

MDT-ASD PRR

Specifications, Design and Performance



Overview

- Specifications

 - Functional

 - Analog

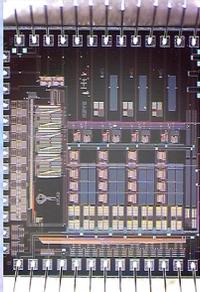
- Architecture

 - Analog channel

 - Programmable parameters, serial control port

- Prototyping - measurements and tests

 - Functionality and performance test results



MDT-ASD PRR

Functional Specifications



Leading edge timing measurement

Goal: single tube position resolution 80 μm



Charge measurement

Pulse width encoding - Wilkinson ADC, for time slew correction

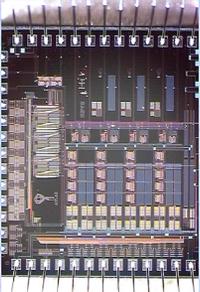


Modes of operation

- ⌘ Time-over-Threshold (ToT) mode
- ⌘ ADC mode

Plus:

- Calibration/Test pulse injection
- Channel modes: Boundary scan
- Programmability of analog and functional parameters
- Serial control data I/O, communication protocol

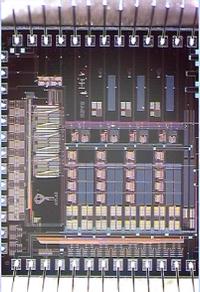


MDT-ASD PRR

Analog Specifications



- ❖ Gain: 3 mV/ primary e^- (~ 10 mV/fC)
- ❖ Dynamic Range (linear): 1.5 V (500 primary e^-)
- ❖ Peaking time: 15 ns
- ❖ Shaping: bipolar, area balance < 500 ns
- ❖ Input impedance: $Z_{IN} = 120 \Omega$
- ❖ Noise: ENC $< 6000 e^-$ (~ 4 primary e^-)
- ❖ Crosstalk: Channel-channel, $< 1\%$
- ❖ Signal path: differential
- ❖ Power supply: Single, 3.3 V
- ❖ Power consumption: < 35 mW/channel

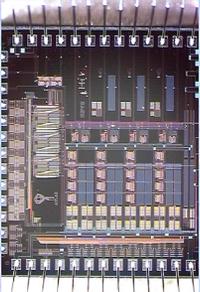


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Architecture

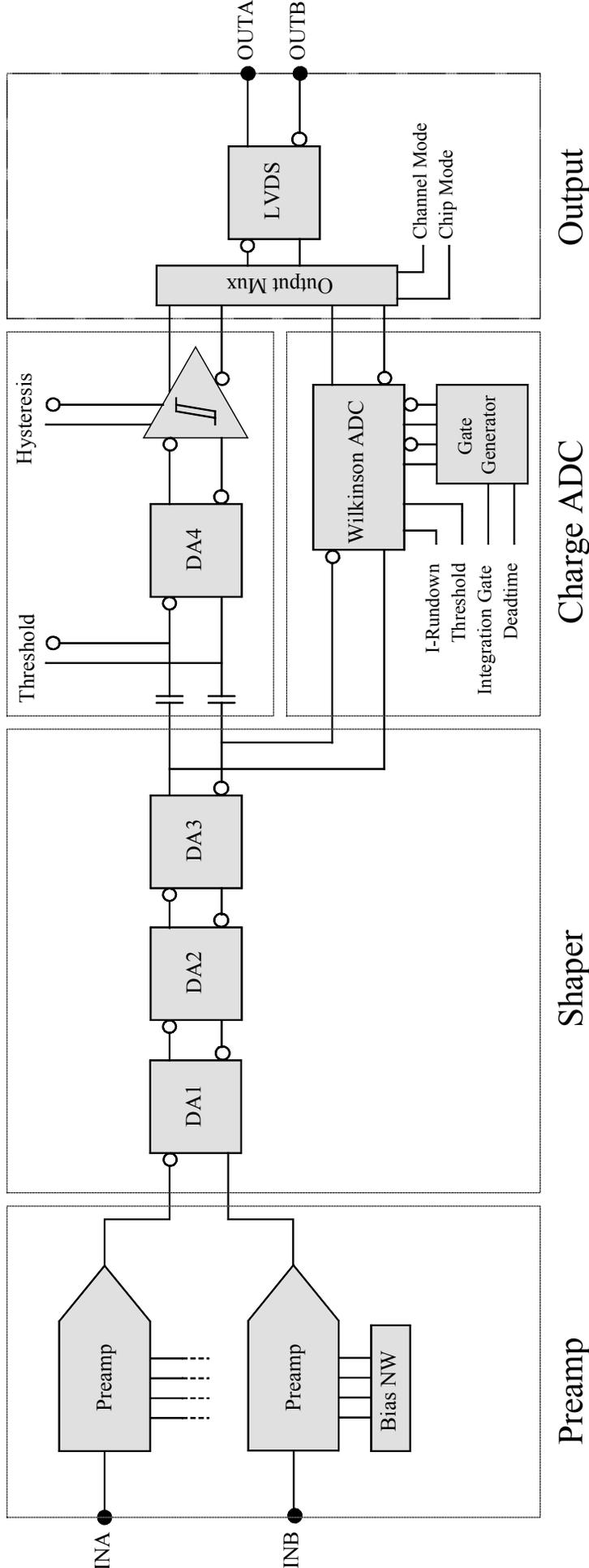


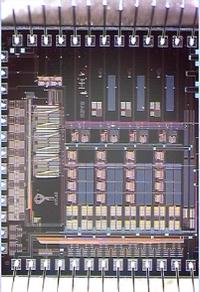
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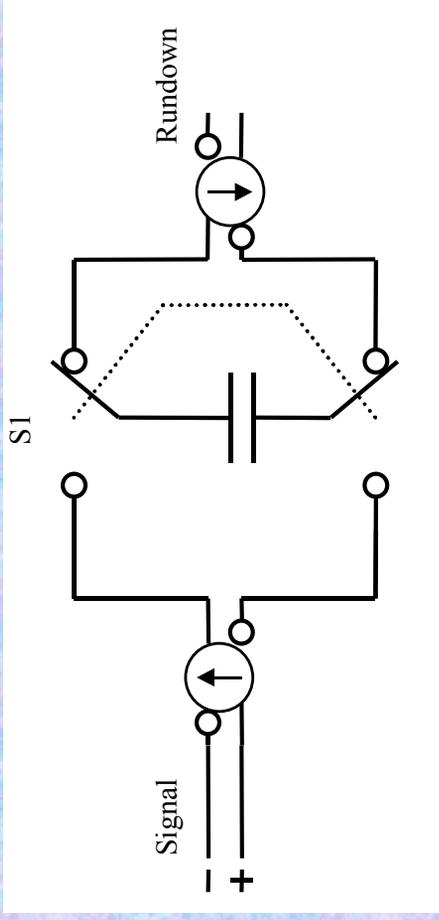
MDT-ASD PRR

Analog Channel – block diagram



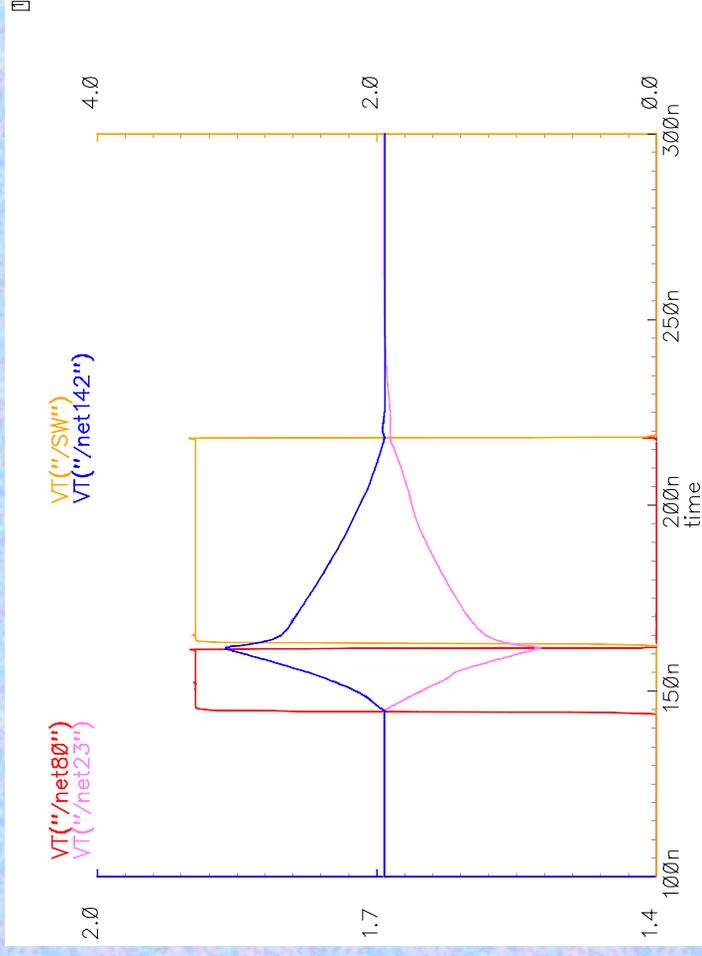


MDT-ASD PRR Wilkinson Charge ADC

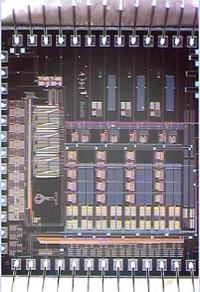


ASD output pulse information:

