Technical note

Low-cost computer-controlled asynchronous-video cross-hair device

J. J. Glerum E. A. Pino R. van Mastrigt

Department of Urology and Department of Biomedical Physics and Technology, Erasmus University Rotterdam, The Netherlands

Keywords—*Computer control, Cross-hair device, Length measurements, Nonsynchronisable video source, Still video frames*

Med. & Biol. Eng. & Comput., 1987, **25**, 467–470

1 Introduction

CLINICIANS and medical research workers often wish to measure simple variables, e.g. the length or diameter of objects such as cells, tissue structures or blood vessels, on previously recorded video tapes. In contrast to on-line measurements made in live video pictures directly produced by a video camera, there is no easy way to synchronise video signals from a measuring computer with signals from a video recorder, except by using very expensive time-base corrector units. If, however, the variable to be measured (e.g. length) is based on a series of two or more *x–y* co-ordinates, a movable cursor or cross-hair in the selected still video frame may be adequate. Relatively simple hardware can then be used to overcome all the synchronisation problems that are encountered when working with non-synchronisable video sources.

If the measuring device is controlled by an on-line computer, measured positions and resulting variables can be directly stored and/or processed. A design for a device of this kind is presented in this paper. It forms an accurate, versatile and useful instrument, and can be built at relatively low cost.

2 Requirements and practical design

(1) The electronic device should add a moveable cross-hair with computer-controlled position to any type of standard video source.
(2) No synchronisation between controlling computer and cross-hair device or video source should be necessary.
(3) The presentation of the cross-hair and its position should be jitter-free, no matter how irregular the timing of the incoming signal may be.

In order to meet these requirements, the cross-hair is added to the displayed video frame as follows. In every frame the frame sync pulse is detected and used to load a set of line counters (Y1 and Y2, see Fig. 1) with a vertical position value from the computer. The subsequent line sync pulses are used to clock these counters until the loaded value is reached, whereupon one line is set to a white video level, thus forming the horizontal part of the cross-hair.

The vertical part of the cross-hair is made in a similar way, using the line sync pulses as data-loading signals for the dot or pixel counters (X1 and X2). These counters are clocked by a 4·8 MHz dot clock signal until the loaded value is reached, whereupon one pixel is set to a white video level. In this way, with just a single white pixel per line, all lines together form the vertical line of the cross-hair.

Sync pulses of the incoming video signal are detected with a TBA 311 (IC 9) and modified to exact durations and TTL levels with an LS 221 (IC 10).

The dot frequency of 4·8 MHz is generated with an Am2925 dot clock generator (IC 11), whose output circuitry is started on the trailing edge of each line sync pulse and stopped on the leading edge of the following line sync pulse, so as to synchronise the dot clock with the tracing of the lines. Both line and dot counters load on the trailing edges of the respective frame and line sync pulses, so as to time the loading and counting processes exactly.

(4) Position and presentation resolution should meet the pixel and line resolution of the video source used.

Most video recorders in current use have a bandwidth which limits the resolution to not much more than 256 pixels per line or about 300 lines in one frame. Therefore a matrix of 256 × 256 position points displayed in the prerecorded video frame is adequate, and so 8-bit digital words are used to represent the horizontal and vertical cross-hair positions.

(5) In order to be able to control the cross-hair device with most types of computers, parallel data input is preferred.
(6) When the controlling computer is not sending data, the cross-hair position should be maintained and only completely positioned cross-hairs should be visible, without any disturbing side-effects caused by the asynchronous updating of the position data.

To meet requirements (5) and (6), position data have to be saved as long as no (new) data are being transferred from the computer to the device. For this purpose latches H1 and H2, and V1 and V2 (IC 13 and 14), for horizontal

Correspondence should be addressed to J. J. Glerum, Department of Urology, Erasmus University, PO Box 1738, Room EE1630, 3000DR Rotterdam, The Netherlands

First received 12th August and in final form 12th October 1986

© IFMBE: 1987

and vertical position data respectively, are used. The combined horizontal and vertical latches contain two 8-bit words for the actual cross-hair position being displayed.

