

DATA-HANDLING SYSTEM FOR THE FLY'S EYE EXPERIMENT

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The Fly's Eye air scintillation experiment presents severe data-handling requirements for two reasons. First, nearly 1000 photomultipliers each produce outputs at rates from 100 KHz to 20 Mhz. Second, much of the signal arrives before a trigger is formed. A data handling system which will deal with this problem is described.

1. Introduction. The Fly's Eye experiment will involve apparatus in which 948 photomultiplier tubes and 79 1.5 m mirrors are exposed to the sky on clear moonless nights in an effort to study EAS above 10^{17} eV via air fluorescence (Bergeson, et al., 1975). The background consists of fluctuations in the airglow, starlight, etc. To maximize the sensitivity and the recorded detail, one wishes to record data near the background level. With nearly 1000 data channels, the data-handling problem is obviously severe.

The problem is compounded by the range of energies to be spanned, hopefully from 10^{16} eV to more than 10^{21} eV. Fortunately, it is not necessary to span so many decades of light intensity: rather a large range of pulse widths must be dealt with. A lower energy shower must be nearby to be seen; the image of such a shower may cross a particular phototube in 50 nsec. On the other hand, the higher energy showers will usually be seen further away, and may give 10 μ sec pulses. To maximize sensitivity it is necessary to run data from each phototube into several channels, each of which has a noise filter with a time constant different from the others.

Finally because the signal pulses come sequentially rather than in coincidence, a trigger may occur only after many pulses have come and gone. Thus pulses large enough to be useful must somehow be saved.

To deal with these problems, the initial data handling is dealt with on three levels: (1) at the individual phototube level; (2) at the level of the cluster of 12 phototubes attached to a single mirror; (3) at the level of the whole detector. In this paper, we will consider each level in turn.

2. Individual Phototube Data Handling. It was originally intended that data from each phototube would be stored in charge-coupled devices used as clocked analog shift registers. However this technology has not developed as rapidly as we had hoped, so alternate methods have been developed.

The key to the system is the Howland active integrator which is described in the appendix. This circuit was developed some time ago, but its virtues seem not to have been widely recognized. For our purposes, its essential characteristics are that it can be quickly and easily gated and equally easily reset, and that it has the fast response of a passive integrator along with the linearity and wide dynamic range of an active integrator. In what follows, any reference to integrators, except for those labeled "passive integrator", refers to Howland integrators.

Figure 1 shows a block diagram of the data handling system for each photo-

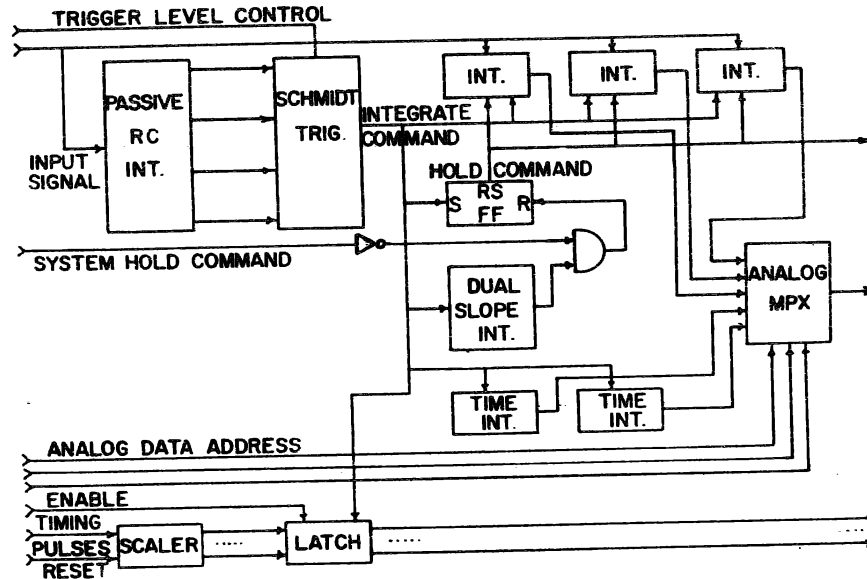


Figure 1.

tube. The input goes to a set of four passive RC integrators which filter with logarithmically spaced time constants. The filtered signals then go to a set of four Schmidt triggers. (The trigger levels are set at roughly five standard deviations of the background fluctuations by an external circuit which periodically checks the phototube current, calculates the standard deviation, and sets a trigger reference.) When any Schmidt trigger fires, an "Integrate Command" is sent to three integrators which integrate the input so long as the command remains. A "Hold Command" is also generated. (Three integrators with different time constants are used to extend the dynamic range of the system.) The integration time is determined with two "time integrators" which integrate a constant voltage so long as the "Integrate Command" is present, thus producing an output voltage proportional to the integration time. The "Integrate Command" also sets a latch which holds the absolute time so that the relative timing between different phototube pulses can be determined.

