Kurze Mitteilungen

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A Home-made Vidicon Digitizer for Ultra-Fast Experiments in the Nanosecond Time-Scale*

Marcel Gremaud, Paul-Hervé Chassot, and Paul Suppan**
Institut of Physical Chemistry of the University of Fribourg, Pérolles, CH-1700 Fribourg, Switzerland

Abstract

A commercial vidicon TV camera can be adapted to digitize the trace from the screen of a storage oscilloscope, with a resolution of up to 9 x 9 bits. With fast storage oscilloscopes this technique is used to digitize and to plot kinetic information in the nanosecond time scale at a fraction of the costs of direct digitizers.

Introduction

Data aquisition in fast experimental techniques (e.g. laser flash photolysis, temperature-jump etc.) presents special problems because of the time scale of possible observations, requiring resolution of nanosecond events by means of rapid oscilloscopes or by direct digitization. The availability of experimental information in digital form is highly desirable, since processing of the «raw» data is invariably necessary for the calculation of reaction orders, lifetimes, rate constants, etc. Direct digitization in the GHz frequency range remains however quite expensive, while the use of photographic cameras with oscilloscopes is time-consuming and inaccurate. In this paper we describe a technique of digitization of kinetic information from a storage oscilloscope by means of a commercial vidicon camera.

This technique is now being routinely applied in our laboratory to the measurement of fluorescence lifetimes [1] and fluorescence quenching by electron transfer processes [2], of the kinetics of formation and decay of radical ions by photoionization and by charge transfer [3], of time-resolved emission and absorption spectra, etc. It should be noted that the resolution of a laser pulse of about 10 ns width requires a digitization inter-point time of 0.2 ns or less if the pulse shape is to be defined reasonably accurately through 50 points.

* Received July 28, 1983
** Correspondence author

Mode of operation

Basic principles

Once a trace y(x) is stored on the screen, the digital representation can be obtained in principle by measuring (in digital code) the vertical distance between the bottom of the screen and the bright trace for n points along the horizontal axis. In a commercial TV camera the sweep is arranged in 512 «horizontal» lines divided in two sub-sets of 256 lines each scanned alternatively. Each line is scanned in 64 μs, the entire screen being explored in about 20 ms. If 8-bit resolution is sufficient for the x signal (e.g. time-base), only one subset of 256 sweeps need be used.

The video signal which corresponds to the luminosity of each point of the screen shows a variation of about 1 V at the bright line of the stored trace. In the simplest design a counter (e.g. 9 bit) is started from zero at each reset of the sweep and a «*sample*» pulse is generated from a comparator when the bright trace is detected. The count at each sweep then represents the vertical height of the trace. This value is kept in a buffer memory from which it is transferred to the main 4K memory which can store up to 16 traces. These traces are then available for transfer in digital form to a computer, or in analogue form to an x-y plotter.

The problem of the width of the oscilloscope trace

The major source of error in a simple vidicon readout system of the oscilloscope trace is the variation in the width of the trace which results from at least three causes:

i. the non-uniform quality of the storage screen
ii. the changing writing speed of the spot
iii. the widening of the signal due to superimposed high-frequency noise.

Concerning the second point, it should be noted that the effective speed of the spot on the screen is the vector sum of the constant x-sweep velocity and the variable y-signal velocity which make the trace thinner in regions of rapid signal change (figure 1a). If in addition some high-frequency noise is present in the signal, of frequency such that the actual signal oscillations overlap on the screen (figure 1b), then the amplitude of such oscillations appears as a widening of the trace which may vary in time and thus produce a further distorsion. Independently of the cause of the variation of the width of the oscilloscope trace, it is clear that the correct trace (dotted lines in figure 1) is always in mid-position between the lower (L) and the higher (H) edges. The distorsions produced by the variation of the trace width can be considerable and some method of correction is essential.