As in our particular case only six free parallel binary outputs were available on the computer, the 8-bit position data words were split up into 4-bit words. The remaining two binary outputs were used for synchronisation of data transfer, one for a data sync pulse, occurring only once in every complete set of position data, the other for an enable pulse, indicating the validity of the 4-bit data word presented.

Fig. 2 shows the Fortran 77 subroutine and communications protocol used to position the cross-hair by means of a DEC 350 personal computer. Fig. 3 shows how the data are transferred from the controlling computer to the cross-hair device.

Data transfer proceeds as follows. First the lower significant bits of the x position are fed into the data inputs together with the sync pulse which resets the data sequence counter (IC 16). Next the enable pulse is given. On its trailing edge the data sequence counter is clocked to its next position. Meanwhile, the enable pulse has latched

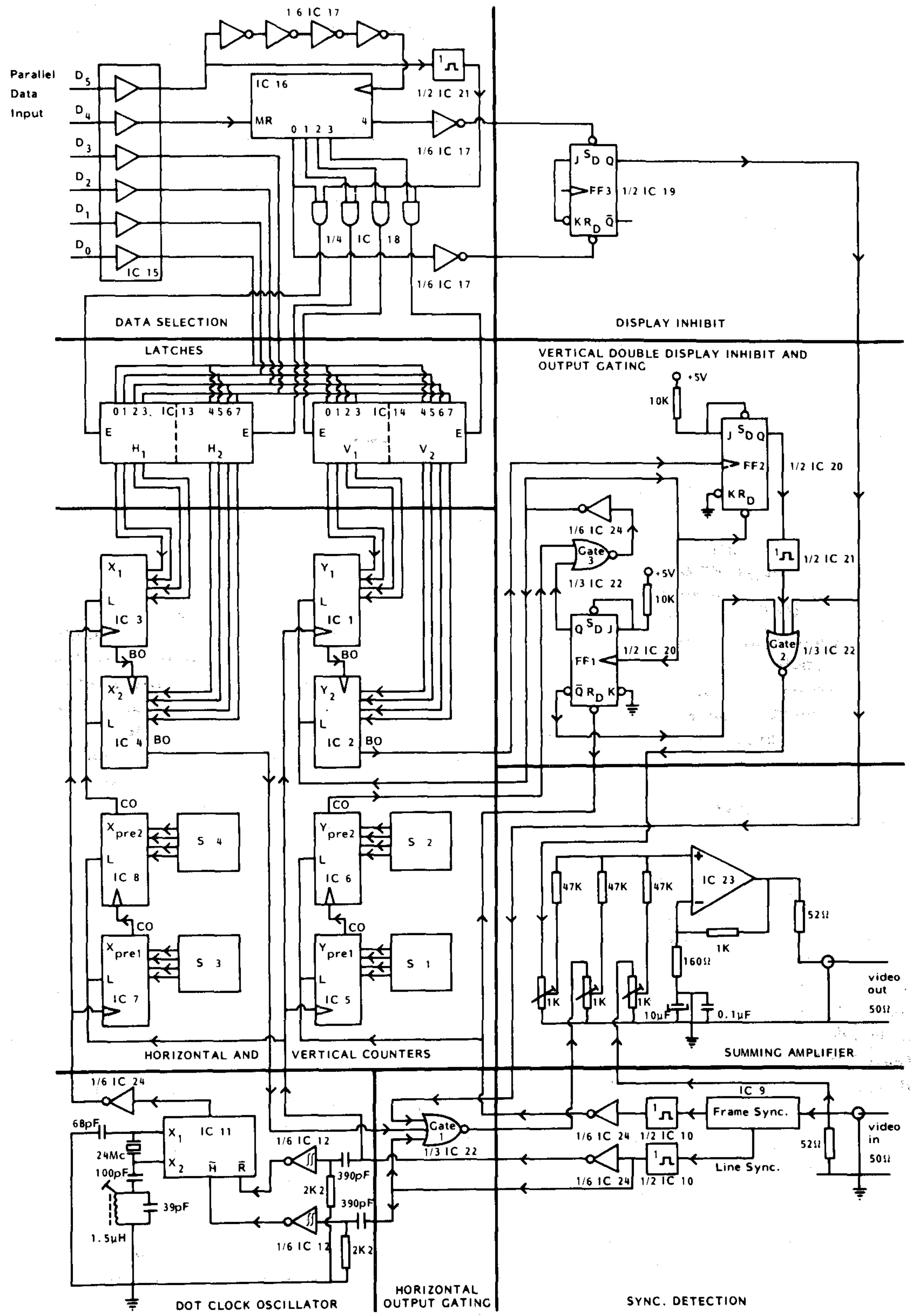

Fig. 1 *Circuit diagram of cross-hair device; IC 1–IC 8: LS 193, IC 9: TBA 311, IC10 and IC 21: LS 221, IC 11: AM 2925, IC 12: LS 14, IC 13 and IC 14: 4508, IC15: 4050, IC 16: 4017, IC 17: 4069, IC 18: 4081, IC 19 and IC 20: LS 109, IC 22: LS 27, IC 23: HA 5195 + LH 0002, IC 24: LS 04; S1–S 4: hexadecimal switch*

the data in the lower significant x position latches (H1). Then the upper significant bits of the x position are fed into the data input, followed by the corresponding enable pulse (H2). The transfer sequence is completed in a similar way with the lower and upper significant bits of the y position (V1 and V2).

The data sequence counter allows a second similar device to be addressed in order to have two cross-hairs in one video frame.