edge \rightarrow timing
width \rightarrow charge

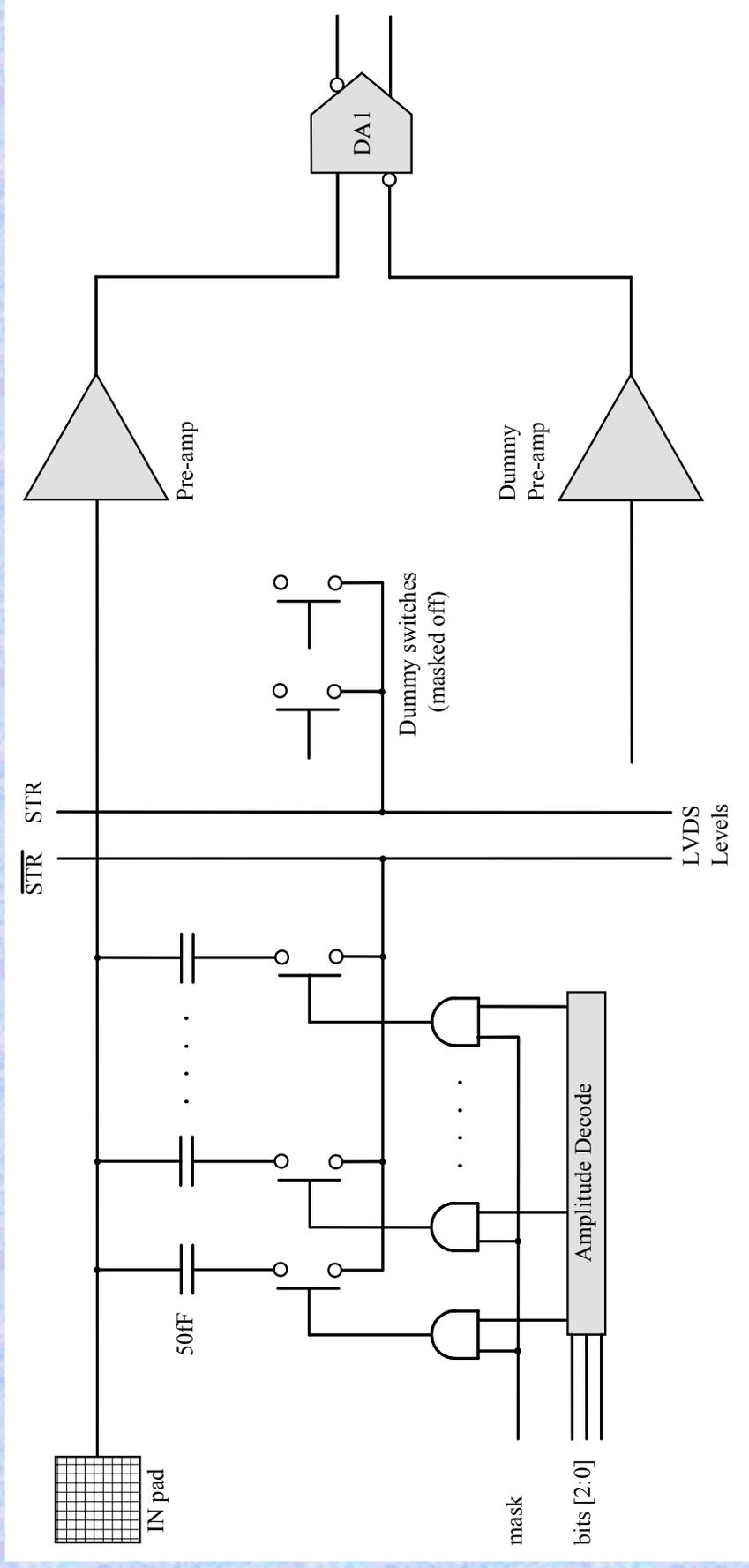


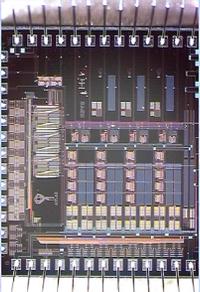
- A Wilkinson type ADC measures the charge in the leading edge of the MDT signal within a given time window and encodes it into a pulse width. (Charge-to-Time Conversion)
- The information will be used for time slew correction.
- Other applications: Diagnostics, chamber monitoring, dE/dx , ...



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Calibration pulse injection





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Programmable Parameters I



Timing Discriminator

- ① **Threshold:**
 - ◆ Range: -256 – 256 mV
 - ◆ Resolution: 2 mV (8-bit)
 - ◆ Nominal: +60 mV (20 primary e⁻)

② Hysteresis:

- ◆ Range: 0 – 20 mV
- ◆ Resolution: 1.33 mV (4-bit)
- ◆ Nominal: 10 mV

Wilkinson Charge ADC

① Integration Gate:

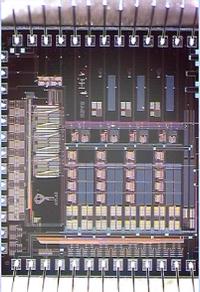
- ◆ Range: 8 – 45 ns
- ◆ Resolution: 2.5 ns (4-bit)
- ◆ Nominal: 14.5 ns

② “Run-down” current:

- ◆ Range: 2.4 – 7.3 μ A
- ◆ Resolution: 0.7 μ A (3-bit)
- ◆ Nominal: 4.5 μ A

③ Discriminator Threshold:

