

CDS tutorial

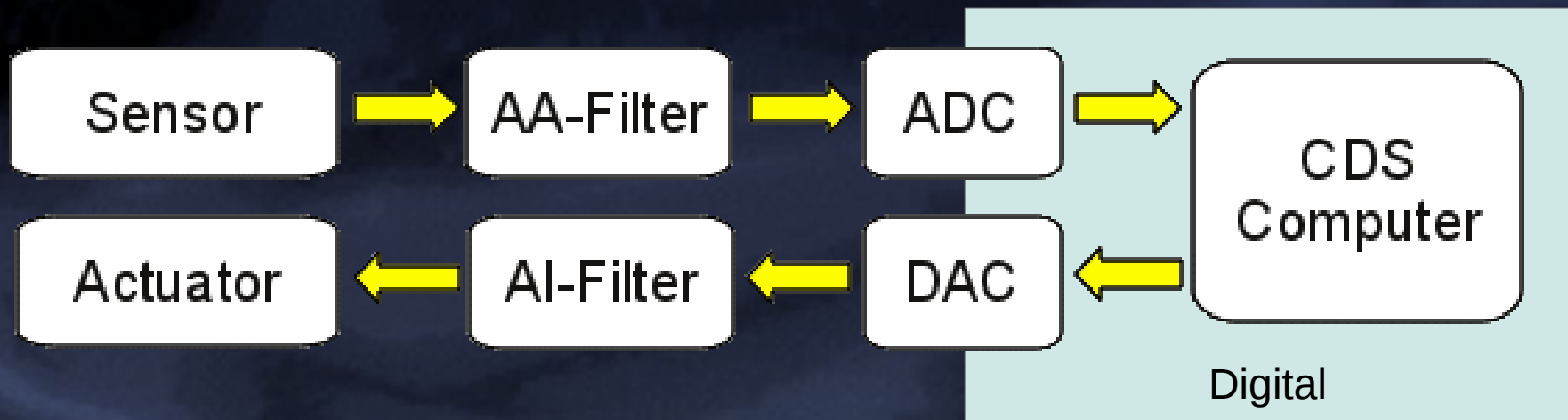
Michael Born
ISC meeting, AEI Hannover
2012/12/06

Overview

- Digital control
- LIGO control and data system (CDS)
 - Basics
 - User interaction
- Digital filters
- CDS tools
- Examples

Digital control

- Analog signal conditioning
 - $f_{\text{Signal}} < f_{\text{Nyquist}} = \frac{1}{2} f_{\text{Sampling}}$
- Control loop with digital filters
 - Bandwidth limitations
 - Signal/noise limitations



CDS control bandwidth

- $f_{\text{Sampling}} = 64 \text{ kHz} (2^{16} \text{ Hz})$
- Signal latency $t = t_{\text{AA}} + t_{\text{ADC}} + t_{\text{CDS}} + t_{\text{DAC}} + t_{\text{AI}}$
 - $t_{\text{AA}} = t_{\text{AI}} = 40 \mu\text{s}$
 - $t_{\text{ADC}} = t_{\text{DAC}} = 10 \mu\text{s}$
 - $t_{\text{CDS}} = 16..24 \mu\text{s}$ (timing system dependent)
- $1 / t = 1 / 120 \mu\text{s} = 8.3 \text{ kHz} = f$
- Control bandwidth $\approx f / 10 \approx 1 \text{ kHz}$