To meet requirement (6) completely, cross-hair display is

```
      SUBROUTINE VIDCUR(X, Y)
C
C     THIS SUBROUTINE CONTROLS A VIDEO CROSS-HAIR CURSOR USING HARDWARE
C     ATTACHED TO THE DIGITAL OUTPUTS ON THE PC350 REALTIME INTERFACE.
C     X AND Y ARE IN CM.
C     VIDCUR CALLS DOUTM, FROM THE DEC REALTIME INTERFACE LIBRARY, FOR
C     ACTUAL OUTPUT OF EIGHTBIT WORDS:
C     BITS 0-3: DATA BITS, 0=LS, 3=MS, CONTAIN POSITION DATA
C     BIT    4: SYNC
C     BIT    5: ENABLE (CLOCK)
C     BITS 6-7: FOR ADDRESSING AND NOT AVAILABLE TO CROSS-HAIR DEVICE
C
      BYTE IBYT(9)
      DIMENSION ISTAT(2), IOUT(9)
      EQUIVALENCE (IOUT(1), IBYT(1))
      IXCNT=X*255./24.
      IXCNT=255-Y*255./16.
      IOUT(2)=IAND(IXCNT,'F'X)                  ! LOW  FOUR X BITS
      IOUT(4)=IAND(ISHFT,-4),'F'X)              ! HIGH FOUR X BITS
      IOUT(6)=IAND(IYCNT,'F'X)                  ! LOW  FOUR Y BITS
      IOUT(8)=IAND(ISHFT(IYCNT,-4),'F'X)        ! HIGH FOUR Y BITS
C
C               !   E S
C               !   N Y
C               !   A N
C               !   B C
C               !   L
C               !   E    DATA
C
      IOUT(1)=IOR('90'X,IOUT(2))     ! 10  01XL  O W
      IOUT(2)=IOR('A0'X,IOUT(2))     ! 10  10XL  O W
      IOUT(3)=IOR('80'X,IOUT(4))     ! 10  00XH  I  G
      IOUT(4)=IOR('A0'X,IOUT(4))     ! 10  10XH  I  G
      IOUT(5)=IOR('80'X,IOUT(6))     ! 10  00YL  O W
      IOUT(6)=IOR('A0'X,IOUT(6))     ! 10  10YL  O W
      IOUT(7)=IOR('80'X,IOUT(8))     ! 10  00YH  I  G
      IOUT(8)=IOR('AO'X,IOUT(8))     ! 10  10YH  I  G
      IOUT(9)=IOUT(7)                ! 10  00YH  I  G
      DO 10 I=1,9
   10 IBYT(I)=IOUT(I)
      CALL DOUTM(ISTAT,8, IBYT,9,'B',1,1)
      RETURN
      END
```

