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LUMPED DELAY LINE SPARK CHAMBER

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1. Introduction

There has been much interest recently in automatic-recording spark chambers[1,2]). We describe the design and performance of such a chamber built as part of a momentum spectrometer. The principle of operation is to convert the position of the spark into a delay with a lumped-constant electrical delay line[3]). To do this, one of the plates consists of a series of strips; each strip is connected to the delay line. This has the advantage over acoustical chambers of being simple and easy to build, requiring no transducers and providing readily usable voltage levels. However, the inherent resolving power is much worse, because of the large attenuation in lumped delay lines.

2. Construction

The chambers were built on 23″ × 11″ × $\frac{1}{16}$″ copper-clad glass epoxy boards, which were etched to provide both the strips for the spark chamber and the mounting for the delay line. Each board had 80 strips, 9½″ long and ¼″ wide, the strips separated by $\frac{1}{12}$″. The delay line, consisting of 80 toroidal inductors and 80 capacitors, was wired in as an integral part of the board and potted. To protect the delay line from pickup from high voltage transients, the entire end of the board with the line was enclosed in a copper shield. The high voltage plate, made of stretched aluminium foil, was separated from the printed circuit board by ⅜″ Lucite spacers. Additional structural support was required around the sides to insure uniform plate separation, because of the tendency of the circuit board to warp. The active area of the chambers is 8″ × 20″.

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3. Electrical

A simple readout is possible if the delay per section is large. Then the delay of the pulse can be measured by gating on and off an oscillator and counting the number of cycles on a scaler. Having scalers with a 10 Mc capacity, we used inductances of 10 mH, which were 1″ diameter ferrite cores wound with about 40 turns of wire, and capacitance of 0.1 μF, which were 25 V ceramic capacitors. Thus the line impedance is 10 ohm and the delay per strip is 1 μs. The clock frequency is 4 Mc. since the Q of ferrite inductors is

$$Q = \mu_{\text{real}}/\mu_{\text{imag.}} \sim 50\text{–}100$$

the attenuation of frequencies above a megacycle for long lines such as this one is quite severe. However, the spark can be accurately located with just the lower frequencies.

The electronics is standard (fig. 1); there is a free-

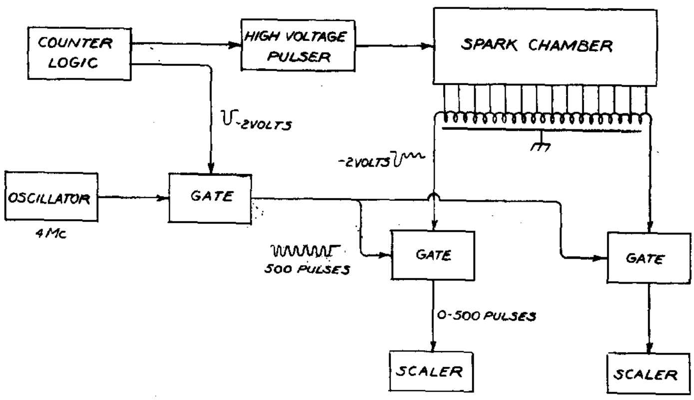

Fig. 1. Block diagram of electronics.

running oscillator which is gated on by the spark trigger. The signal from the delay line is about one V high and 10 μs long. This signal is differentiated and then amplified to start a single-shot multivibrator, which gates off the oscillator. When the clock is gated off by the delay line current exceeding a certain threshold, the output is erratic and insufficient to localize the spark to one strip; much better results are obtained by differentiating and operating close to zero crossing. The impedance of the line is low to reduce interference from the discharge of the spark, but in practice it was necessary to take additional precautions of shielding the spark chamber, placing a few additional sections of delay line between the chamber and the electronics to act as a low-pass filter and also, using the first gate to hold the second gate on the first few μs.

4. Operation

The chamber was tested for accuracy of spark localization and efficiency in a 200 MeV π beam. Two clocks were operated, one from each end of the delay line (figs. 2 and 3). The output and the actual spark were recorded on film for studying the accuracy. We used a total of 670 pictures in arriving at the conclusions below. The data was analyzed in two ways: first, a straight line regression was made between the spark

