Multi-Channel Analyzers
An Introduction to Their Operation and Use in Junior Lab

1 INTRODUCTION

One of the most prevalent tools one encounters in Junior Lab (and within Nuclear Physics) is the multi-channel analyzer or MCA. The MCA is essentially a signal averaging device and is used to generate energy spectrum histograms of one sort or another depending on the needs of the investigator.

MCA’s in pulse height analysis mode (PHA) are used within the following Junior Lab Experiments.

1. Compton Scattering
2. Rutherford Scattering
3. Quantum Mechanics of Alpha Decay
4. Relativistic Dynamics
5. Muon Lifetime and Time-of-Flight
6. Parity Non-Conservation

Furthermore, MCA’s operating in multi-channel scaling (MCS) mode are used in:

1. Neutron Physics
2. Mossbauer Spectroscopy

1.1 Pulse Height Analysis (PHA)

When operating in PHA mode, a MCA records the pulse-height distribution of analog signals generated by a detector, (e.g. scintillator and photomultiplier tube (PMT) combination, solid state detector, proportional counter detector, etc.). The important characteristic of the pulses is their height, measured in Volts. The MCA’s used in Junior Lab (Trump-PCI
from Perkin Elmer) can record pulse-height distributions ranging from 0 to +10VDC. These pulse heights are typically mapped onto a histogram containing 2048 channels or bins (fewer bins may be used if coarser resolution is desired).

1.2 Multi-Channel Scaling (MCS)

2 JUNIOR LAB MCA’S

MIT’s Junior Lab has standardized on the Trump-PCI MCA card for use within all of it’s experiments utilizing an MCA for signal averaging. This sections details the specific operation and functions of these cards.

1. Buffer - The buffer is provided to properly match impedances between the input and the TRUMP-PCI circuitry.

2. Linear Gate - The linear gate protects the peak stretcher during conversion of an event. When the linear gate is “open”, its output is identical to its input. When the linear gate is “closed”, its output is always zero.

3. Peak Stretcher - The peak stretcher operates in one of two modes: Track or Hold. In Track mode, the output of the peak stretcher is identical to its input. In Hold mode,
the peak stretcher acts like a maximum function. It outputs the maximum value which is applied to the input. The peak stretcher also has a peak-detect output which goes active when its output is greater than the value at its input.

4. A/D Converter - The Analog-to-Digital Converter (ADC) takes an analog signal and converts it to a digital equivalent.

5. Zero-Level, Lower-Level, and Upper-Level Discriminators - These adjustments provide three control signals that help control the conversion process. The zero-level discriminator (ZLD) is active when the input signal is greater than half of the LLD setting. The LDL is active when the input signal is greater than the LLD setting. The ULD is active when the input signal is greater than the maximum possible ADC output.

6. ADC Control - This circuit accepts all of the various status signals and provides the control signals required to complete a conversion.

7. Microprocessor - The microprocessor accepts the digital data and adds it to the spectrum histogram.

When an input pulse arrives, the sequence of events is as follows:

1. ZLD goes active when the input reaches half of the LLD setting.
2. When ZLD goes active, the peak stretcher is switched to Hold mode.
3. When peak detect goes active, LLD, PUR, GATE and ULD are sampled. If any of these signals rejects the pulse, the peak stretcher is returned to Track mode. If the pulse is accepted, the linear gate is closed and the ADC is given the convert signal.
4. When the ADC is finished converting, the data is transferred to the microprocessor for histogramming, the linear gate is opened, and the peak stretcher is returned to Track mode.

When the peak stretcher is in Hold mode, the MCA is unable to respond to other pulses arriving at its input stage. The time it takes for the MCA to complete the acquisition and return to sense another pulse is referred to as ‘Dead Time’. The TRUMP-PCI has a dead time specification of 8 μs, per event. Beware of signals with very high pulse rates (greater than a few 10’s of kHz). The dead time percentage of an MCA can increase so as to saturate the input stage and prevent it from working properly.

Other TRUMP-PCI Specifications:

1. Input - Accepts positive unipolar or positive leading bipolar inputs in the dynamic range from 0 to +10VDC. Zin ≈ 1 kOhm.
2. Gate - Optional, slow-positive NIM input. Computer selectable coincidence or anti-coincidence. Signal must occur prior to and extend 0.5 μs beyond the peak of the pulse.