One important problem remains. The various integration levels must be held long enough to permit a system trigger to be formed. (The system trigger will be essentially a coincidence between "Hold Commands" from different phototubes.) On the other hand, the length of time they should be held varies enormously from one event to the next. The hold time is set with a "dual slope integrator". So long as the "Integrate Command" is present it integrates a constant voltage. At the end of the "Integrate Command", it integrates a smaller constant voltage of the opposite sign. When the integration level returns to zero, all integrators are reset unless a "System Hold Command" (essentially a coincidence) is received. Thus the hold time is proportional to the input pulse width: it will probably be about 20 times the input pulse width, thus allowing sufficient time for a coincidence to form without producing uncomfortably large dead times. If there

is data being held, that fact is signalled by the "Hold Command" output. The various analog data levels can be multiplexed to a single output for subsequent digitization.

3. Mirror Cluster Data Handling. The data handling at this level is much simpler than at the individual phototube level. Coincidences between phototubes in the cluster will be formed here and system hold commands generated. Digital and analog data from individual phototubes are multiplexed and sent to the central system. Trigger level controls are provided to each phototube data handling circuit.

4. Central Data Handling. The Central Data Handling System has the task of collecting and digitizing data and of storing it for subsequent transmission to the University of Utah campus. To collect data, the various "Hold Command" outputs are multiplexed digitally to see where non-zero data are stored. These data are then multiplexed in analog fashion to fast Analog-to-Digital Converters. The digitized pulses and the digital times are all stored in a central mini-computer. After some preprocessing, the data will be stored on a magnetic disk or preferably a semi-conductor equivalent and then transmitted to the campus via a telephone line.

The central computer will also perform a number of diagnostic chores such as monitoring the behavior of the various phototubes and their data handling circuits. In addition it will deal with all sky data such as would come from gamma and neutrino bursts.

Acknowledgments. The work of Joe West in circuit development is gratefully acknowledged. This work was supported by the National Science Foundation (USA), Grant #MPS70-01999-A04.

Appendix

In Figure 2 we show a simplified diagram for the Howland integrator (Smith, 1971). Let us assume that switches S_1 and S_2 are closed and S_3 is open. As usual in operational amplifier circuits we ignore amplifier input currents; the open loop amplification is assumed to be so large that the voltages at points 1a and 2 can be assumed to be essentially equal because of the feedback. In this particular circuit R_1 and R'_1 are matched as are R_2 and R'_2 . If the output is v_0 then the voltage at point 1 (and consequently at point 2) is fv_0 where $f = R_2/(R_1 + R_2)$. Now $i = i_1 + i_2 = (v_s - fv_0)/R'_2 + (v_s - fv_0)/R'_1 = v_0/R'_2$. Also $v = q/c = \int v dt / R'_2 C$, exactly the same as if the amplifier had been extremely fast and had given the active integrator response derived above. The inexpensive CA 3130 is a suitable operational amplifier for this integrator. The switches are CD 4066 analog switches which, though inexpensive, can open or close in 20 nsec.

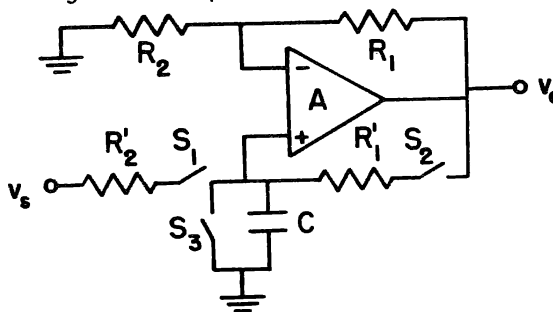


Figure 2.

REFERENCES

- Bergeson, H. E., Boone, J. C. and Cassidy, G. L., "The Fly's Eye - A Novel Technique for Sensing Extensive Air Showers", Paper EA 5-16, Fourteenth International Cosmic Ray Conference.
- Smith, J. I., Modern Operational Circuit Design, Wiley-Interscience, New York (1971).