Fig. 2 *Fortran-77 routine for transferring position data to the cross-hair device*

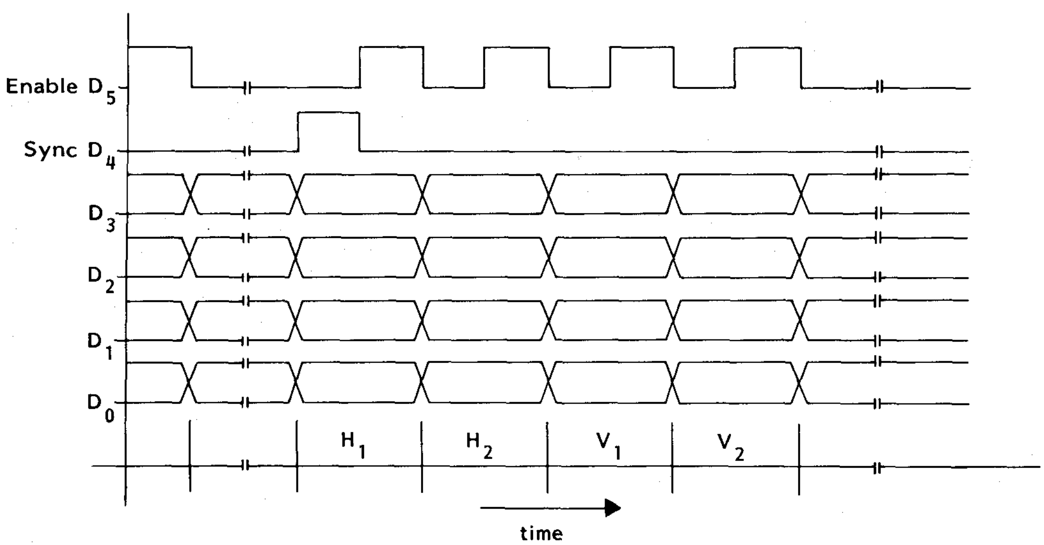

Fig. 3 *Timing diagram of the data transfer sequence; D_0 to D_3 : position data bits, D_4 : sync pulse, D_5 : enable pulse, H_1 : transfer of lower four bits for horizontal position, H_2 : transfer of upper four bits for horizontal position, V_1 : transfer of lower four bits for vertical position, V_2 : transfer of upper four bits for vertical position. Time scale depends upon the data transfer rate*

inhibited by setting a D-type flip-flop (FF 3) with the zero output of the data sequence counter and resetting it with the 4 output of the same counter, so gating the x and y video outputs through the triple-input NOR gates 1 and 2.

(7) The number of lines displayed in one frame is 312·5 for a 625-line video system. As this number exceeds 256 and as particular monitors might not display some lines of a frame or parts of lines, offsetting should be possible in order to position the range of cross-hair movement centrally in the displayed area.
(8) No double display of horizontal or vertical parts of the cross-hair should occur.

Position range alignment and offsets are provided by two sets of LS 193 counters (Xpre1 and 2 and Ypre1 and 2), one set for each direction, which delay the timing of the respective counter loading pulses by a number of dots or lines that can be preset with hexadecimal switches.

