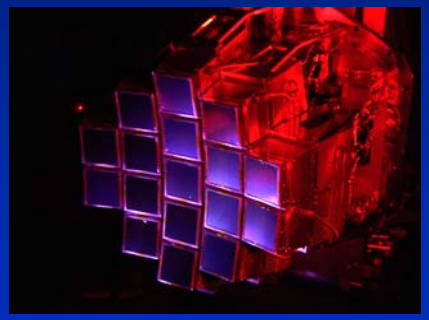
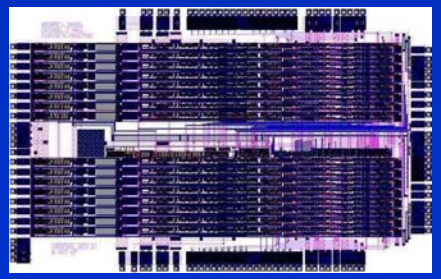
Argonne Undergraduate Research Symposium
November 2-3, 2007

Multi-Channel Integrated Circuits For Use In Nuclear Physics Experiments





Southern Illinois University Edwardsville

IC Design Research Laboratory

James F. Brown (undergraduate)

Dr. George L. Engel (faculty adviser)

Long-Term Goal of Research

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Our long-term goal is to develop a ***family*** of multi-channel custom integrated circuits (ICs) suitable for use in a wide variety of low- and intermediate-energy nuclear physics experiments.

The ICs will be useful in experiments where energy, relative timing, and position information is desired.

Particle identification using pulse shape discrimination will also be supported.

Inter-University Collaboration

Southern Illinois University Edwardsville
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Washington University in Saint Louis
Department of Chemistry
Nuclear Reactions Group
St. Louis, MO 63130-4899
lgs@wuchem.wustl.edu

Greater collaboration includes researchers at

- Western Michigan University
- Michigan State University
- Indiana University

Integrated Circuit Design Team

Southern Illinois University Edwardsville

IC Design Research Laboratory

- Dr. George L. Engel (Professor)
- Michael Hall (Graduate Assistant)
- Justin Proctor (Graduate Assistant)
- Dinesh Dasari (Graduate Assistant)
- Nagendra Valluru (Graduate Assistant)
- James F. Brown (Undergraduate Assistant)

- Dr. Lee G. Sobotka (Nuclear Chemist)
- Dr. Robert J. Charity (Nuclear Chemist)
- Jon M. Elson (Electrical Engineer)

Overview

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Past

Shaped and peak-sensing analog micro-chip which we call HINP16C used for obtaining energy and time information.

Present

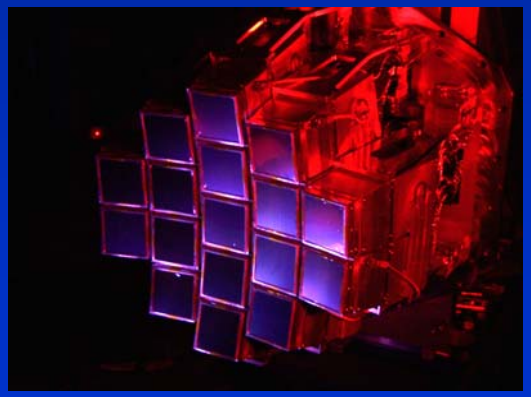
Analog micro-chip which we call PSD8C capable of particle identification using pulse-shape discrimination (PSD).

Future

Micro-chip capable of multi-region integration. We plan to use what we term “analog-assisted DSP” techniques to obtain energy, time, and position information.

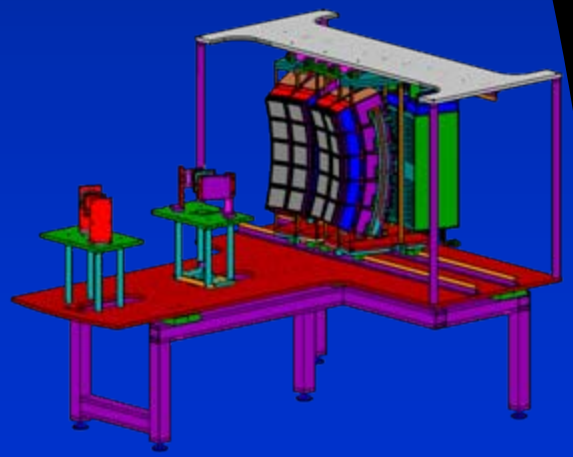
Why design custom micro-chips?