- ◆ Range: 32 – 256 mV
- ◆ Resolution: 32 mV (3-bit)
- ◆ Nominal: 32 mV



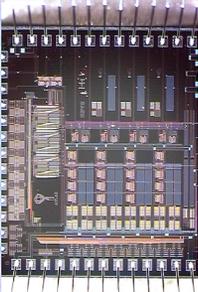
MDT-ASD PRR

Programmable Parameters II



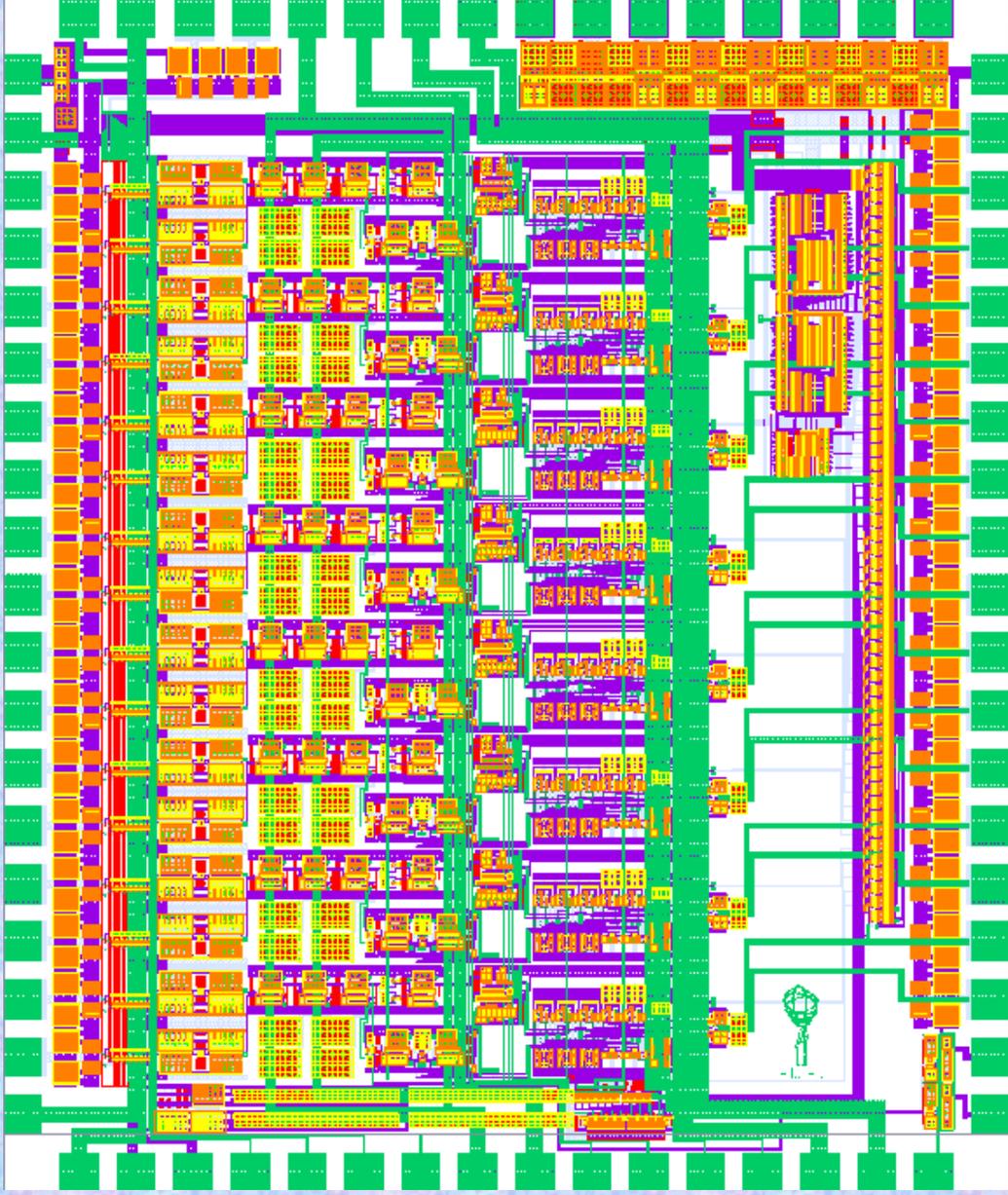
- ① **Dead Time:** ADC mode: Logic does not accept/process new hit
 - ◆ Range: 300 - 800 ns
 - ◆ Resolution: 70 ns (3-bit)
 - ◆ Nominal: 800 ns
- ② **Calibration/Test Pulse Injection**
 - ◆ Range: 10 - 80 fC (50 – 400 fF Caps @ LVDS 200mV)
 - ◆ Resolution: 10 fC (3-bit)
 - ◆ Each channel individually selectable (8-bit mask register)
 - ◆ “Delayless” (RC time constant ~ 150 ps)
- ③ **Chip Mode:** Time-over-Threshold (ToT), ADC mode
- ④ **Channel Output Mode:** Active, Set HI, Set LO

Total number of setup bits: 53 Serial I/O, shift + shadow registers, daisy chain

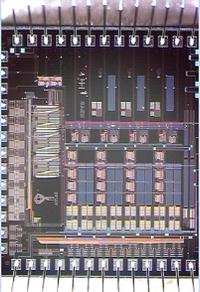


MDT-ASD PRR

Fabrication process, layout



- ⌘ Full custom design (standard cells in serial data interface)
- ⌘ I/O pads ESD protected
- ⌘ Die 3.2×3.7 mm, 70 bonding pads
- ⌘ QFP80 package
- ⌘ Fabrication process:
 - 0.5 μ m CMOS, triple-metal, 1 poly, N-well,
 - Analog option with linear capacitor, silicide block for poly resistors (HP AMOS14TB)

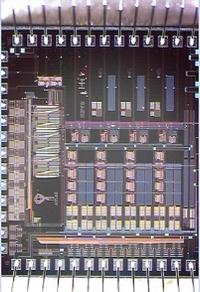


MDT-ASD PRR

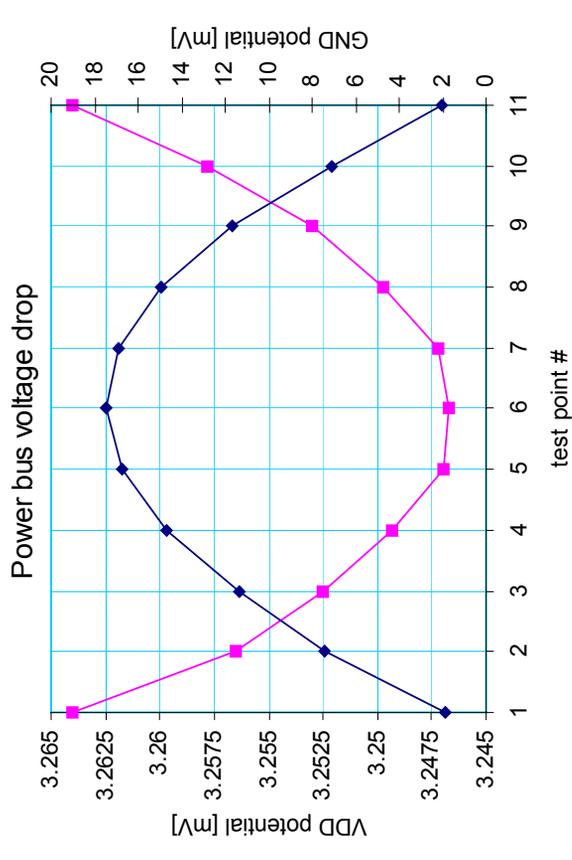
Prototyping - measurements and tests



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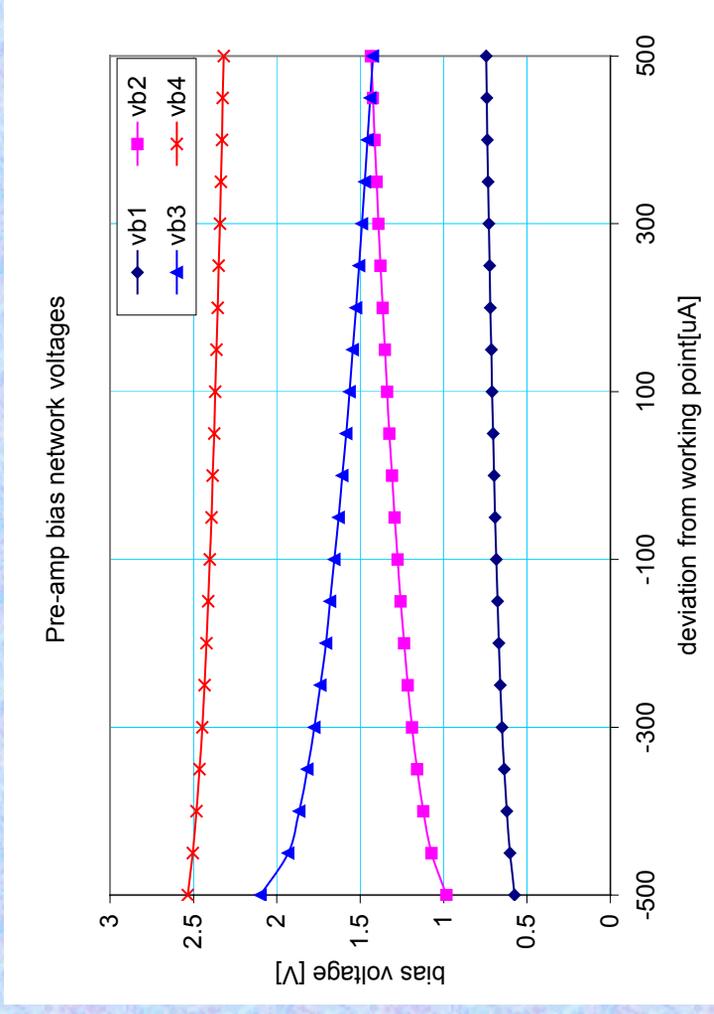


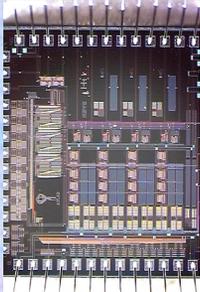
MDT-ASD PRR DC Measurements



VDD and GND levels at equally spaced test points along the pre-amplifier power bus

Scan pre-amp bias network DC levels - possible to extract transistor parameters (K_p , V_0)



