CMOS Analog ASICs
For low-energy nuclear physics

Why

2. Cost
(save in ADC’s due to pipelining)

2. Ease of setting up “big” experiments

3. Flexibility - Expandability

BUT

Makes no sense for channel counts ~1000

Only makes sense for channel counts ~ 1000 due to
a) MOSIS and b) university based (student) design

However, once developed, it makes sense for experiments with as few as a few hundred!!
What has/can be done?

   What we have done with HiRA and others have done before.

2. Multisampling for PSD
   What we are now proposing as the next step.

3. DSP inspired Analog “round-robin” multisampling.
16 channel HiRA chip
Beginning of our Chip “tool box”

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

(6.4 mm x 4.5 mm)
Specifications - result of evolutionary process

- **Multi range options**
  - 125 MeV full range with 35 keV (FWHM) resolution, 2.5 pF feedback
  - 600 MeV full range with 150 keV (FWHM) resolution, 12.5 pF feedback
  - **external preamp (CSA) capability**

- Capable of processing either polarity

- **Built in pseudo CFD with time resolution of ~ 1ns (FWHM)**

- **Time-to-voltage analog circuitry with two time measurement ranges:** 250 ns or 1 μs

- **Fast OR and Analog multiplicity outputs**

- **Automatic reset of time-to-voltage and peak sampling circuits unless vetoed by user with variable decision time (300 ns – 30 ms)**

- **Data sparsification: Hit, ALL, or intelligent logic**

Compatibility with modern pipeline ADCs
Cost
(production only)

A. Chip
30,000$/100 chips = 20$/ch

B. Chip Board CB (32 ch)
250$/CB = 10 $/ch

C. Mother board (512 ch)
1500$/CB = 3 $/ch

D. ADC (4*2*512 or more ch)
7500$/sys = 15 $/ch

C. System control (512 ch)
3000$/sys = 6 $/ch

TOTAL (512 ch)
3000$/sys = ~ 50$/ch
First HiRA experiments 7/05
Only 1500 strips of Si

$^{232}$Th Source
Summary spectrum
(64 ch, 1 of 16 tels)

$\sim$ 35 keV pulser
$\sim$ 55 keV ind. Ch
$\sim$ 75 keV system

$^{232}$Th source
ALL Fronts (~500)
added together.
(Device $\sim$ 75 keV)

p (Coulomb ring) from:
$^{71}$Br $\rightarrow$ $^{69}$Br + 2n
$^{69}$Br $\rightarrow$ $^{68}$Se + p
+ a hell of a lot of other crap.

PID for
most of HiRA
(added together)
HiRA experiments

1. R p-process waiting points (Famiano)  
   \[ ^{78}\text{Kr} \rightarrow ^{71}\text{Br} + x \rightarrow ^{69}\text{Br} + 2n \rightarrow ^{68}\text{Se} + p \]
   done

2. \(^{64}\text{Ge}\) R p-waiting point (Wallace)  
   done but

3. ‘Molecular resonances’ in \(^{12}\text{Be}\) (Charity)  
   done

4. Diffractive Contributions to p knockout on \(^{9}\text{C}\) (Bazin)  
   NOW

5. Structure of \(^{10}\text{C}\)  
   (This summer at TAMU)
Integration with Other tools without hitch

The S800 Spectrograph

Tracking systems (CRDC’s + CP’s)

HiRA (Si – Si – CsI)

Soon with MoNA

Certainly Gretina and LARGE Si arrays in the future.
PSD chip proposal
to design, build and use in 18-20 mo. for 200k$
Analog assisted Digital signal processing

“Standard” analog → PSD → “Multisampling”

Present
Electronics for HiRA (up to 512 ch/box-tower)

future
Multisampling ASIC

How DSP morphs when analog “CMOSed” lose some power & price drops an order of magnitude

Imagine two wheels rolling in time, picking up a “bite” of the signal, dropping it and picking up a new “bite” when the wheel comes full cycle.

EACH of, say, 12 integrators (on each wheel)

INTEGRATES – HOLDS - DUMPS

The two wheels are used to record different time ranges.
Analog multi sampling:
Test of principle

Analysis of GRETA primary and induced signals.

