

## Technical note

# Analogue data collection via a telephone line: a microprocessor-based remote-controlled data-acquisition system

**Keywords**—Analogue-digital conversion, Data acquisition systems, Microprocessors, Modems, Telephone line

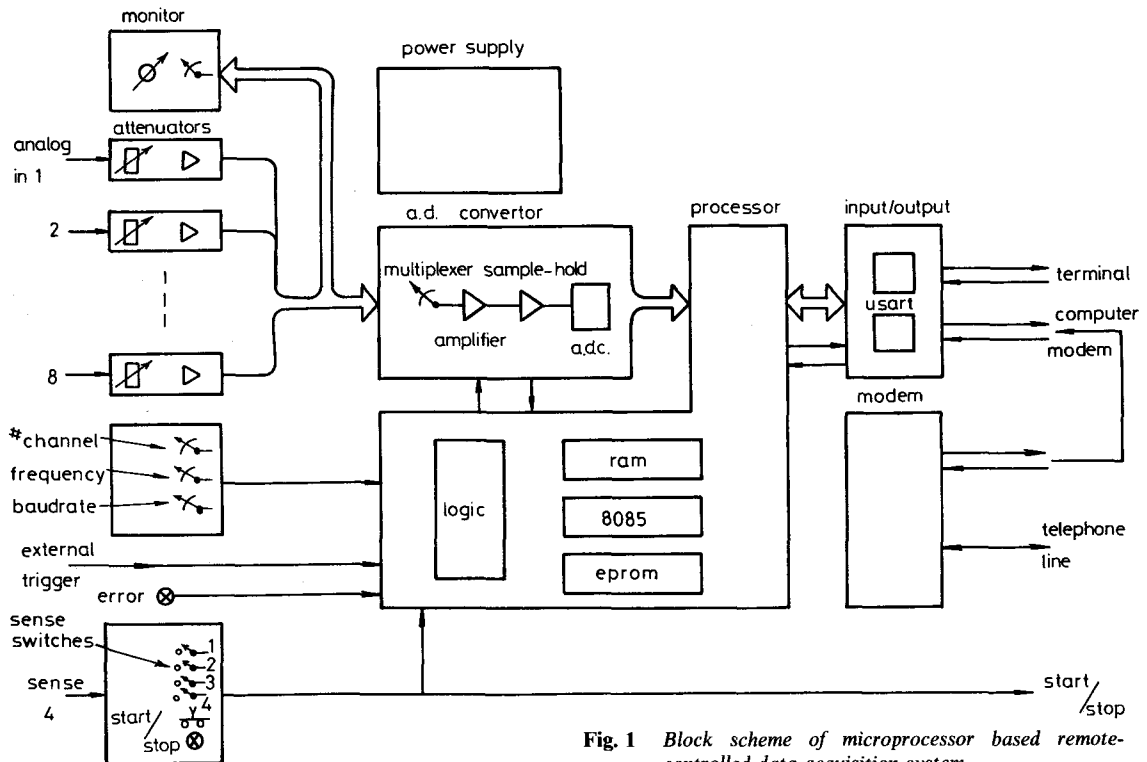
### 1 Introduction

IN MANY applications analogue data must be collected at a location some distance from the computer which is to process the data. Usually the data are then stored in a transportable form (e.g. on magnetic tape) and processed off-line. If, however, the necessary sampling rates are not too high, an attractive alternative is to convert the analogue data into digital form and to send these via a telephone line to the computer. This procedure has all the advantages of on-line processing, for example the possibility of intervention in the process being sampled on the basis of the calculated results, and need not be more expensive than a conventional tape-deck. A microprocessor-based device will be described which

has enabled us to process urodynamic data from remote locations in this way.

### 2 Description of system

Basically the device consists of a standard 12-bit analogue-to-digital converter (see Fig. 1). Up to eight input channels are individually attenuated (input ranges 1-50 V) and multiplexed, and the converted digital signals are temporarily stored in a random access memory (r.a.m.). This memory is controlled by an 8085 microprocessor, which also controls the timing of the samples and the formatting of the output data stream from the system. The attenuated input signal



**Fig. 1** Block scheme of microprocessor based remote-controlled data-acquisition system

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values can be checked by an independent monitor circuit with a front panel meter and channel select switch. Since only serial data can be sent to a host computer via a standard modem connection, and since most computers expect ASCII characters (7 bits + parity bit) from a modem, the converted

data has to be serialised and split up into characters. Since the number of the channel from which the sample was taken also has to be sent, and the characters sent should be unequivocally recognisable, a minimum of three characters per sampled channel is necessary. It is then possible to send some extra information, e.g. the setting of four sense-switches on the front panel of the device, which enable the user to intervene in the program executed by the host computer. The package of three characters sent per sampled channel is shown in Table 1. Notice that if more than four channels are sampled, bit 6 of character 1 signifies the channel number and not sense switch 4. The number of channels sampled and the sampling frequency are both limited by the baud rate of the modem transmission. With the usual 1200 baud transmission rate 120 characters per second can be sent. This is 40 samples per second, equivalent to one channel sampled at 40 Hz, two channels sampled at 20 Hz, etc.