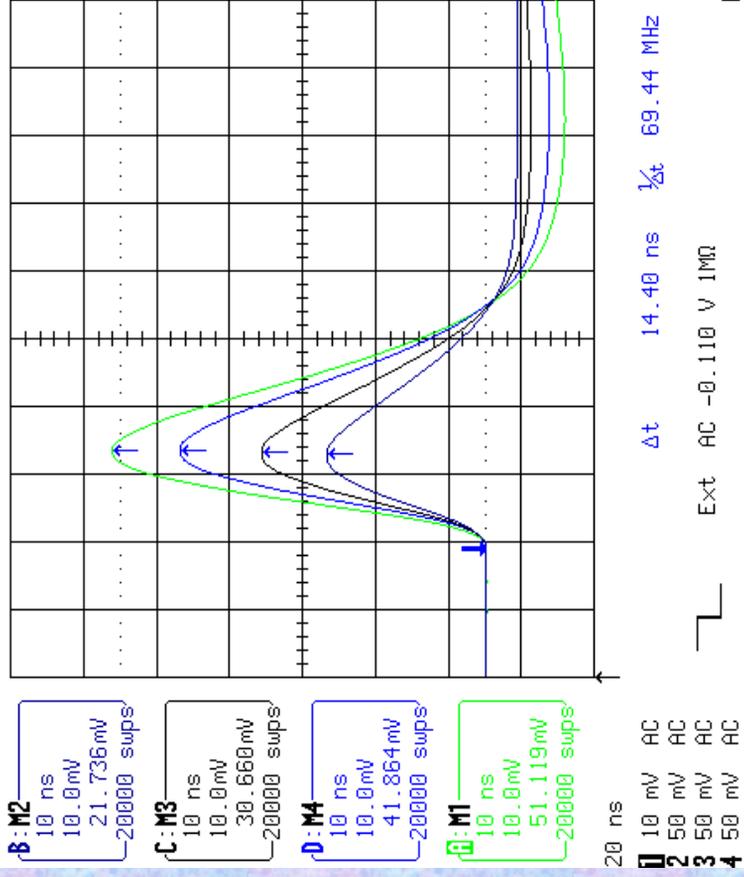


MDT-ASD PRR

Sensitivity

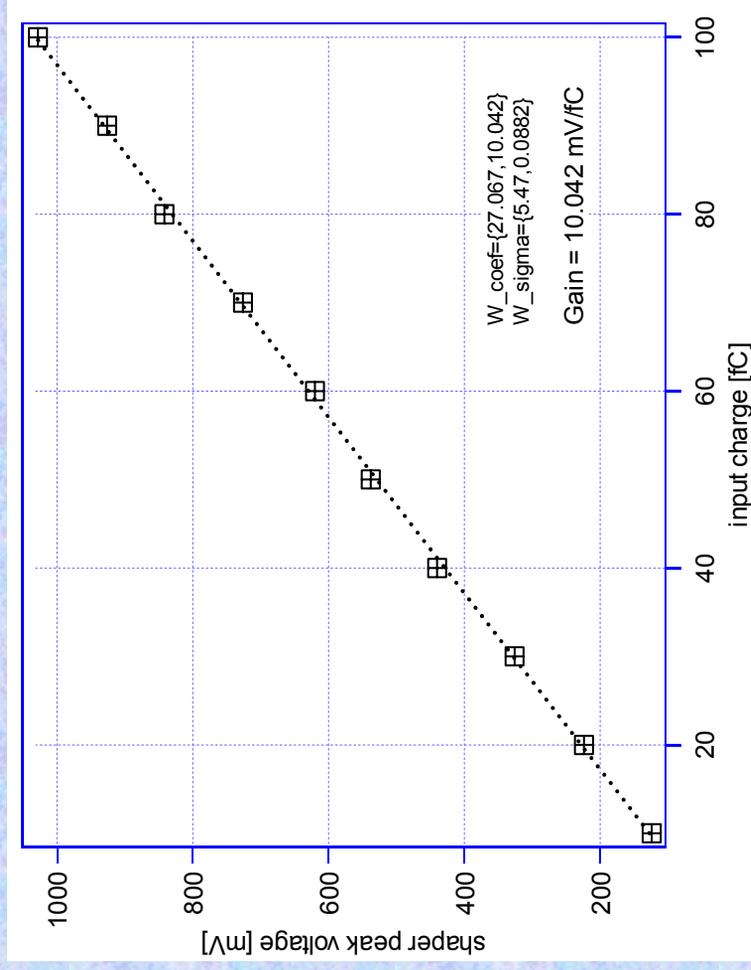


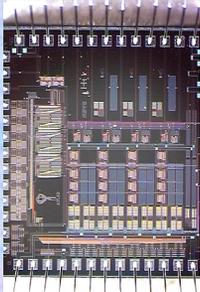
12-Feb-01
20:52:56



Probe attenuation 10:1
 Single ended pulses,
 40, 60, 80, 100 fC

Sensitivity:
10 mV/fC



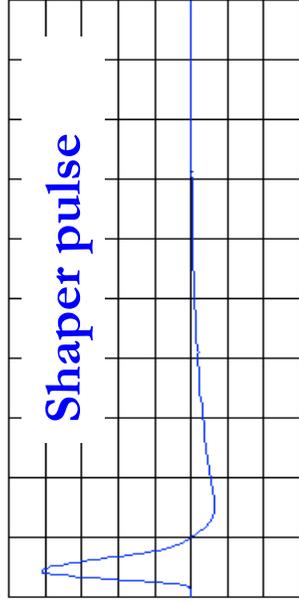


MDT-ASD PRR Bipolar Shaper

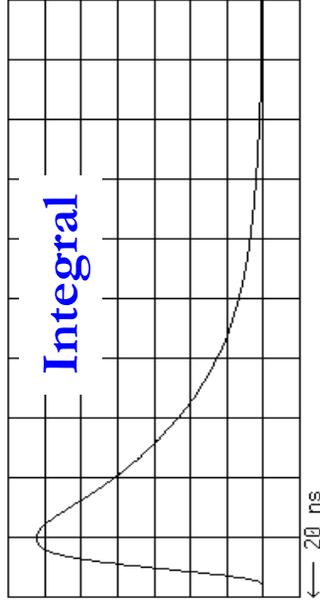


9-Feb-01
12:35:50

A: Average (1)
50 ns
100 mV
5430 supps

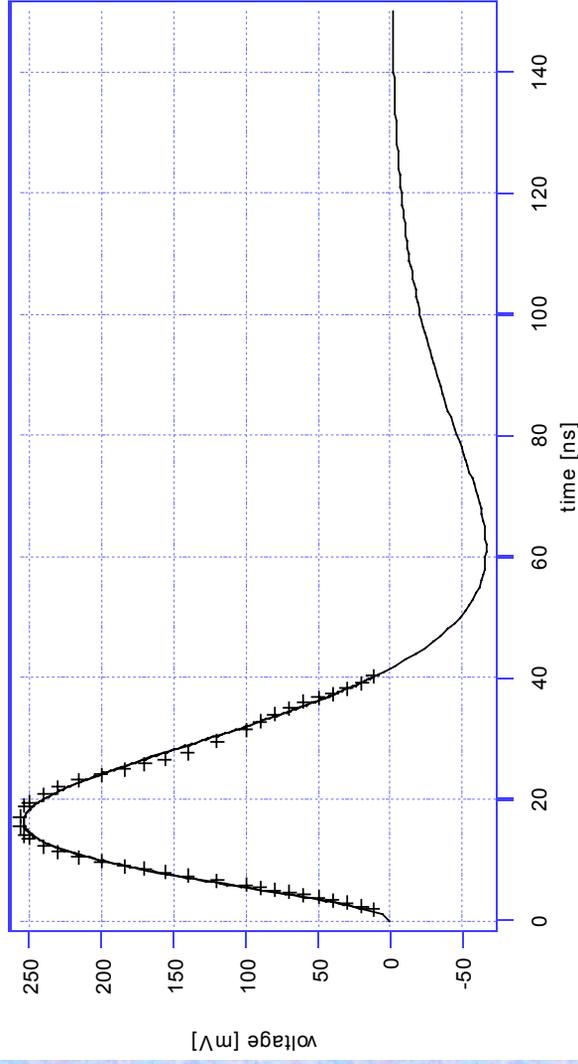


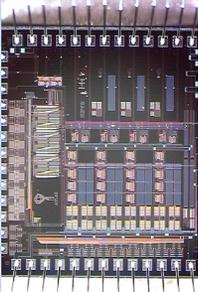
B: $\int (A+k) dt$
50 ns
1.26 nVs
5430 supps