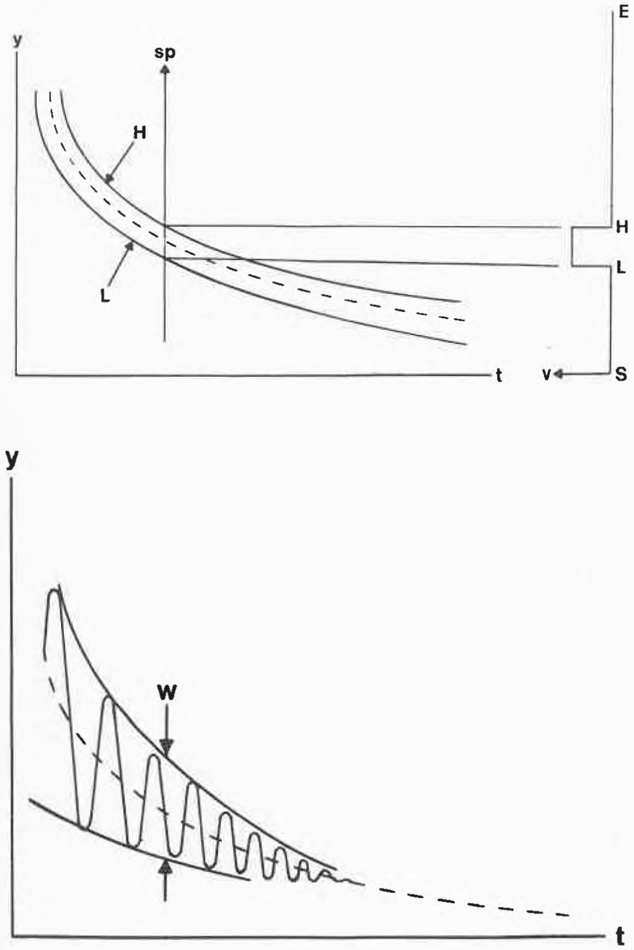


Fig. 1: Effect of oscilloscope trace width.
(a) widening due to variation of spot writing speed.
- y vertical signal
- t horizontal signal (e.g. time-base)
- L low edge of oscilloscope trace
- H high edge of oscilloscope trace
- sp spot scanning direction
- v video signal level
- S start of vertical sweep
- E end of vertical sweep

(b) widening due to superimposed high-frequency signal.
- y vertical signal
- t horizontal signal (e.g. time-base)
- w apparent trace width when the high-frequency «noise» cannot be resolved from the low-frequency trace (in dotted line)

The solution adopted in our read-out system is illustrated in fig. 1. At each vertical sweep of the vidicon the distance S → L is derived from the number of counts of a 8-MHz clock; when the lower trace edge L is detected this clock is switched to 4 MHz which increments the counter until the high edge H (light → dark) of the trace is reached. In this way the total count corresponds to the distance (S → L) + ½ (L → H).

Description of Installation

The vidicon camera is held on the oscilloscope by means of a modified camera adaptor which makes it possible to vary its distance from the screen. The lens of the camera is fitted with a baffle to keep the screen free of stray light. *The camera is held at right angle from its normal position since its «horizontal» sweeps must correspond to vertical lines on the oscilloscope screen.*

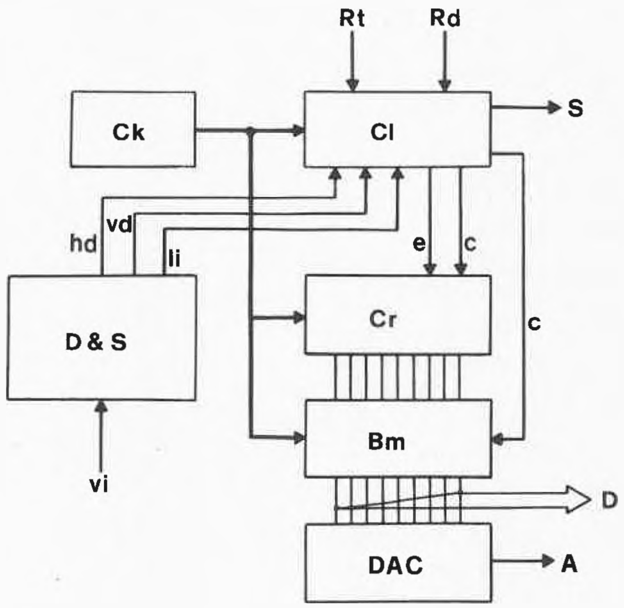


Fig. 2: Block diagram of vidicon digitizer unit.
- Ck clock
- Cl control
- Cr counters
- Bm buffer memory
- DAC digital to analogue converter
- D&S detection and synchronization
- Rt reset
- Rd read command
- Vi video signal input
- e enable
- c clear
- S sample command
- D 9-bit data (digital) output
- A analogue output (0-5 V)

