Kodaikanal Obs. Bull. (1985) 5, 27-30.

A FAST OPTICAL PULSE COUNTING SYSTEM FOR CRAB PULSAR

P. Santhanam and J.C. Bhattacharyya

Abstract

A sub millisecond resolution counting system for recording shapes of short periodic pulses is described. Results obtained in recording the shape of optical pulses from Crab pulsar are given here. The flexibility of the system for multi-channel photoelectric photometry application is explained.

Key words: optical pulses, crab pulsar, fast photon counter

1. Introduction

Modern observational system has brought out information about new objects displaying rapid changes in their radiation outputs. Pulsars belong to one such category from which periodic rapid pulses in the radio region are received. Theoretical models for such sources suggest that synchronous optical pulses from each sources should be detectable. Until now optical pulses from only two such pulsars have been found. (1,2) As most of these objects are very faint, careful signal processing becomes necessary. The most straight forward approach is that of signal averaging over the repetitive pulse periods. Earlier attempts involved use of on-line computers at the focal planes of large telescope. It is easily recognised that alternative methods can also bring out the information sought. In the present paper, a microprocessor based signal averaging system is described which yields the light curves of faint periodic pulses.

2. Instrumentation

The basic set up consists of a photometer at the focal plane of a telescope which receives the light from the pulsar. We can consider this light as a stream of photons modulated by the pulsar pulses. A statistically steady fraction of the incident photons generates photoelectrons at the photomultiplier cathode, which multiply by cascaded secondary electron generation and appear as electrical pulses of short duration (10^{-8}s) at the anode. These photon pulses are sorted out according to the pulsar phase and arranged in a block of memory locations, where successive series of pulses are integrated to produce the characteristic light curve. The arrangement is schematically shown in Fig.1.

Design of the signal averaging system has been used on the principle outlined by Kristian et al[1]. The present instrument has been developed around an INTEL 8080 microproc-

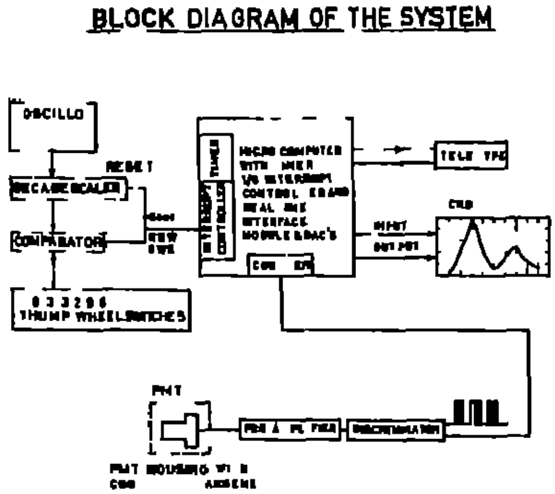

Fig 1 Block diagram of the system

essor chip The schematic of the single board computer used is given in Fig 2 The basic

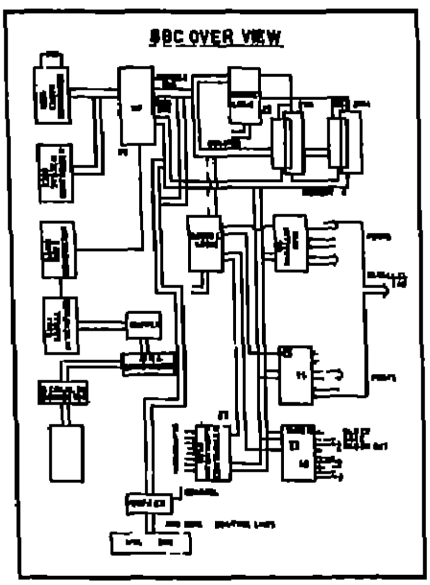

Fig 2 SBC overview

system contains 24 parallel I/O lines, an 8251 serial communication interface to teletype, an 8253 timer and an 8259 interrupt controller This board can accommodate 16 K bytes of EPROMS for program and 4K bytes of RAMS for data storage The interface card contains parallel I/O expander, a set of counters for counting electrical pulses from photomultiplier tubes, timer control and interface logic, and two digital to analog converters for dis play of light curve on C R O