The 8085 microprocessor programs an internal programmable timer for generating crystal-based sample frequencies from 1 to 200 Hz. External triggering is possible.

Two baud rates are switch selectable: 1200 baud for normal modem transmission and 9600 baud for possible direct connection to a host computer, without intervening modems. Other baud rates can be wired.

Any wrong combination of sampling rate, number of channels and baud rate is noted by the microprocessor and indicated by a lighted 'error' l.e.d. Since the modem connection generally also has to be used for the presentation of results to the user of the sampling system and for conversation with the host computer program, a video terminal has also to be connected. This has been performed as in Fig. 2. All data from and to the video terminal pass through the data-acquisition system. As seen from the host computer there is no difference between data sent from the video terminal and data sent from the data-acquisition system. Therefore the analogue-to-digital conversion has always to be started and stopped by the host computer, so that it knows the origin of the data. The starting and stopping, and other functions performed by the analogue-to-digital system, are controlled by sets of three characters sent by the computer

Table 1. Coding of one 12-bit data sample, channel number and sense switch settings into three ASCII characters

character number	bit number	1	2	3	4	5	6	7	8	
1		parity bit	0	sense switch 1	sense switch 2	sense switch 3	sense switch 4	channel number		
2		..	0	MSB six bits data						
3		..	1	six bits data						LSB

Table 2. Three-character sequences recognised by the data-acquisition system for performing various functions. Numbers between parentheses show hexadecimal representation of ASCII character

character number	1	2	3	function
ENQ (05h)	SH (01h)	1-8 (31h-38h)		single shot channel 1-8
..	ETR (04h)	..		set frequency 1-8
..	ENQ	..		set # channel 1-8
..	..	ET (03h)		stop overruling frequency and # channel
..	ET	..		stop sampling
..	ST (02h)	ST		start sampling

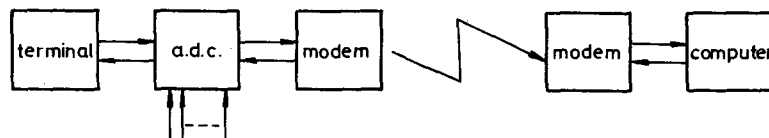


Fig. 2 Block scheme of connections of data-acquisition system to modems, host computer and videoterminal. In reality the modem was integrated into the data-acquisition system

(see Table 2). The data-acquisition system intercepts these characters from the data stream from the host computer to the video terminal and takes action if necessary. As can be seen from Table 2 it is possible in this way to start and stop the analogue-to-digital conversion, to ask for a single-shot conversion for a specified channel, to overrule the front panel settings of the number of sampled channels and the sample frequency, and to restore these front panel settings. The receipt of most of these commands is acknowledged by a specific comment sent by the microprocessor to the video terminal. Error messages from the microprocessor are indicated in the same way. Running analogue-to-digital conversion is further indicated by a front panel light and a t.t.l. logic signal, and can for testing purposes also be controlled from the front panel. A special problem is formed by the echoing of characters received by the host computer. In normal full-duplex use, all data entered on the video terminal are echoed back by the host computer and displayed on the video screen. This would normally also happen to data sent by the analogue-to-digital system, resulting in enormous quantities of nonsense characters on the video screen. To prevent this, the data-acquisition system interrupts the data flow from the host computer to the video terminal for as long as it is sending data, or even for exactly three characters when it sends a single shot. Furthermore echoed data cannot accidentally form a valid combination, which might start or stop conversion, since every third character of the data contains a one in bit 2, while the characters in Table 2 all have a zero in this bit. Nevertheless, it may be necessary to suppress the character echoing in the host computer, especially if this computer cannot receive data during the echoing process, which effectively reduces the baud rate by a factor of two. Full documentation on this data-acquisition system is available on request.

### 3 Application

The system described has been used for two years for an application in which urodynamic data is sampled in the

Sophia Childrens Hospital and processed on a computer at the university (VAN MASTRIGT, 1980), to determine the contractility of the urinary bladder (VAN MASTRIGT and GRIFFITHS, 1979). In fact, the situation is even more complicated than indicated in Fig. 2, because the video terminal used consists of a normal terminal and a preprocessor in series, which allows graphical displays. This preprocessor also intercepts special control characters, and therefore the set of characters in Table 2 had to be carefully chosen. Except for parity check, no error detection or correction routines are implemented. The whole system performs excellently.

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