Blue are digitized waveforms

Red are the output of a simulated (MATLAB) chip integrators.

Information Including T generated on-chip and prepared for single pipeline.

but ....

Some things cannot be done.
Delayed decays
High M events harder to figure out
High rate primary beam more problematic
Why analog ASIC’s?

1. $’s
2. The analog ASIC “toolbox” could be MUCH deeper than it presently is! The ASIC’s could be built to use a standard “platform” so they could be used mix and match. (Like are used to for NIM, CAMAC, VME standards.

Greater importance

Large arrays (thousands to 10’s of thousands of elements) of CZT are being built for medical imaging and space science. Will Low energy NP play a role and thus get what we want?

Just as it made sense for HE to develop ASIC’s,
The development of ASIC’s for these 1-component charge carriers makes sense. The problems of positional localization in CZT and large Ge are actually very similar.
Oct. experiment (Charity):
‘Molecular resonances’
in $^{12,14}\text{Be}$
1) existence
2) structure

Some of the existing data for $^{12}\text{Be}$  
(M. Freer et al.)

HiRA (no background simulation) of
“known” states in $^6\text{He}+^6\text{He}$ states
1. As for $^{10}\text{Be}$, $^{10}\text{C}$ should have strong clustered (2$\alpha$x) structure.

2. Can be calculated with GFMC.

3. All states with $3.8 < E^* < 14.5$ can ONLY decay by 2$\alpha$2p.

4. Study of the 5 particle exit channel of: $^{10}\text{C}(p,p') \rightarrow 2\alpha2p$ can identify the intermediates $^6\text{Be} (\alpha2p) \text{ 92 keV}$

$^8\text{Be} (2\alpha) \text{ 6.8 ev}$

$^9\text{B} (2\alpha p) \text{ 540 ev}$

This experiment should be done at both TAMU and NSCL energies.
rp process waiting points*

New program involving S-800 + HiRA
e.g. studying the “inverse” of $^{68}\text{Se}(p,\gamma)$
$^{78}\text{Kr} \rightarrow ^{71}\text{Br} + x \rightarrow ^{69}\text{Br} + 2n \rightarrow ^{68}\text{Se} + p$

The relative energy between the residue ($^{68}\text{Se}$) and and proton
is the excitation spectrum of the parent ($^{69}\text{Br}$)

Experiment finished last week.
This experiment (and the ones that follow) were 3 years in the making.

* Waiting point: $Q_\beta$ small enough for $t_\beta > t_{rp}$ and $Q_p$ low enough to suppress p cap
Next (?): $^{64}\text{Ge}$ waiting point (M. Wallace)

$^{64}\text{Ge}$ half-life = 63.7 s
$^{65}\text{As}$ half-life = 190 ms (GS particle stable)
$^{66}\text{Se}$ half-life > .2 μs

$^{64}\text{Ge}(p,\gamma)^{65}\text{As}$ rate is based on 3 states in (mirror) $^{65}\text{Ge}$,
$^{65}\text{As}(p,\gamma)^{66}\text{Se}$ rate is based on 3 states in (mirror) $^{66}\text{Ge}$.

$^{65}\text{As}(\gamma,p)^{64}\text{Se}$ and $^{66}\text{Se}(\gamma,p)^{65}\text{As}$ rates are calculated from detailed balance

$Q\ [^{64}\text{Ge}(p,\gamma)^{65}\text{As}] = -73 \text{ keV} \pm 303 \text{ keV}$

$^{66}\text{As}(p,d)^{65}\text{Ge}$ and
96 ms
$^{65}\text{Ge}(p,d)^{64}\text{Ge}$
31 s
Can fix the $Q_p$ value to < 25 keV (if $M_{^{66}\text{As}}$ and $M_{^{65}\text{Ge}}$ determined)
Excited states will also be found.

? Requires HiRA dE’s
\[ E(\rho, \delta) = E(\rho) + E_{\text{sym}}(\rho) \delta^2 \]