The block diagram of fig. 2 and the timing diagram of fig. 3 show the electronics required for the digitization. When a suitable trace is stored on the screen, the digitization sequence is started by a «*read-out*» command. At the next start of a screen sweep the buffer memory is cleared and the 8-MHz clock increments the counter until the signal from the comparator shows that the edge of the bright trace is reached; the 4-MHz clock then increments the counter until

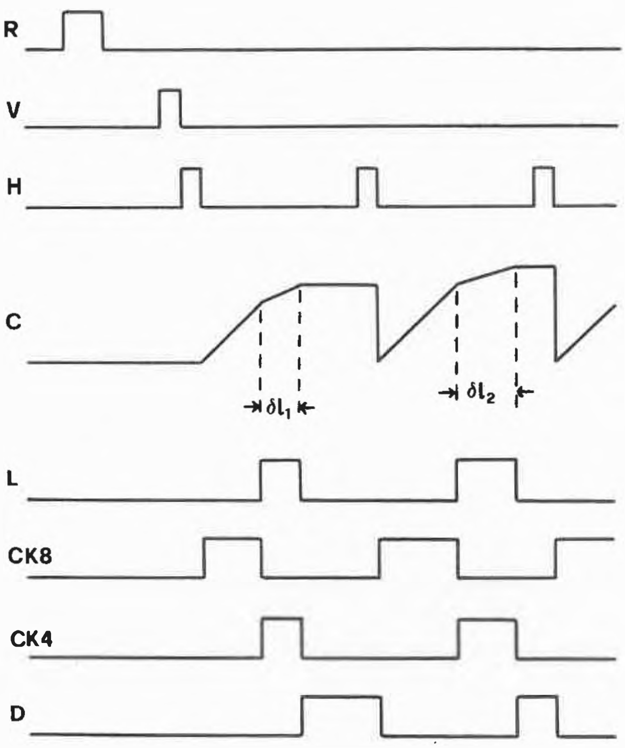


Fig. 3: Timing diagram of vidicon digitizer.
R read command
V vertical drive of vidicon sweep
H horizontal drive of vidicon sweep
C counter ramp (the digital steps are not shown)
δl_1, δl_2 oscilloscope trace widths
L video signal comparator level
CK8 8-MHz clock
CK4 4-MHz clock
D data valid (for transfer to the main memory)

the comparator shows that the bright trace has been scanned through. At that time the counter is stopped and its contents are transferred to the buffer memory, while a *sample* pulse ist generated to show that the data are valid on the 9-bit *data* line and on the output of the digital to analogue converter. The sequence is repeated 256 times and is then stopped until the next *read-out* command is received.

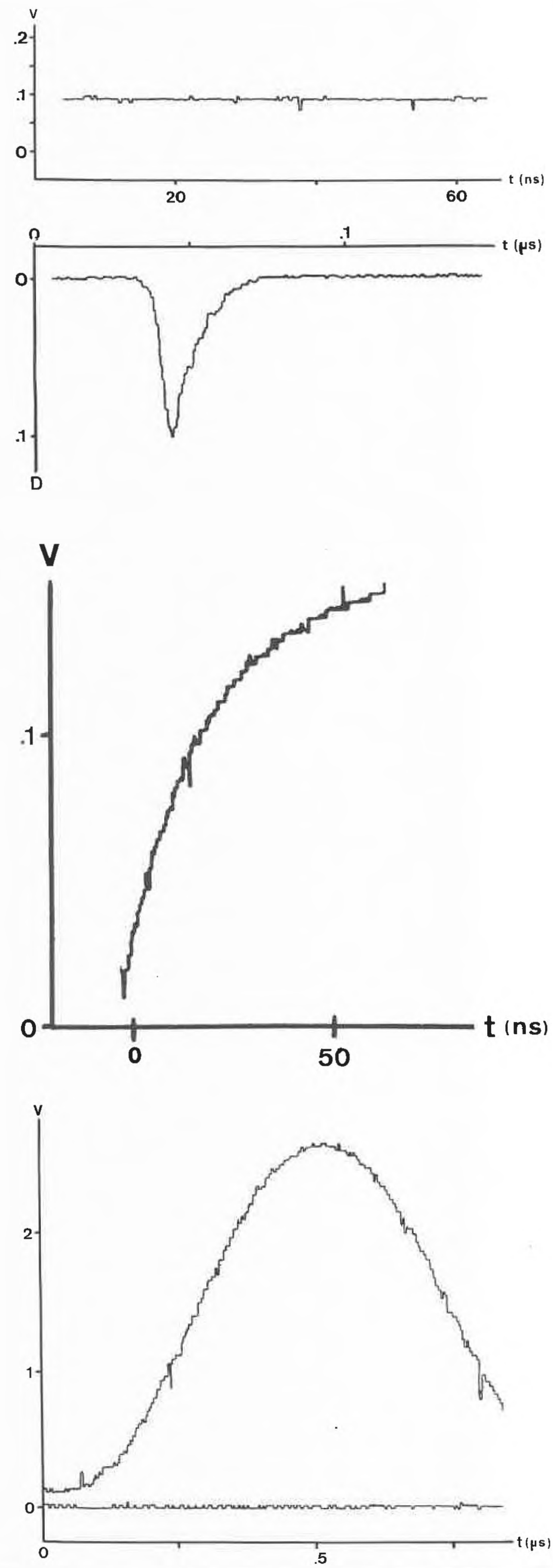
The oscilloscope is a Tektronix model 7834 (fast storage) fitted with a 7A26 dual-trace amplifier, and with 7B80 and 7B85 time-bases. The camera is a JVC model GX-88E. As main memory a Data Laboratories DL 912 transient recorder was used; this permits to store up to 16 traces for display on a J.J. Lloyd type PL100 x-y chart recorder.