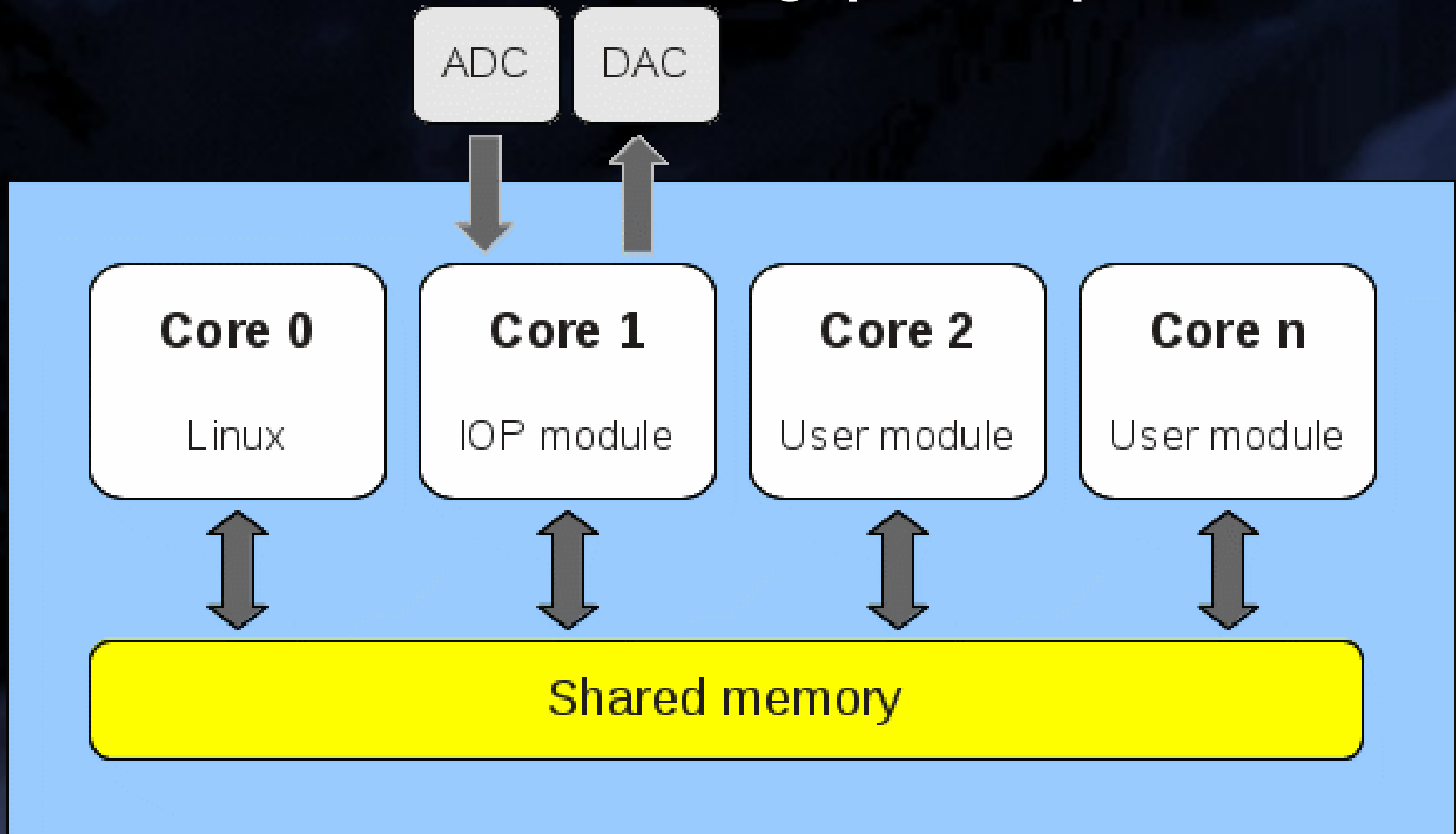


LIGO CDS

- Development @Caltech (Bork, Ivanov)
- Standard PC hardware (multi-core, fast networks)
- Linux operating system
- Commercial 16/18bit ADCs/DACs
- Custom filters (LIGO or AEI design)
- Scalability
- Large user base



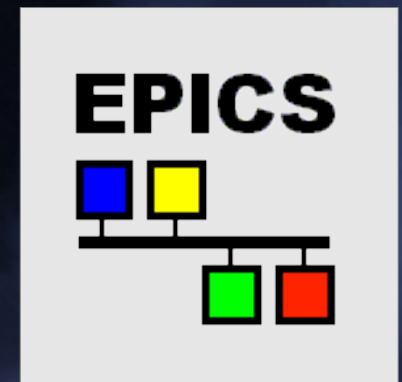
CDS working principle



- Control loops in user modules
- Modules individually (un)loadable

User modules

- Run @2, 4, 16, 32 or 64kHz
- Communication between modules



- Remotely controllable via EPICS channels
- Experimental Physics and Industrial Control System
- EPICS channels over network @16Hz
- MEDM graphical user interface (customizable)

MEDM screens

PMI-Control2.adl (edited) <@pt-ws1>

Phasemeter Settings

- BIN: 25,000
- NFFT: 1304,000
- Data Rate [Hz]: 613,497
- Heterodyne Freq.[Hz]: 15337,423

PMI Network Driver


- Status: 1,000
- Errors: 2,000
- Driver Version: 1,000
- Packet Latency [μ s]:
 - Mean 1000: 47796,000
 - Min: 12,000
 - Max: 0,000