- **Need for high density signal processing in low and intermediate energy nuclear physics community is widespread.**
- **No commercial chip was found to do exactly what we wanted. It is necessary for the "experimenter" to be in the "designer's seat".**



Our first chip! - HINP16C

Heavy Ion Nuclear Physics – 16 Channels



Sample Applications

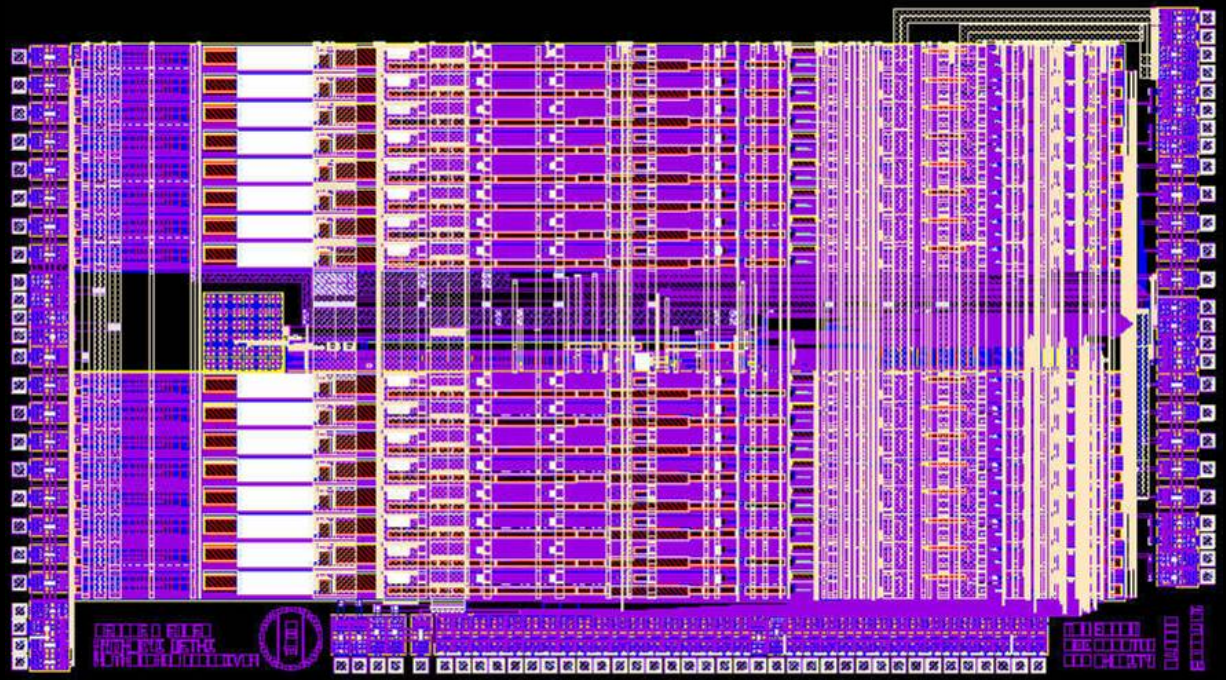
- **Spectroscopy of low lying particle unstable states by resonance decay correlation techniques**
- **Inverse (d,p) scattering experiments designed to study shell structure and paring in n-rich nuclei**
- **Inverse (p,d) reactions examining the n single particle structure of secondary unstable beams**
- **Particle-particle correlation experiments at intermediate energy designed to refine temperature determinations**

HINP16C Features

- Two gain modes: 100 MeV or 500 MeV
- Capable of processing either polarity
- Channel by channel disable of on-chip CFDs
- Analog multiplicity output (and logical OR)
- User selection of either hit channels or all to be read out i.e. **data sparsification**
- Two time measurement ranges: 250 ns or 1 μs
- Automatic reset of time-to-voltage and peak sampling circuits unless vetoed by user with variable decision time (300 ns – 30 μs)

