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INDIANA UNIVERSITY PROPORTIONAL CHAMBERS*

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Mechanical Construction Detail

A plane of parallel 0.0005 inch diameter gold plated tungsten wires spaced 2.0 millimeters apart is wound with wire tension of 20±5 grams. The wires are epoxied to one surface of a 1/4 inch thick G-10 epoxy-fiberglass frame which is machined to allow a smooth surface distance of at least 1/2 inch between high voltage and ground. The wires are soldered to a printed circuit strip of parallel conductors on 2 millimeter centers, and the solder joints are sealed under epoxy. A mating 1/4 inch thick G-10 frame is epoxied over the wire plane. A stainless steel wire cloth cathode (0.0021 inch diameter wire, 200/inch mesh) is epoxied to the outer surface of each G-10 piece forming a total chamber gap of approximately 9/16 inch. Mylar windows 0.005 inch thick are attached over the wire cloth with RTV 108 silicone rubber to form a gas seal. Gas inlet and outlet ports are in the edges of the G-10 frames. Typical chambers have 60 or 90 wires approximately 7 inches long.

Basic Electronics Layout

Signals from each wire are carried approximately 8 inches distance from the printed circuit strip on the chamber frame to Amphenol 225-805-30 printed circuit card edge connectors through individual twisted pairs of number 30 insultated wire. One member of each pair is grounded to shield the signal line., Pins on the connectors are paired to improve reliability. A printed circuit card consisting of 15 amplifiers, one per chamber wire, plugs into each connector. Power is supplied to each card through an Amphenol 225-20621-401-117 connector. The Amphenol connectors and amplifier cards are enclosed by an aluminum electronics box which is electrically isolated from the circuit ground inside the box. Signals from the amplifier cards are carried via flat ribbon cable to a gated parallel-input serial-output shift register which is read into a SAC scaler system.

Electronics Construction and Operation Detail

The amplifier used on each wire is an integrated circuit, the MC1710G differential comparator. Pin connections for the 1710 are shown in figure 4. Input offset is maintained by putting 1.5 K Ω to ground on the non-inverting input and 1.0 K Ω to ground on the inverting input. This results in a self biasing of the amplifiers due to the required base current of the inputs. The resulting d.c. offset is We have found that this results in a sufficiently stable system of biasing and we have been able to operate the electronics over a temperature range of 40-110°F and interchange amplifiers without biasing adjustments. The chamber signal, which is negative, is connected to the inverting input.

Layout on the 1/16 inch thick amplifier printed circuit board places 15 amplifiers in a row with etched lines for inputs, outputs, and +12 volt, -6 volt and ground lines. Positive and negative voltage lines are each bypassed upon entering the board with a 1.0μfd electrolytic capacitor and at 4 other points along the board by 0.01μfd ceramic capacitors. Sockets for the amplifiers and output cables are Robinson-Nugent pin sockets #001-004-A.

Amplifier outputs are carried via 12 inch long 16 conductor flat ribbon cables Model 14010-3P8 (15 signal lines and 1 ground line per cable) with an Augat 16 pin DIP connector (Model 2P16-1) on each end.

Each signal line is terminated with 100 ohms to ground at the input to the shift register.

The shift register consists of several MC4012P integrated circuits wired in series. Pin connections for the MC4012P are shown in fig. 4. Each 4012 contains 4 bits. In our applications the parallel mode of operation is used to store data, and the serial mode is used to read out the data. Parallel inputs to the first but one and last but one bits in the register are always in the "1" state (their neighbors are zero), thereby storing fiducials along with the data.

When the MODE control is set for parallel operation ("1" state), a negative going transition on the LOAD input loads whatever data are on the parallel inputs from the chamber wire amplifiers into the register. LOAD must remain in the low state until MODE has been set to the "0" state for serial readout, or else the negative going MODE transition will act as another LOAD and write over the previously loaded data. Once MODE has changed to the "0" state it gates off further LOAD's and all of the parallel data inputs, and it also allows CLOCK pulses to be applied to the register to shift data out one end of the series at a rate of one bit per clock negative transition. The maximum clock rate is 35 MHz.