The arrangement of the set up is explain ed in Fig 1 The constant clock from micropro cessor board of 9 MHz is initially divided by 10 to yield a frequency of 9 MHz for proper functioning of 8253 timer This timer contains three independent 16 bit counters and each of them is individually programmable through proper mode control words written in it These counters can count either in BCD or in binary mode depending on the mode control word In our application, the timer is confi gured in BCD mode to divide the input frequency by 9 so as to get a pulse train at 100 KHz These pulses are gated through a monoshot of 100 n sec and fed to the counters through a NAND gate This arrangement generates inter vals of programmable duration during which photomultiplier pulses may be counted

The shaped PMT signal is also gated through another NAND gate and given to 74193 counters for upward counting Arrangements have also been provided to clear the counters and to simultaneously set the timing interval During this very short interval when resetting is being done, the up counters are cleared and the control line is enabled

When the set time on 74193's is elapsed it produces an overflow which triggers a flip flop interrupting the processor The processor then reads the contents of the upcounters, and the data are added to the previous integra ted counts in corresponding bins

3. Experimental set up at the telescope

The arrangement was set up at the Casseggrain focus of the 1m telescope at Kavalur for recording the light curve of Crab pulsar. The object was observed on the night of 1-2 February 1984. Pulse counting photometer equipped with cooled 9658B photomultiplier was used. The period of the pulsar was measured as 33.296 m sec. The synchronisation between the apparent period of the pulsar and the instrumental period has to be maintained to a high degree of precision. This is essential to minimise the drift which would cause smearing of the observed pulse shape. This was achieved from a precision 5 MHz oscilloquartz crystal and a coincidence circuit supplied by the group of scientists from Tata Institute of Fundamental Research. An accurate interval between timing pulses of required duration may be set on the thumbwheel switches and the coincidence circuit produces a pulse of 100 n sec width. This triggers a flipflop whose output is connected to 8259's highest priority interrupt.

On executing the program the processor initialises all the I/O lines; interrupt

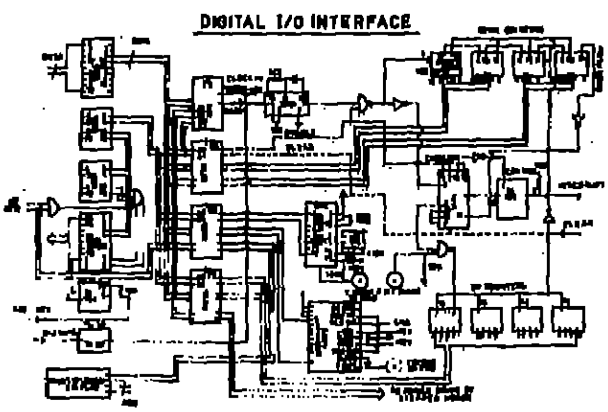

Fig 3 Digital I/O Interface

controller, timers and clears the buffer memory for data storage. The system then waits for sync pulse interrupt. When this occurs processor positions the memory pointer, sets the times for 450μ sec and enables the upcounters to count the PMT pulses. The buffer data are dumped on to DAC for CRO display enabling realtime monitoring of the data. After 450 μ sec the lower priority interrupt arrives signalling the processor to read the counters. The microprocessor reads the upcounters and adds with the memory contents corresponding to the particular bin and stores in the same bin. This cycle repeats till the start new sweep - interrupt comes. As time passes, one can see on the CRO the building up of light curve. The experiment may be suspended at any predetermined time either from another coincidence circuit or from a switch at the front panel.