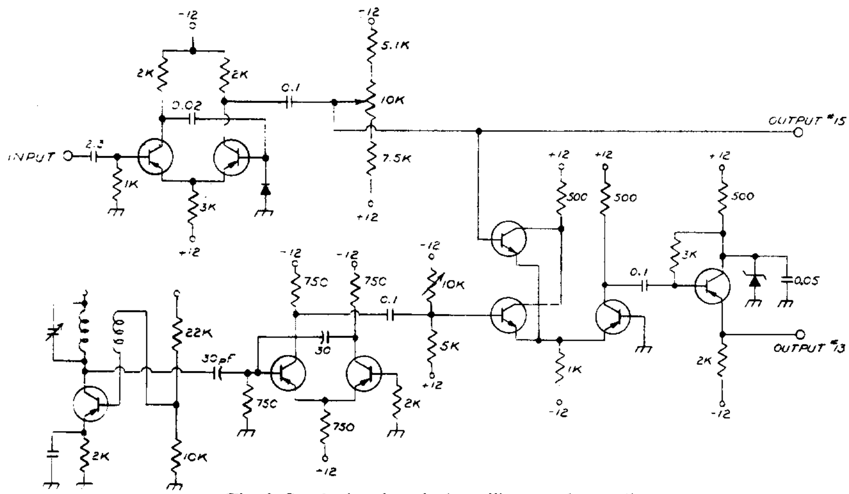

Fig. 2. Spark chamber clock oscillator and gate #1.

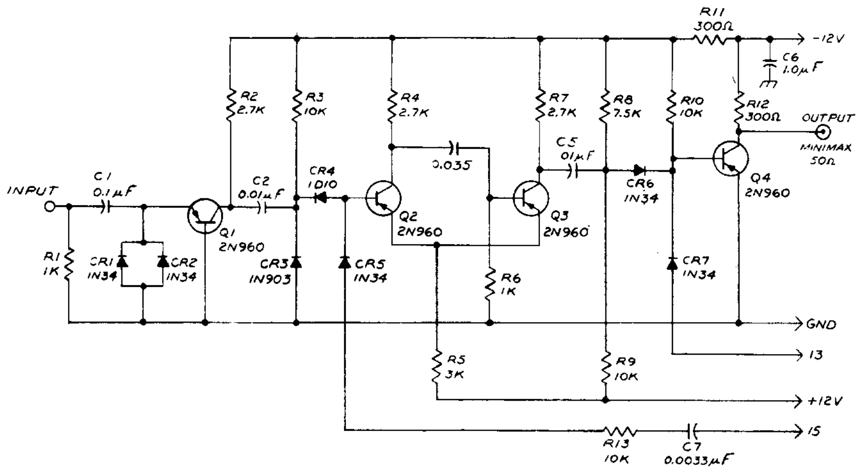

Fig. 3. Spark chamber clock gate #2.

positions and delay line data. This would be the easiest way to use the chambers in an experiment. However, one core was found shorted and the delay per section was not uniform. So, the data was also analyzed by considering the variation in clock readings from a spark going to a given strip. Using the first method, the correct strip can be identified 67% of the time and the answer will be off by one strip 32% of the time. If the difference of readings from both ends of the delay line is taken to find the position of the spark, the correct strip is identified 89% of the time and off by one in 11% of the cases. The last five strips on each side were not included in this analysis, as there the deviation from a straight line was very marked. The second method gave slightly better results, but probably not sufficiently better to justify the trouble to calibrate each strip individually.

The efficiency was measured with a beam going through the chamber well away from the sides. When a particle goes through, the output of the clock is examined to see whether the chamber fired, whether there was only one spark and whether is occurred in the area defined by the counters. In this way efficiencies ranging from 97–99% were measured in a π beam. The efficiency was relatively insensitive to clearing field and sparking voltage. However, the time between turning on the high voltage and start of the breakdown was of the order of 0.5 μs and dependent on the voltage. Thus changing the voltage shifts the apparent zero delay.

When the beam was altered, increasing the electron contamination to 40%, the efficiency was much lower, due mostly to multiple sparking.

When two sparks occur simultaneously, they may be recognized by observing them from different ends of the delay line. However, if the sparks are within 4–5 strips of each other, the clocks will record only one apparent spark, occurring somewhere between the two positions and depending on how much charge was put into the line at each position. If one of the sparks is very much weaker than the other, it can be observed photographically but not electrically. Very many sparks at once in the chamber occasionally give the same output as no sparks.

5. Conclusion

This method of reading spark positions is fairly accurate and quite simple to operate. The interference from the high voltages can be overcome because the actual signal occurs at a later time when the transients have died out. The maximum number of strips which can be used is slightly more than what was used here; the electronics was capable of clocking with sparks 120 strips away. With faster scalers, the line impedance could be increased, and therefore the line attenuation made less. We estimate that a practical maximum would be about 300 strips in a chamber.

The chamber tested on the π beam was constructed by L. Hammersky and P. Boynton. I want to thank Dr. T. J. Devlin and Dr. J. Solomon for encouragement and advice.

References

1) Review and some recent techniques: *Informal Meeting on Filmless Spark Chamber Techniques* (ed. Macleod and Maglic) CERN 64-60.

2) V. Perez-Mendez and J. Pfab, UCRL-11620, unpublished.

3) This principle was first used with solid state counters by Bilanuk, Marsh, Hamann and Heurtley, Nucl. Instr. and Meth. **14** (1961) 63.