Performance

Examples of read-out

Fig. 4 shows a few examples of plots obtained from the digital to analogue converter on a standard x-y plotter. These plots simply reproduce the oscilloscope trace in permanent form (and with any desired magni-

Fig. 4: Examples of analogue plots of oscilloscope traces. →
(a) a base-line at 50 ns full-scale
(b) a transient signal at 200 ns full scale, 1.2 V vertical deflection
(c) a fluorescence decay at 100 ns full scale
(d) a sinusoidal signal at 1 MHz, 2 V vertical deflection



fication or reduction). The digitization steps are clearly seen; the resolution is equivalent to a 256 x 512 x-y matrix.
The performance of the vidicon-based digitization system depends of course on the quality of the storage oscilloscope's screen and on the correct adjustment of the brightness of the trace. With the oscilloscope used in this work satisfactory digitization of single events has been obtained up to sweep speeds of 10 ns/div.

Possibility of multiple-trace recording

In principle the oscilloscope screen can be «split» in two vertical areas which correspond to counts of 0 to 255 for the lower part and 256 to 511 for the upper part; two traces stored in the lower and upper parts respectively, can then be digitized in sequence, the *sample* being active only during the relevant part of the count. Such synchronous recording of two simultaneous events requires of course a real double-beam oscilloscope, unless the sweep speeds are low enough to permit the use of chopped signals.

Possibility of general x-y recording

The uses of vidicon-camera digitization are of course not restricted to kinetic events, but cover all x-y information which can be obtained on storage oscilloscopes. As an example, absorption and emission spectra from rapid-scanning spectrometers have been digitized in this manner.

Automation of sequence for repetitive observations

In many cases an experiment is repeated several times in order to average the result. The entire sequence of operations is readily automated with the vidicon digitizer system:

1. Deactivate *save* mode of oscilloscope
2. Activate *erase* of oscilloscope
   Activate *trigger reset* of oscilloscope
3. Trigger experiment
4. Experiment triggers oscilloscope
5. Activate *save* mode of oscilloscope
6. Pause for *n* seconds (operator can reset to 1)
7. Activate *read*

Such a procedure is suitable for low-repetition rate experiments, the minimum time for the sequence being set by the oscilloscope's *erase* operation which requires about 1 second.

Concluding remarks

The essential features of the vidicon-based digitizer are its low cost and simplicity of operation. Whenever a storage oscilloscope is available, such a digitization unit (including camera and monitor) can be built by any reasonably competent electronics engineer at a cost of around sFr. 4000.— (using a simple monochrome «surveillance» camera) or sFr. 6000.— if a colour camera is preferred.

Acknowledgement

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2 *E. Butty, E. Haselbach* und *P. Suppan:* to be published in Helv. Chim. Acta.
3 Current research project directed by Prof. *E. Haselbach.*