The flow chart describing the software algorithm is shown in Fig.4. For Crab pulsar

FLOW CHART FOR CRAB PULSAR PROGRAM

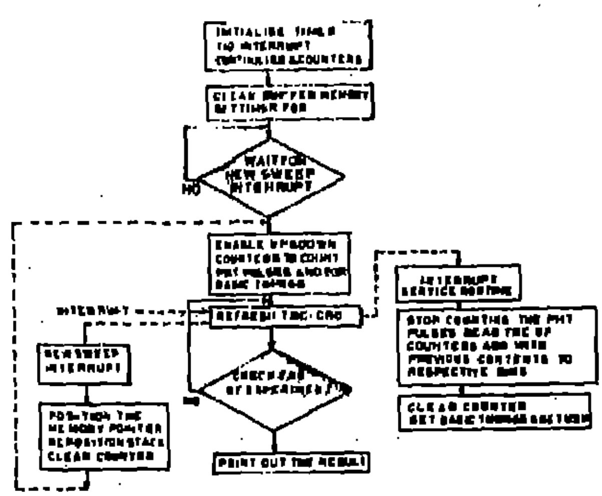

Fig 4 Flow chart for Crab Pulsar program

the calculated period was 33.296 m sec on that occasion. Accordingly T.W. setting was 33.296 m sec; the interrupt service routine took 60 μ sec. After sufficient integration the experiment was stopped, and the values of all the 66 bins were printed out. 67th Bin was omitted which contains photon counts over a fraction of the normal 450 microsecond period per sweep.

4. Experimental Results

The light curve of Crab pulsar obtained using 40 inch reflector at Kavalur on 1 & 2 Feb. 1984 for an integration of 6 minutes is given in Fig.5. This represents integrated

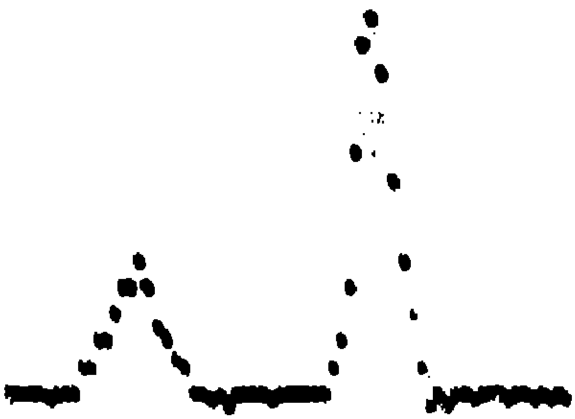

Fig 5 Light curve of crab Pulsar as seen on C.R.O.

data over about 10600 periods. Several features of the optical pulses are clearly seen in the curve. The symmetry, size and spacing of the main and sub pulses and the fact that the level of radiation outside the pulse is very low are all exhibited in the curve.

The microprocessor based design of the system is basically intended for catering to the varying observational needs. Only one example of the various types of observations possible has been described here. The need for simultaneous multichannel photometry in astronomical work is very important. This instrument with a little modification can be used for this purpose. This is achieved by adding some more sets of up-counters, clearing and enabling in parallel and reading the counters through expanded I/O lines. This system has also been used in experiments involving occultation of stars, fast photometry of rapid variables etc. wherein only changes in software program are called for.

5. Acknowledgement

We wish to express our thanks to Prof. P.V.Ramanamurty and his group at Tata Institute of Fundamental Research, for providing the hardware for the generation of sync pulses. Our thanks are also due to our colleagues in the Institutes, A.V.Raveendran, M.Jayakumar and M.S.Rosario for their help in this project.

References

Kristian, J., Visvanathan, N., Westphall, J.A., and Snellin, G.H., 1970, Astrophys. J. 162, 475.

Peterson, B.A., Mundin, P., Wallace, P., Manchester, R.N., Penny, A.J., Jorden, A., Hartley, K.F., and King, D., 1978, Nature, 276, 475.