HINP16C

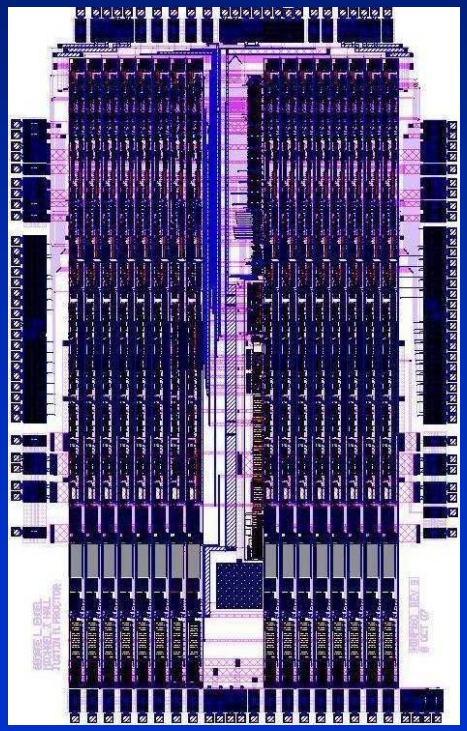
Has been used in many experiments!

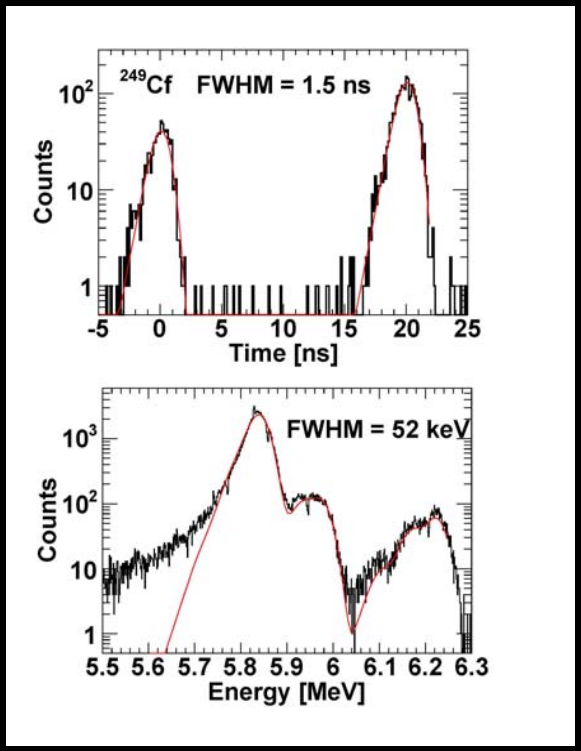


Input **CSA (multirange)** **Shaper + active peak tracker** **CFD+TVC**

Area: (6.4 mm x 4.5 mm) **Power: 800 mW**

HINP16C Performance





a) Time and b) energy spectra of a 249Cf source obtained using internal CSA (15mv/MeV) . The time spectrum presents two measurements of start-stop time difference offset by 20 ns. The lifetime of the t1/2 = 0.45 ns intermediate state is easily observed. Advancing time runs to the left. For reference the upper two energy peaks seen in b) are separated by 54 keV. The resolutions are extracted from the fits (lines) which are a) an exponential convoluted with a Gaussian resolution function and b) slightly skewed Gaussians with the known relative intensities.

PSD8C

Pulse Shape Discrimination – 8 Channels

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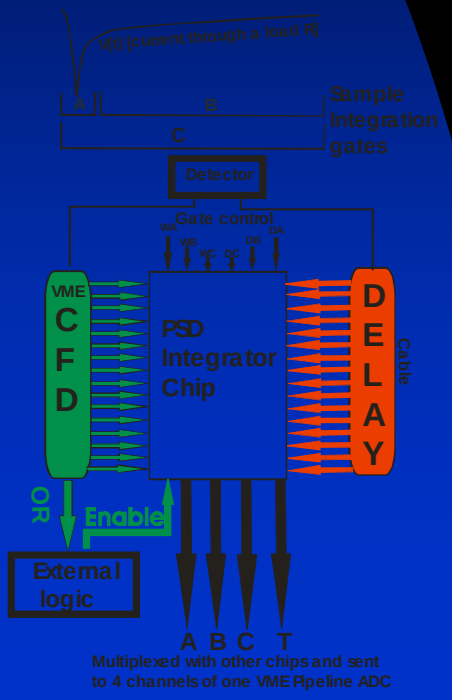
We are currently developing a micro-chip useful in experiments where particle identification is needed.

