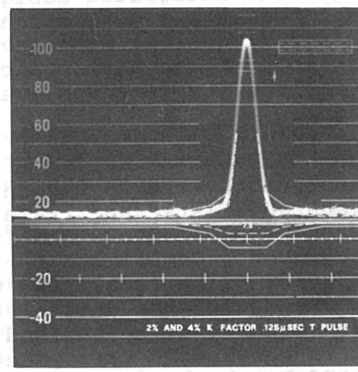
(c) 525 output for 625 2T pulse input



(d) PAL output for NTSC color bars input



(e) PAL output color vectors for NTSC color bars input



(f) 625 output for 525 2T pulse input

Fig. 8 Output signals in conversion from PAL to NTSC and vice versa

REFERENCES

(1) CCIR Rep. 311-2, "The Present Position of Standards Conversion," C. C. I. R. XIIth PLENARY ASSEMBLY, NEW DELHI, 1970.

(2) H. Wendt, "Ein Electro-optischer Normwandler für Farbfernsehsignale," NTZ, 1969, Heft 5.

(3) E. R. Rout, R. E. Davies, "Electronic Standards Conversion for Transatlantic Color Television," Journal of the SMPTE, vol. 77, January 1968.

(4) H. Sakata, H. Tanimura et al., "Television Standards Converter," NHK Technical Journal, 124 vol. 23, No. 3 1971. in Japanese.

(5) H. Satoh, K. Kinuhata, H. Makita, "Television Standards Converter," KDD Technical Journal, July 1971. in Japanese.

(6) A. D. Stalley, "A Field Rate Converter Using Digital Techniques," 8th International Television Symposium and Technical Exhibition, May 1973.

(7) K. Kinuhata, I. Takahashi et al., "An Experimental Digital Standards Converter," Convention of the ITEJ, No. 2-16, 1973. in Japanese.

(8) K. Kinuhata et al., "Line Interpolation of TV Signals," Report of Technical Group of IECEJ, CS73-34 (1973-07). in Japanese.

(9) K. Kinuhata, H. Yamamoto, "Capacity of Memory for Digital TV Field Conversion," Report of Technical Group of IECEJ, CS72-157 (1973-03). in Japanese.

(10) H. Yamamoto et al., "A Field Memory System for Digital TV Standards Conversion," Report of Technical Group of IECEJ, CS73-35 (1973-07). in Japanese.