Double display of the vertical part of the cross-hair normally does not occur because the counting process is restarted in time by the next line sync pulse, which reloads the dot counters with data from the latches. Double display of the horizontal part of the cross-hair is prevented by two additional flip-flops, FF 1 and FF 2 and NOR gates 3 and 2, which prevent a second loading of the y position counters or further line pulses from occurring in the same frame.

In order to make the horizontal line white over its whole visible trajectory, and also to prevent disturbance of line sync pulses delivered to the display monitor, an LS221 (1/2 IC 21) one shot is employed to time the length of the white line. Ultimately, the x and y video outputs are combined with the original video signal in a video summing amplifier (IC 23) and fed into the display monitor.

3 Results and discussion

The hardware of the device was built on one Eurocard, the high-frequency parts such as the dot clock generator being soldered and carefully decoupled, the rest of the circuit being wire wrapped. The apparatus gives a very stable, well defined cross-hair, even when the incoming video signal is of bad quality with irregular sync pulses caused by poor video recording techniques.

Although the vertical range of the device is limited to 256 of the 312 lines theoretically displayed, there is no shrinkage of the effective area, as the first 25 lines following the frame sync pulse are used for vertical flyback, and also about 5 lines in the upper and lower parts of the frame are not actually displayed by most monitors. Thus only 10 lines in the upper and lower parts of the displayed area cannot be reached without changing the vertical offset. As the object of interest is normally situated in the middle part of the screen and seldom reaches the top or bottom, adding more operational lines to the vertical range seems unnecessary.

The cross-hair moves without flicker, the smoothness of its movement depending on the magnitude of the position changes sent by the computer (in our case this was selectable: 1, 10 or 50 lines or pixels per position step). If the controlling computer is programmed to send both horizontal and vertical position changes within one data transfer block, simultaneous movement in both directions is possible.

The minimum time in which the screen can be traversed is one frame period, but the actual time depends on the data transfer rate and the size of the position steps. With our DEC PC 350 and a step size of 10 pixels or lines, a full screen traverse takes 2 s.

To obtain maximum accuracy, the device was calibrated as follows: with the same microscope, objective (20 ×), camera and video recorder as used during the experiments, recordings were made of a microscope calibration slide, showing a graticule with a division in microns. The slide was placed in the vertical, horizontal and diagonal directions and also at intermediate angles. The vertical and horizontal recordings were replayed and measured with the cross-hair device, thus yielding scale factors in the vertical and horizontal directions. These scale factors were then incorporated in the software and all the graticule recordings were replayed and measured. Even in measurements in oblique directions the greatest errors encountered were only approximately 2 μm, thus showing that the overall precision was 2 μm or 1 per cent, which is close to the theoretical value of $1/256 \times 2 \times 100 = 0{\cdot}8$ per cent (the factor 2 represents the 50 per cent duty cycle of the dot clock or the non-scanned area between two lines for the two parts of the cross-hair, respectively)

More than 4000 length measurements have been made with this device in video recordings of contracting single smooth muscle cells isolated from pig urinary bladders (Glerum *et al.*, 1987). During the measurements the data obtained were processed and stored in files together with other data concerning the cells being measured.

In our opinion the device described here solves the problem of making length measurements in pre-recorded video pictures. In applications which require only measurement of simple position data, its low cost (material: approximately US \$ 50) and ease of construction (approximately 25 hours, including debugging) outweigh the advantages of more expensive systems embodying time-base correctors (approximately US \$ 5000) and/or frame grabbers (approximately US \$ 5000) or even more expensive dedicated video computers. Only if direct manipulation of the video information, such as image subtraction or contrast enhancement, is desired, is it worth considering such costly machines.

Reference

Glerum, J. J., van Mastrigt, R., Romijn, J. C. and Griffiths, D. J. (1987) Isolation and individual electrical stimulation of single smooth-muscle cells from the urinary bladder of the pig. *J. Muscle Res. Cell Motility*, (in press).