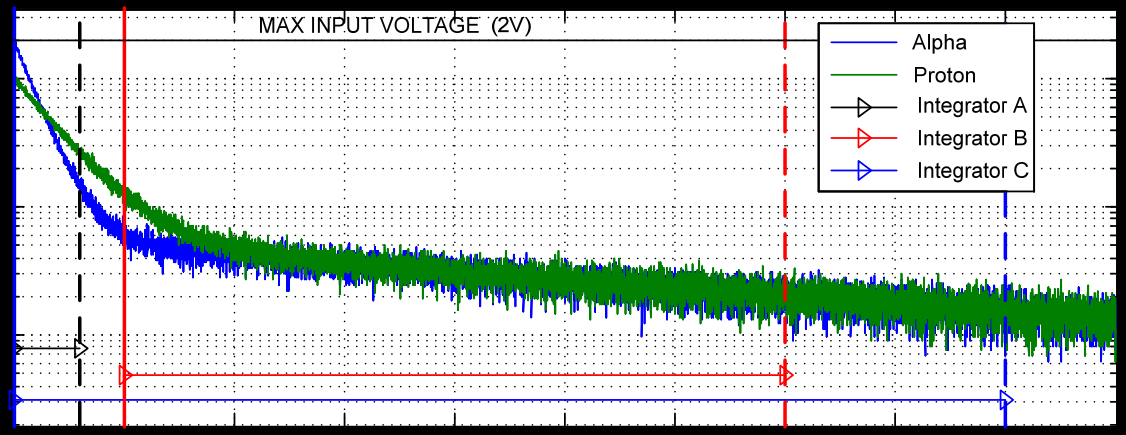
The chip employs a technique known as pulse shape discrimination (PSD) to classify the radiation type.

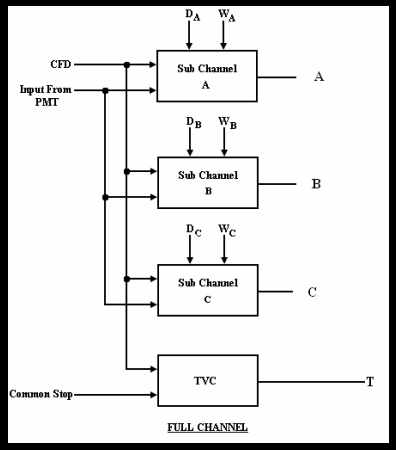
The micro-chip will be suitable for use with both CsI(Tl) (used for charge-particle discrimination) and liquid scintillator (used for neutron-gamma discrimination) detectors.

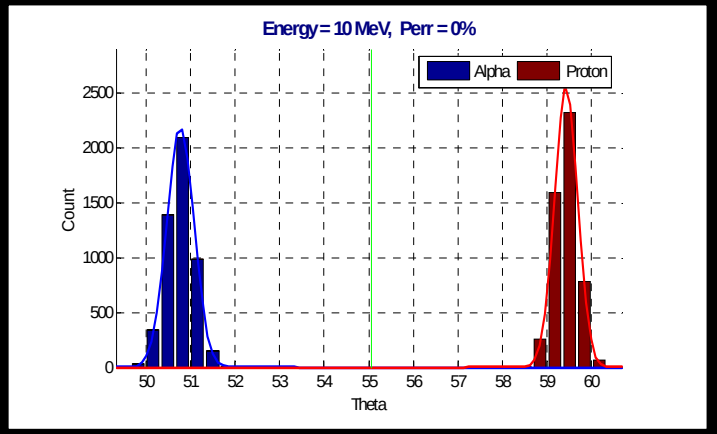
The research is funded by NSF Grant # 0618996 (Sep 1, 2006 – Aug 31, 2008).