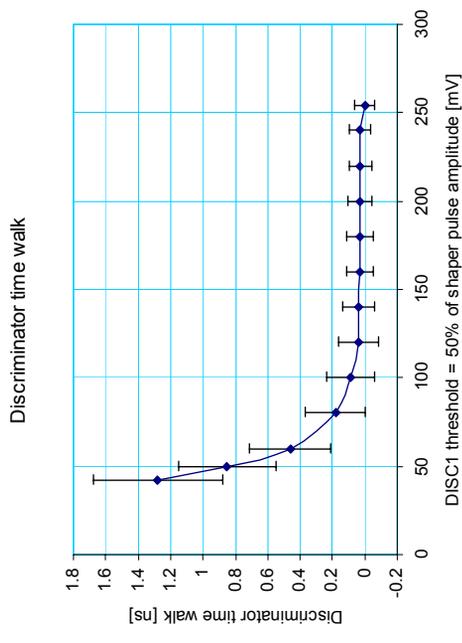
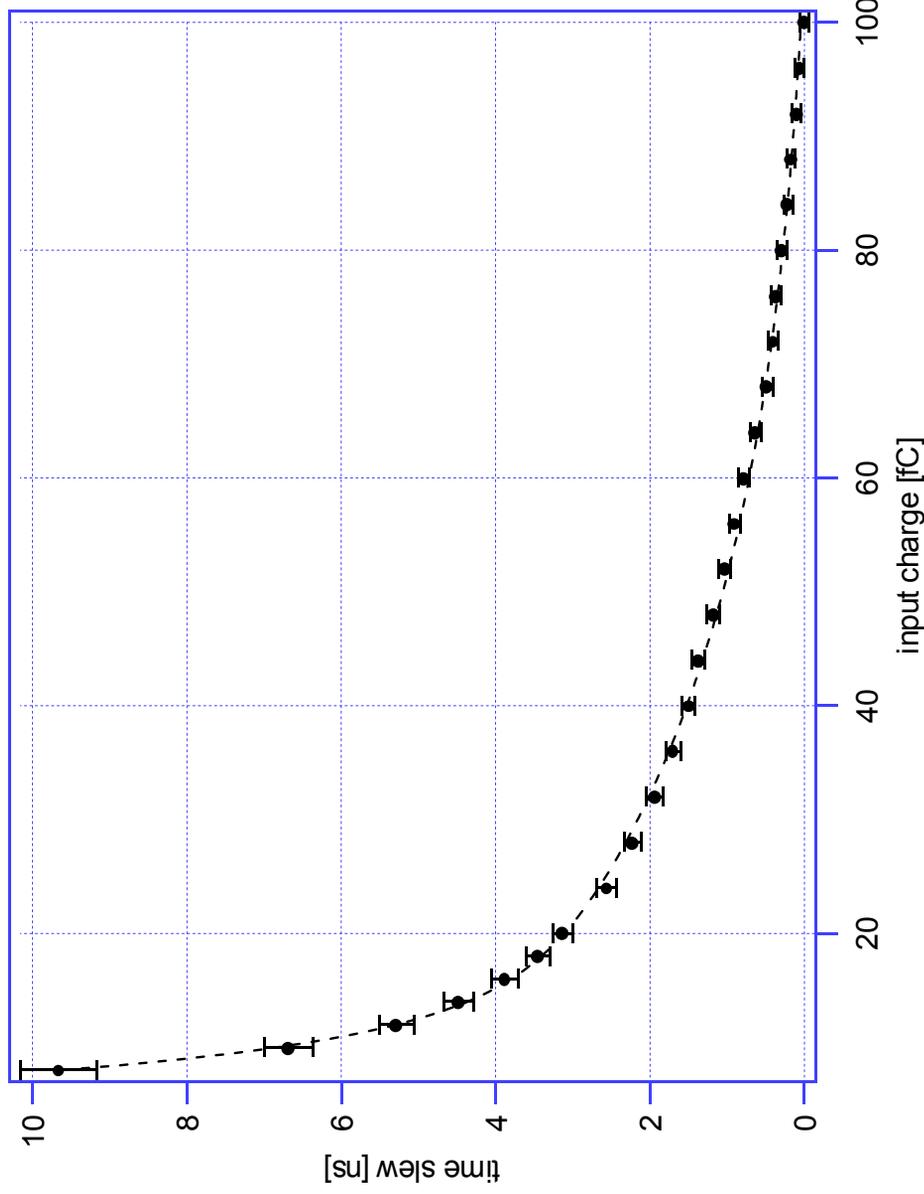
Area balance after
~ 400 ns

ToT mode shaper pulse reconstruction + theoretical fit

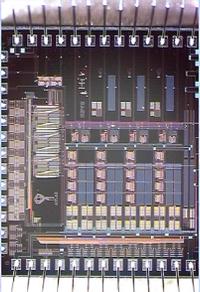




MDT-ASD PRR Time Slew

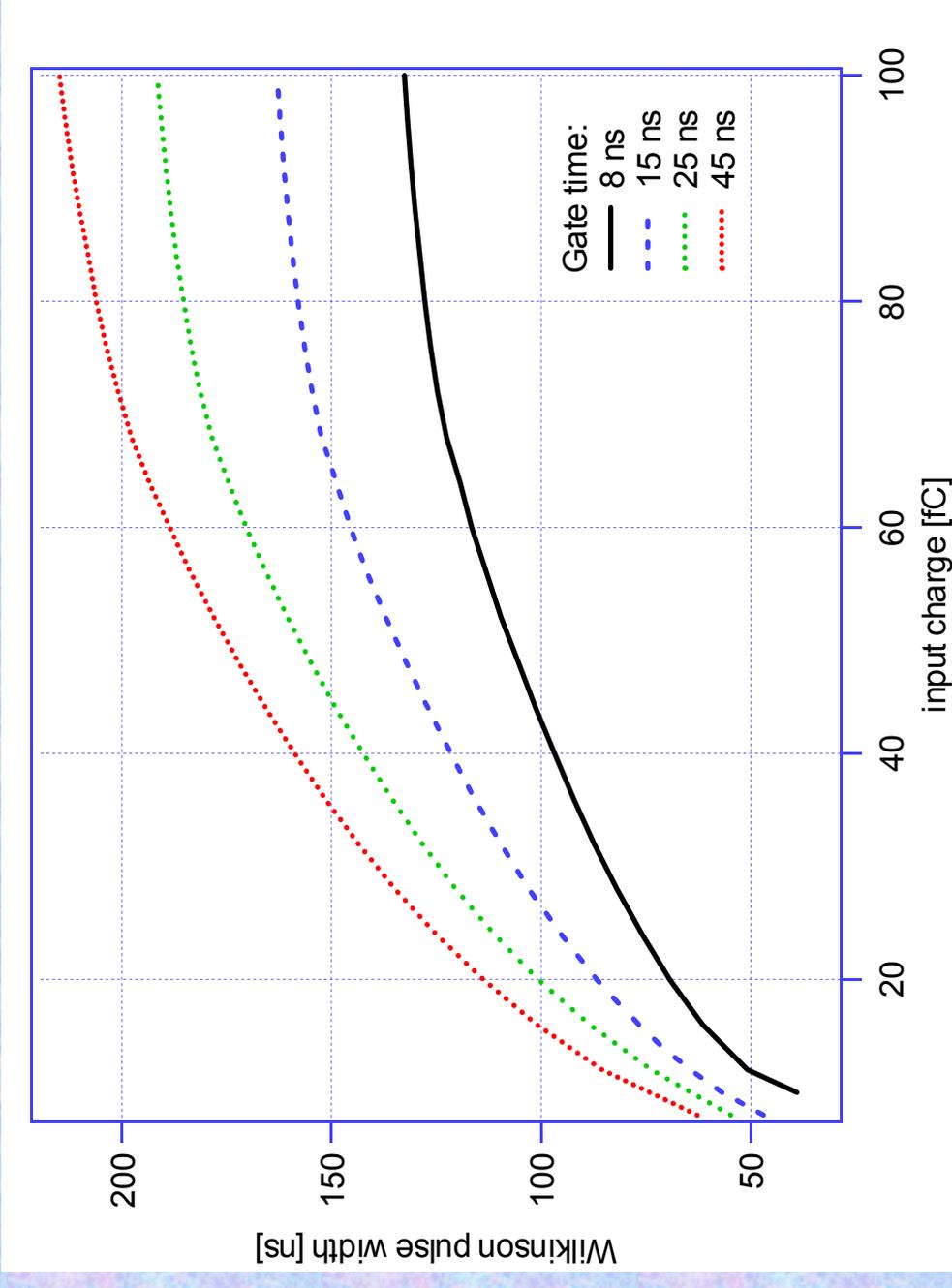


Time slew for expected
input signal range of the
order of **2 – 3 ns**



MDT-ASD PRR

Charge Measurement: Wilkinson ADC

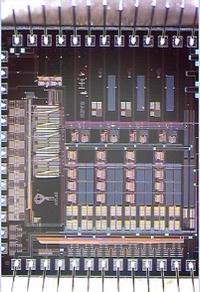


Non-linear converter transfer characteristic (compressive)