In order to make the LOAD signal be active on its leading edge (thus saving time which is of the essence), a HOLD signal has been created in the fast logic of the experiment. A STROBE signal is derived from a scintillation counter located near the chamber. Coincidence of a pair of counters may be used to reduce accidentals. However, this is not necessary. The STROBE and HOLD signals are "NOR'ed" before entering the 4012's as LOAD.

The HOLD signal comes from the output of a fast logic flip-flop which is set by the STROBE signal and remains set until it has been decided either not to read out the event causing that STROBE, or until the event has been read out. HOLD is then returned to the "0" state, and a new STROBE may be accepted by the system. No reset is needed since the LOAD signal causes all the data to be stored (Zeros as well as ones).

The logical layout for thes electronics is shown in fig. 11. The inputs for HOLD and STROBE are designed to be driven by a bridged NIM output through 90Ω cable. Here the TRUE signal is zero current in and the FALSE signal is -28 ma. in. Note that the other half of the bridge of the NIM module should not be terminated. The DATA output is matched to 50Ω cable.

The relative timing for the various signals is shown in fig. 6. Notice that data are loaded into the shift register only at the positive transition of STROBE (Neg. transition of LOAD). The system is not sensitive to noise or other data except at this time. Notice also that the output pulse train is the same as that from a magnetostrictive delay line and can, therefore, be digitized in the same way.

The interface and control from The Science Accessories Corporation MIDAS spark chamber readout system which we use is shown in fig. 7. The main functions here are to fan out the CLOCK and to derive a MODE and CLOCK signal when an event is to be read out.

Performance

Chamber gas is 15 to 20% isobutane + 0.30% freon 13B1 + balance argon. Typical gas flow is 0.1 cubic foot per hour with 50% of the gas being bubbled through methylal at room temperature. The methylal helps to flush hydrocarbon deposits out of the chamber.

Chambers operating in the 5 Kilovolt range give pulses into 1000 ohms of 20 to 50 millivolts amplitude with a FWHM of approximately 75 nanoseconds when operated in a beam of minimum ionizing particles e.g., $\pi\pm$ with $\vec{p} \sim 4.0$ GeV/c. Total time jitter of the leading edge of signals out of the amplifiers is on the order of 20 nanoseconds as measured against the strobing scintillation counter (see Fig. 9). Total delay from particle passage to amplifier output is typically 60 nanoseconds. Amplifier threshold in the operating configuration is approximately 10 to 15 millivolts. Amplifier output signals are saturated at +3.0 volts amplitude into 100Ω with a FWHM of 200±50 nanoseconds. STROBE timing at the shift register may vary at least 50 nanoseconds without significant loss of events.

In operation it has been found that a particle will produce signals on two neighboring wires only about 2 to 3 percent of the time (Fig. 9). This indicates that the spatial resolution of chambers with 2 millimeter wire spacing is essentially 2 millimeters (i.e. ±1 mm).

A major limitation in chamber performance is radiation rate per unit area i.e., the beam current density of radiation. Although the negative pulse on the wire may be only about 200 nanoseconds long, the positive charge left in the chamber gas requires at least 100 microseconds to drift out to the cathodes to be neutralized.[1] During the drift time that region of the chamber wires is partially shielded from the high voltage by the space charge and is less efficient in detecting a new event. At current densities of less than 10^4 particles/cm^2-sec all chambers are greater than 95% efficient. However, the system shows approximately 8 to 10 percent loss of efficiency at 5×10^4 particles/cm^2-sec; where efficiency is defined as

$$E = \frac{\#\text{ single tracks in chamber}}{\#\text{ single tracks in beam telescope}}$$

At high beam densities 5×10^5/cm^2-sec the chambers become inefficient due to missing tracks. The readout electronics is all d.c. couples so that pile up in the electronics would result in inefficiency due to multiple tracks. Using pairs of chambers separated by a few inches along the particle's direction, the inefficiency is reduced by less than 50 percent. The inefficiencies are correlated.

