Influence of Capacitance Networks on the Pulse Dynamic Range and Recovery Time of TOF Detectors

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INTRODUCTION

A variety of capacitance networks have previously been used with discrete-dynode multipliers to improve their pulse dynamic range (linear response to high abundance ion peaks). These have been used with some success. In response to demand for even greater dynamic range and recovery time performance, a detailed computer model has been developed, which accurately simulates the mechanisms involved in the pulse response of the detector. This model has been used to investigate the effects of gain suppression and recovery time after high abundance ion bursts and has led to capacitance network designs that improve the pulse dynamic range of a detector by around 2 orders of magnitude.

RESULTS

Figure 1 is a schematic of a basic discrete-dynode electron multiplier showing the dynodes and the resistor chain connecting them. Discrete-dynode multipliers have an inherent small capacitance between the dynodes which has been measured to be ~5pF. When a signal pulse is drawn from the multiplier, the charge removed from each dynode has to be instantly supplied by these small capacitances, which act as reservoirs of charge - the resistor chain is too slow to supply the large instantaneous currents needed. When charge is removed from a dynode by a signal pulse, the voltage across these small capacitances will be changed, and importantly, this will also change the voltages on the dynodes.

Figure 2 is a plot of the voltages between each dynode after different numbers of single ion pulses have been put through the multiplier. The x-axis is the dynode number with 1 being the first dynode and 22 the last dynode, just before the output. Initially (zero ions) the voltage between each dynode is about 77 volts, which is just the applied high voltage divided by the number of dynodes.

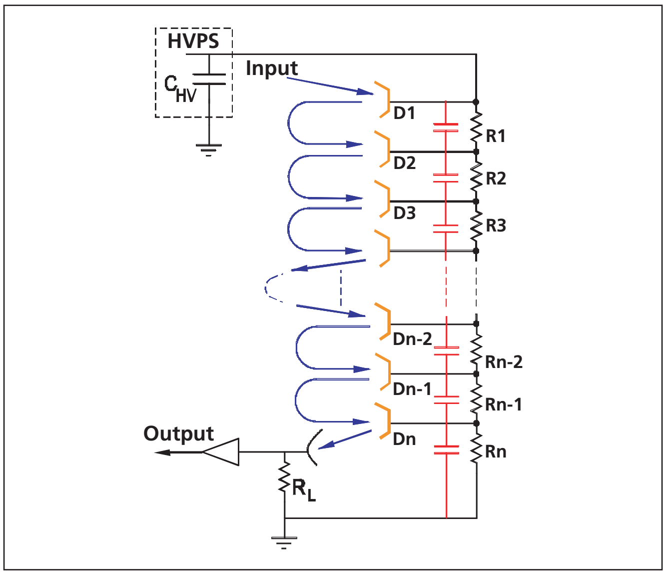

Figure 1. Schematic of a discrete-dynode multiplier showing the small inter-dynode capacitances.

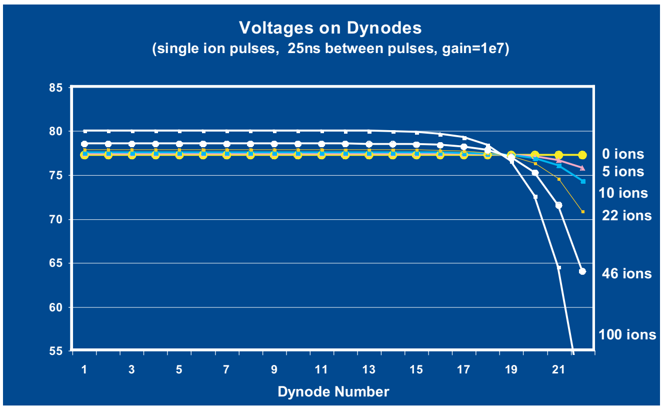

Figure 2. Change in the voltages between the dynodes of the multiplier. The zero ion line is the initial condition with all the dynodes having equal voltage between them. As single ion pulses pass through the multiplier drawing charge from the capacitors, the voltages between the last few dynodes begin to collapse. This is called saturation.

A very typical layout for a multiplier for high pulselinearity applications is shown in Figure 3, where a number of capacitors have been added to the last few dynodes of the multiplier. In this case we have our standard multiplier circuit with our standard 1.4 megohm resistors between the dynodes and 5nF capacitors are connected between the last 4 dynodes. These capacitors act as very large reservoirs of charge and prevent the voltage on the last 4 dynodes from changing, and so we would expect this to greatly increase the pulse dynamic range of the multiplier.