Calibration per single tube:

- ◆ ch-ch variations
- ◆ variable parameter settings

nominal threshold

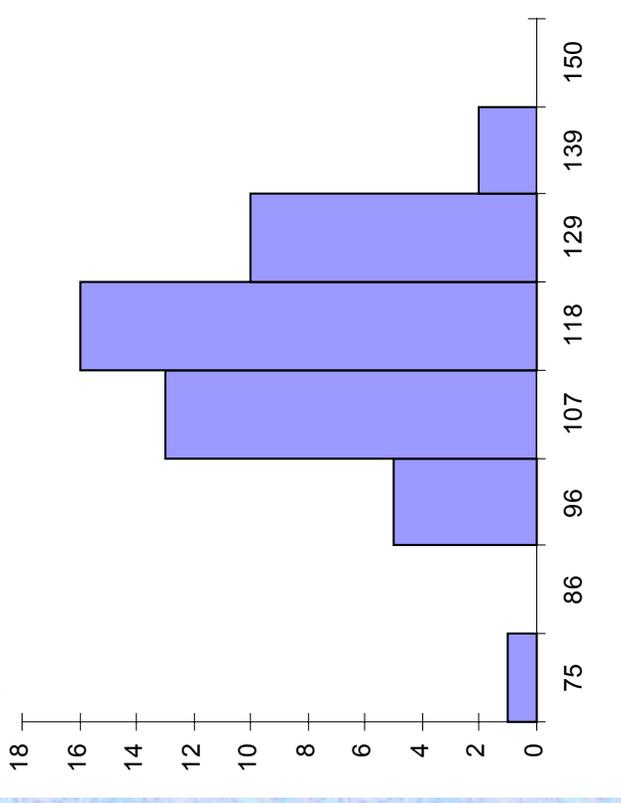


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Channel - Channel Variations

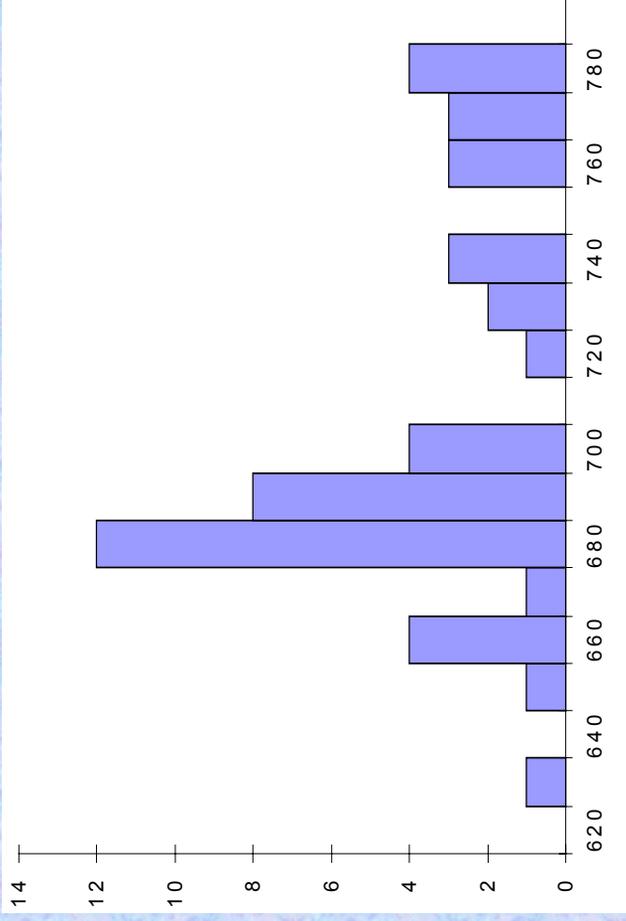


Wilkinson output pulse - 48 channels
for typical settings and input signal

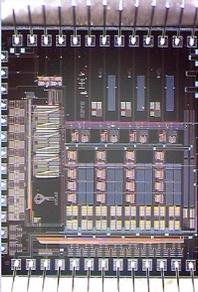


MEAN: 110
 SIGMA: 12.46
 11.33%

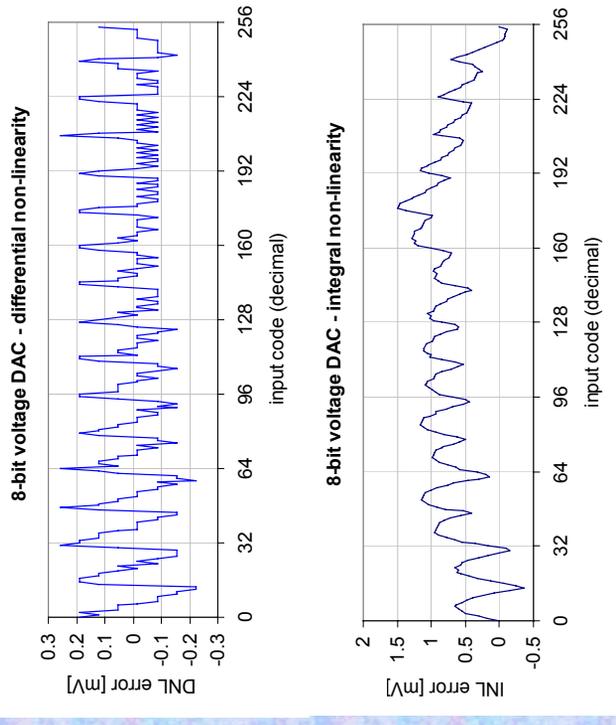
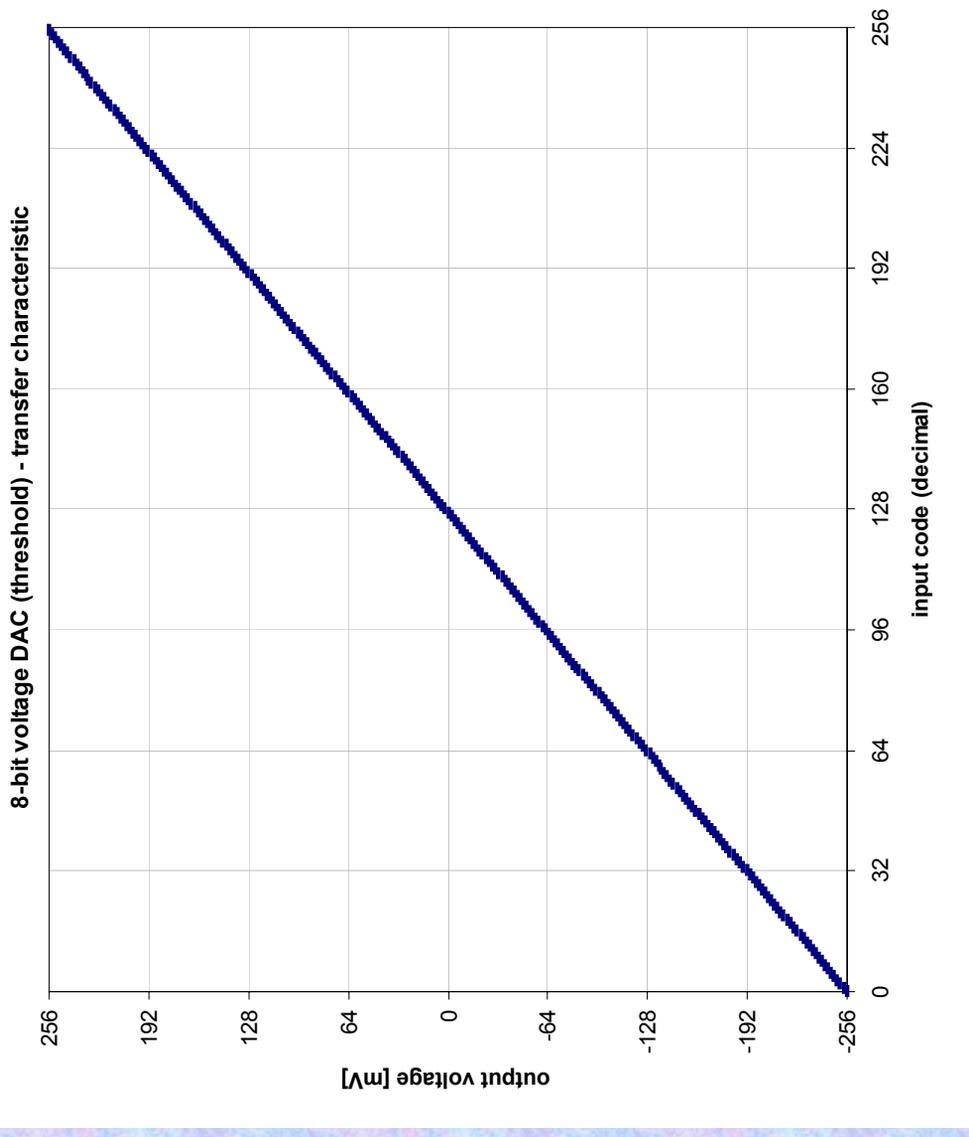
Deadtime window - 48 channels
same settings and input signal