It has been noted by several groups testing chambers with freon 13B1, that this component in the gas limits usable ionization to a cylindrical region about each wire, the radius of the cyclinder depending on the freon 13B1 concentration. Thus, it is important to choose the freon 13B1 concentration based on the wire spacing of the chambers in which it is to be used.[1] This suggests that the optimum total gap between cathodes should be at least as great as the wire spacing, but otherwise as small as mechanical construction allows, since it is desirable to minimize the distance which positive ions must drift.

Eight chambers similar to the above description were used successfully in experiments E-266 and E-307 at the ZGS during 1971-1972. The most intensely irradiated chambers were exposed to approximately 10^{11} minimum ionizing particles per square centimeter. No deterioration of efficiency was observed in their operation. When the chambers were disassembled there was a slight visible discoloration on the wires and cathodes in the area of most intense irradiation.

REFERENCES

1. Charpak, et al., Nuclear Instruments and Methods, 88 (1970) 149-161.

2. Charpak, Some Developments in the Operation of Multiwire Proportional Chambers, CERN Report (7 November 1969).

SOURCES OF MATERIALS USED IN CONSTRUCTION

1. Gold-plated (3-5% by weight) tungsten wire 0.0005 inch diameter.

   Thermionic Products Company
   North Plainfield, New Jersey 07060

2. Model T-101 Tenarol Wire Tension Control.

   Tenarol Division of Rollan Electric Co.
   Electronic Center
   Mt. Carmel, Illinois 62863

3. 1/4" x 36" x 48" G-10 epoxy-fiberglass sheet.

   Meyer Materials, Inc.
   P. O. Box 20049
   Indianapolis, Indiana 46220

4. Eccobond 45/15 epoxy-2 lb. kits.

   Emerson and Cuming
   Dielectric Materials Division
   Northbrook, Illinois 60062

5. Stainless Steel wire cloth 0.0021" diameter wire, 200 mesh.

   Hubbell Metals, Inc.
   Indianapolis, Indiana 46225

6. Clear Mylar 0.005 inch thick.

   Cadillac Plastic & Chemical Company
   Indianapolis, Indiana 46225

7. RTV-108 General Electric silicone rubber.

   Newark Electronics Corp.
   Chicago, Illinois 60624

8. Amphenol connectors 225-805-30 and 225-20621-401-117.

   Allied Electronics
   Chicago, Illinois 60612

9. Number 30 "kynar" insulated computer wire for twisted pairs.

   Newark Electronics Corp.
   Chicago, Illinois 60624

10. Printed circuit etching and assembly.

Indiana University Central Electronics
Bloomington, Indiana 47401

11. Electronics boxes made from Vector extrusion.

Vector Electronic Company, Inc.
Sylmar, California 91342

12. 3M 16 conductor flat ribbon cable and Augat 16 pin DIP connectors.

Augat, Inc.
Attleboro, Massachusetts

13. MC 1710 G motorola amplifier.

Semiconductor Specialists, Inc.
Indianapolis, Indiana 46225

14. Pin sockets model 001-004-A.

Robinson Nugent, Inc.
New Albany, Indiana

15. Amplifier board resistors 1/4 watt, 5% carbon. Shift register input resistors 1/8 watt, 10% carbon. Amplifier board capacitors 1μfd. type 150D electrolytic, 0.01μfd. ceramic Sprague HY-520.

Newark Electronics Corp.
Chicago, Illinois 60624

16. Chamber gas - 15% isobutane + 0.30% freon 13B1 + balance argon.

Matheson Gas Products
Joliet, Illinois 60434

17. Methylal-Fisher stock number M-222 pints.

Fisher Scientific
Chicago, Illinois