The modeled response to single ion input is shown in Figure 4. As expected, the voltage on the last 4 dynodes does not change. However, something unexpected has happened at the dynode immediately above the capacitors. The voltage on this dynode has now collapsed, and this is now the place where the multiplier becomes saturated. So we have simply moved the problem further up the dynode chain. In this case we are not seeing substantial voltage suppression effects until after about 1000 single ion pulses, compared to ~20 single ion pulses for the case with no added capacitors. **This is an improvement of about a factor of 50 times.**

If we now add capacitors between ALL the dynodes of the multiplier, we get the result shown in Figure 5. In this case, voltage suppression effects are just beginning to be seen on the last dynode after about 20000 single ion pulses have been run through the multiplier. This is a factor of about 1000 times better than the case with no capacitors added to the multiplier, and should result in a major increase in the pulse dynamic-range of a Time-Of-Flight detector. This model has allowed us to design new multipliers with greatly enhanced pulse-dynamic range.

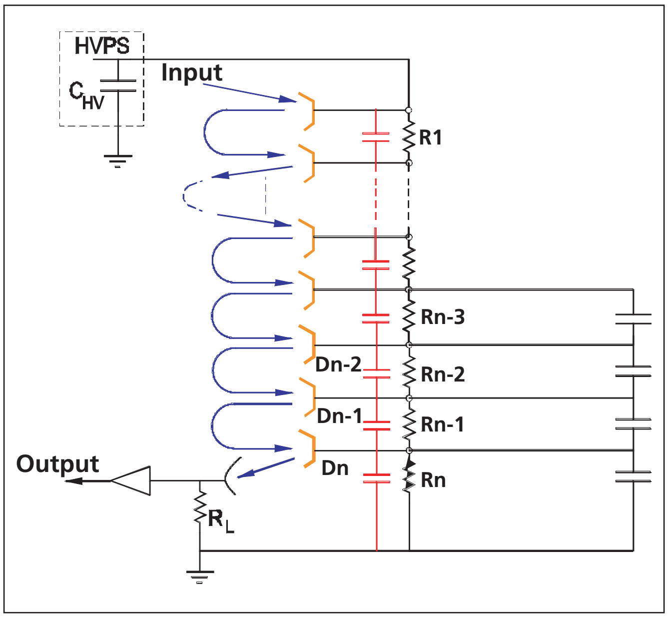

Figure 3. Schematic of a discrete-dynode multiplier showing the addition of 5nF capacitors on the last four dynodes.

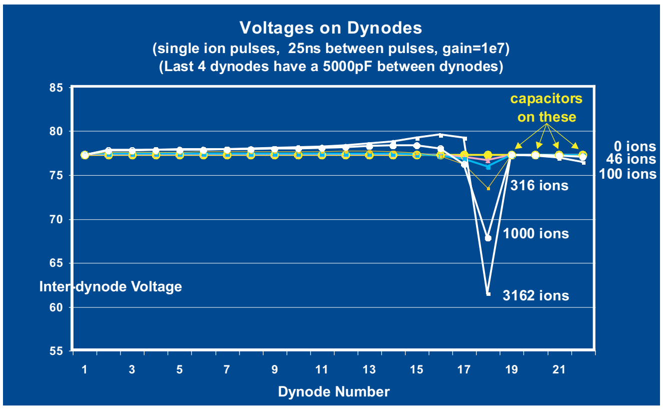

Figure 4. Change in the voltages between the dynodes of the multiplier shown in Figure 3. Now the voltages on the dynodes with 5nF capacitors attached do not change as charge is removed. Instead the voltage suppression now occurs at the next dynode above the capacitors.

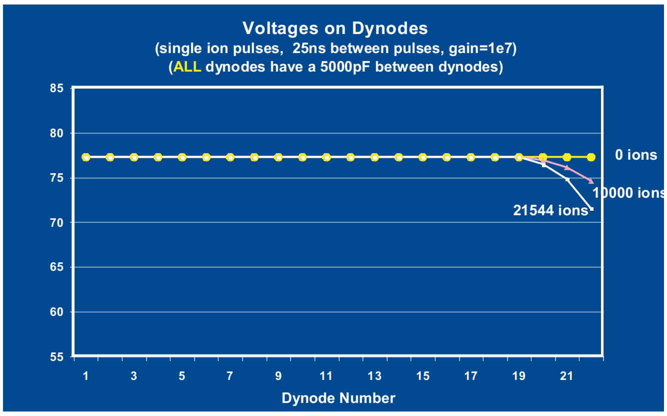

Figure 5. Change in the voltages between the dynodes of the multiplier with 5nF capacitors connected between all the dynodes. Now the onset of voltage suppression is delayed until after ~20000 single ion pulses. This corresponds to an increase in pulse dynamic range of a factor of ~1000 over the same multiplier with no capacitors attached.

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