MEAN: 701
 SIGMA: 40.6
 5.79%



MDT-ASD PRR Main Threshold DAC



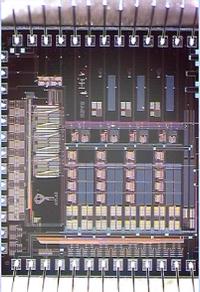
8-bit VDAC

Range: 512 mV

LSB: 2 mV

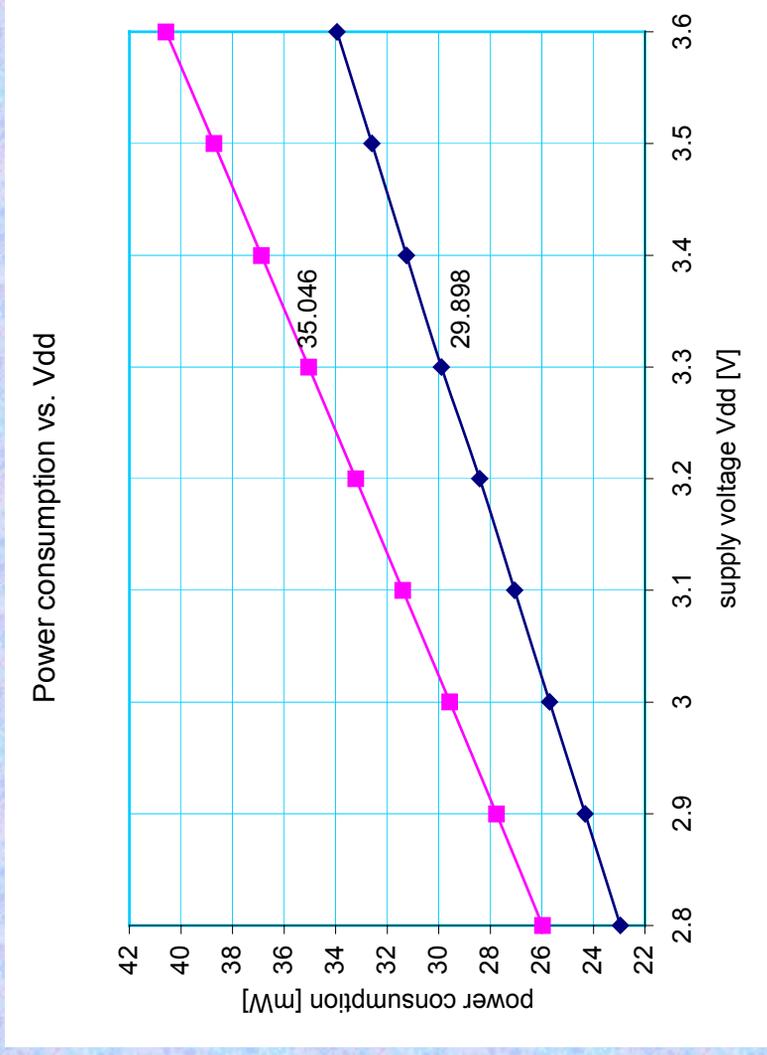
MAX diff. Nonlin.: $\pm 250 \mu\text{V}$

MAX int. Nonlin.: 1.5 mV

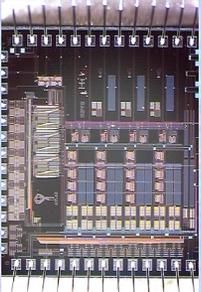


MDT-ASD PRR

Power Consumption



Power consumption with loaded and unloaded LVDS drivers



MDT-ASD PRR

Noise behaviour and non-systematic errors



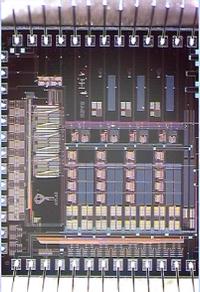
Time Measurement

- The timing information carried by the ASD output signal is recorded and converted by the AMT (Atlas Muon TDC) time-to-digital converter at a resolution of 0.78 ns.

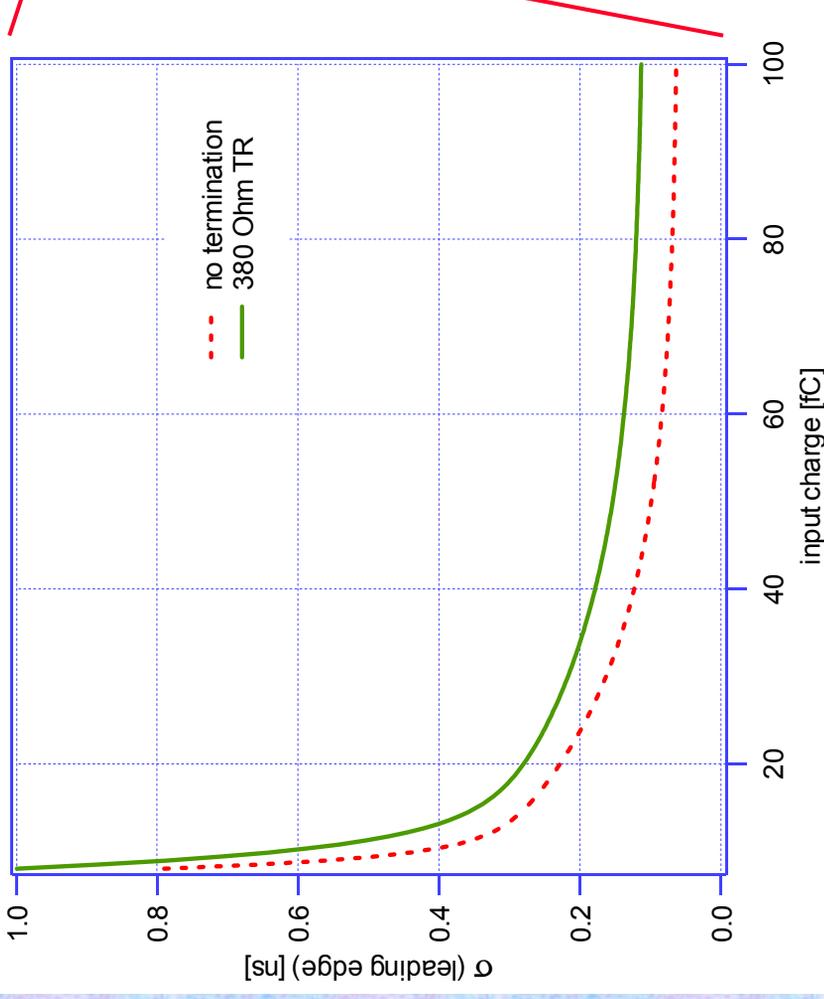
Charge Measurement

- The AMT can be set to provide a dynamic range for the pulse width measurement of 0 - 200 ns with a bin size of 0.78 ns.
- If the ASD is programmed to produce output pulses up to a maximum of 200 ns, then the combination of the ASD and the AMT chip represents a charge-ADC with a resolution of 7 - 8 bits.