Particle Identification Using Pulse Shape Discrimination



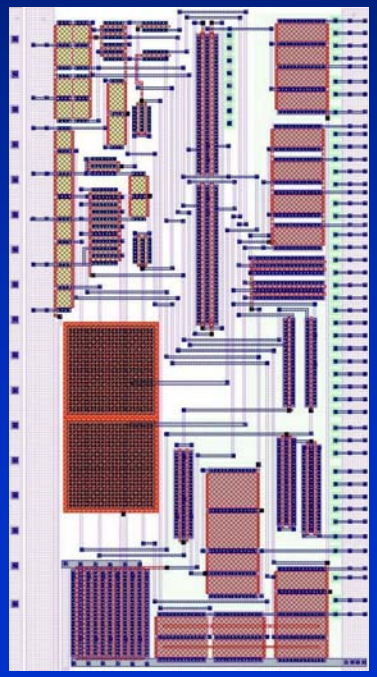


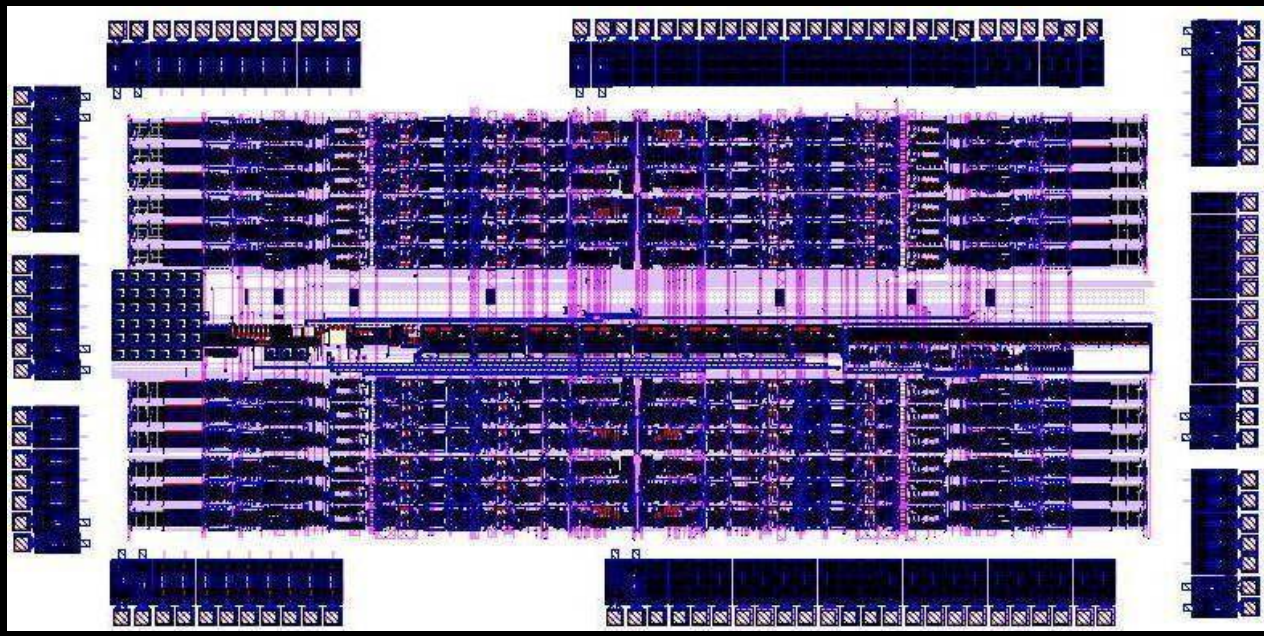




PSD8C Microchip

To Be Sent Off For Fabrication: Nov 26, 2007





Under construction!

Area: 2.4 x 5.6 mm

Power: 125 mW

Summary

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The development of custom micro-chips for use in nuclear physics experiments puts the experimenter “in the driver’s seat”.

Our “existing” HINP16C (revised) chip is useful where quality timing information (< 1ns) and high energy resolution (35 keV) is required.

Our PSD8C chip is useful where modest energy resolution and/or particle identification using pulse shape discrimination is required. Time-to-voltage converters are on-chip but external CFD circuits are required.

In the future we hope to have a chip that will allow for more complex pulse shape analysis so that position information may be extracted.