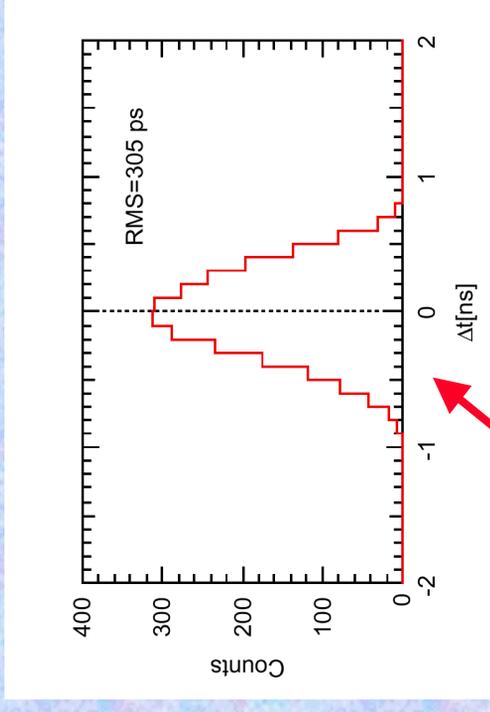
Non-systematic errors in the timing and charge measurement due to electronic noise in the ASDs and AMTs, and quantization errors set a limit to the performance of the system.



MDT-ASD PRR Time measurement

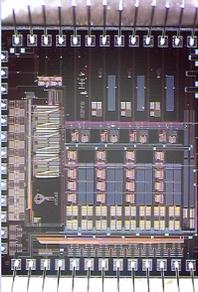


Measured RMS error of the leading edge time measurement at the output of the ASD as a function of threshold overdrive.



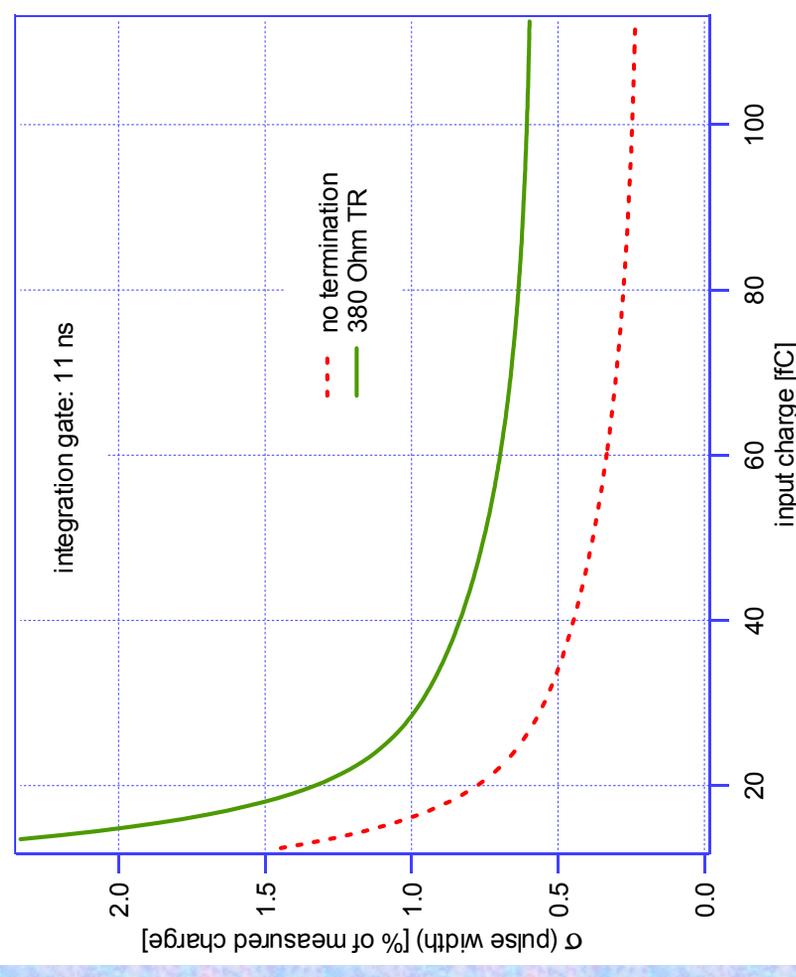
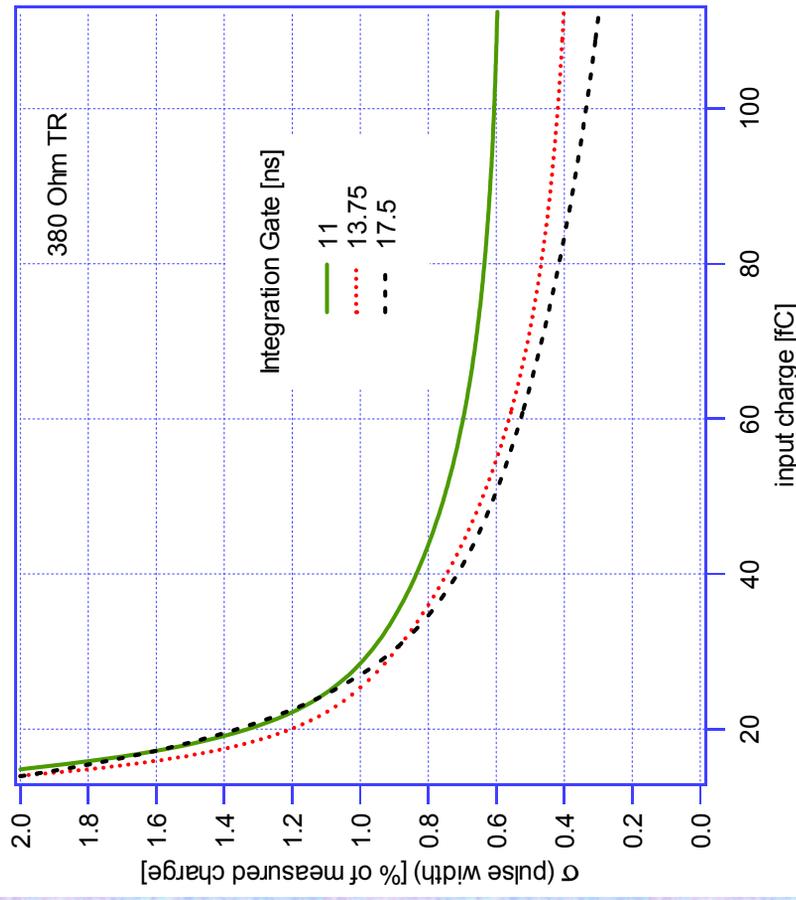
(Y. Arai)

The time-to-digital conversion in the AMT shows a RMS error of 305 ps, including 225 ps of quantization error. The resulting total error of the time measurement, covering all noise sources from the front-end down to the A/D conversion, will typically be of the order of 360 ps RMS.

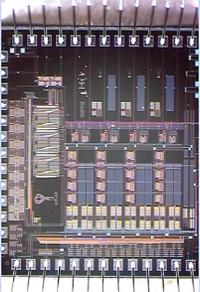


MDT-ASD PRR

Charge measurement



The pulse-width conversion in the AMT has a **RMS error of 430 ps** (including quantization error). The **resulting total error** of the charge measurement, covering all noise sources from the front-end down to the A/D conversion, will typically be **< 800 ps RMS**. This corresponds to a **typical error of well below 1%** of the measured charge for the vast majority of signals



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Measurement Errors - Summary



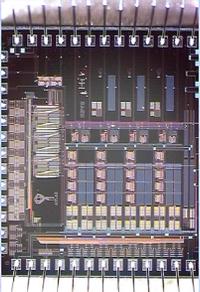
Time Measurement

Total noise in the range of 360 ps RMS (typical)

Charge Measurement

Total noise in the range of $\ll 1\%$ of measured charge

- ◆ All other sources of error in the readout electronics are systematic
e.g. converter non-linearities, channel-channel variations
- ◆ Can in principle be calibrated out to any extent (automatized, using the pulse injection system)



MDT-ASD PRR

Known Issues

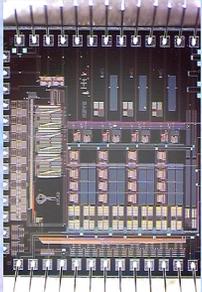


Floating Substrate Guard Ring

One of the guard ring structures composed of substrate contacts was unintentionally left unconnected (floating). No adverse effects have been noticed.

Programmable Deadtime

The artificial deadtime window at its maximum setting has a mean length of ~ 700 ns for a typical input signal. This is of the order of the maximum drift time. This could be an issue if different gas mixture or pressure than nominal is being used.



MDT-ASD PRR

Conclusions



- Final ATLAS MDT front-end prototype fabricated and successfully tested
- Shows complete functionality, meets all design specifications → design ready for production
- ATLAS demand: 46,000 pieces
- Automatic PCI bus production tester in preparation