Errors per Channel

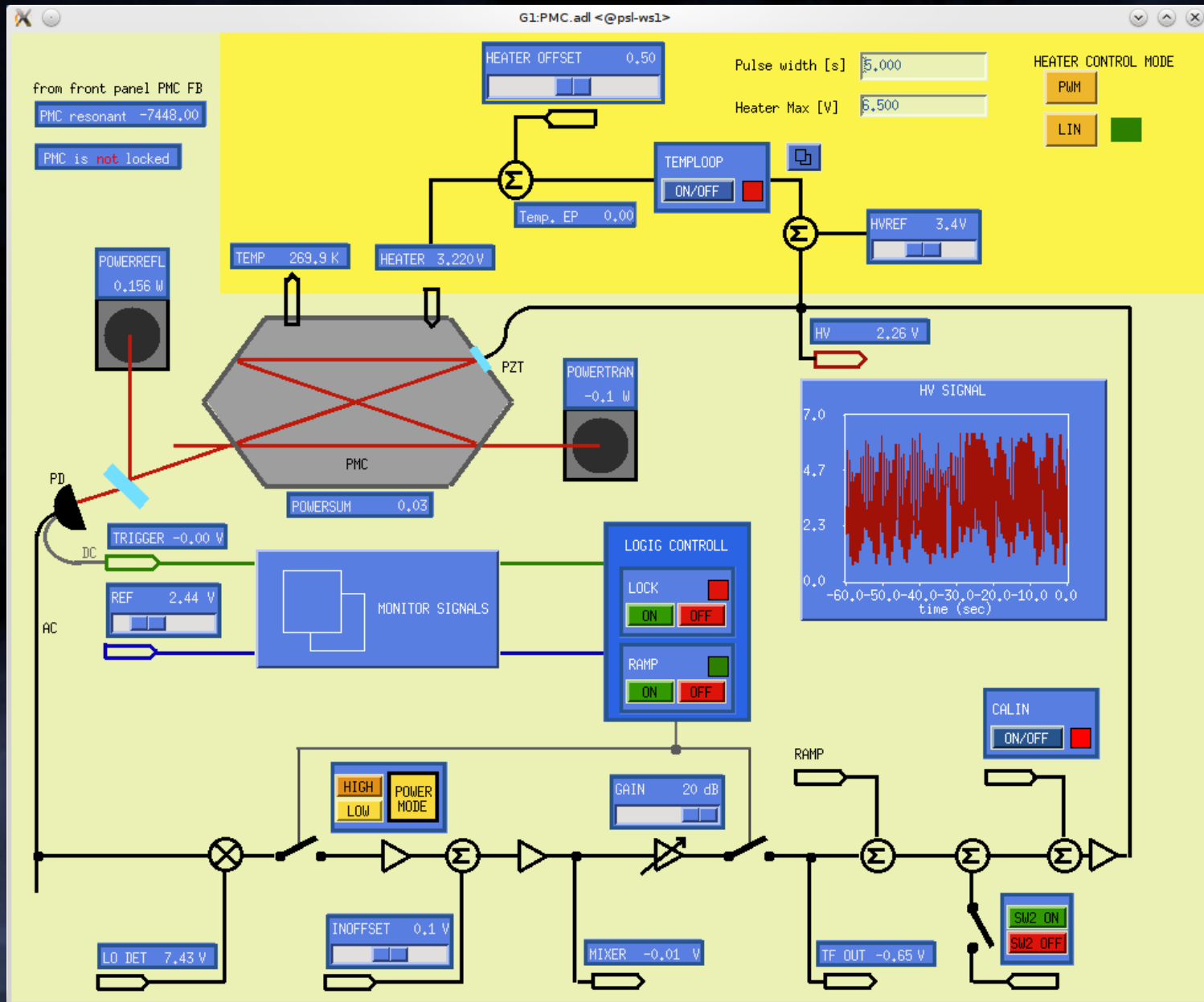
Channel	Errors
00	0,000
01	0,000
02	0,000
03	0,000
04	802661,000
05	0,000
06	0,000
07	0,000
08	0,000
09	0,000
10	2,000
11	0,000
12	0,000
13	0,000
14	0,000
15	0,000
16	0,000
17	0,000
18	0,000
19	0,000

CDS Real-Time Driver

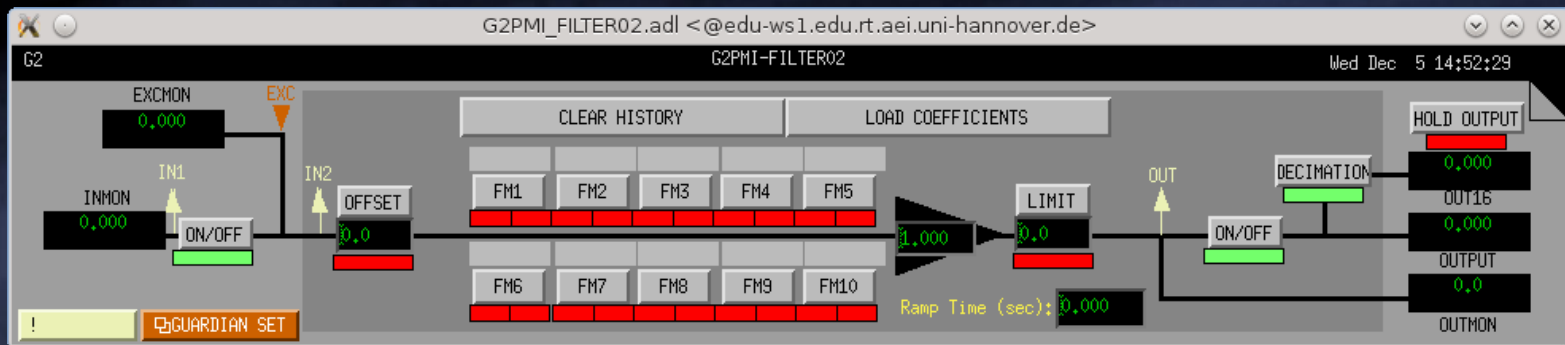
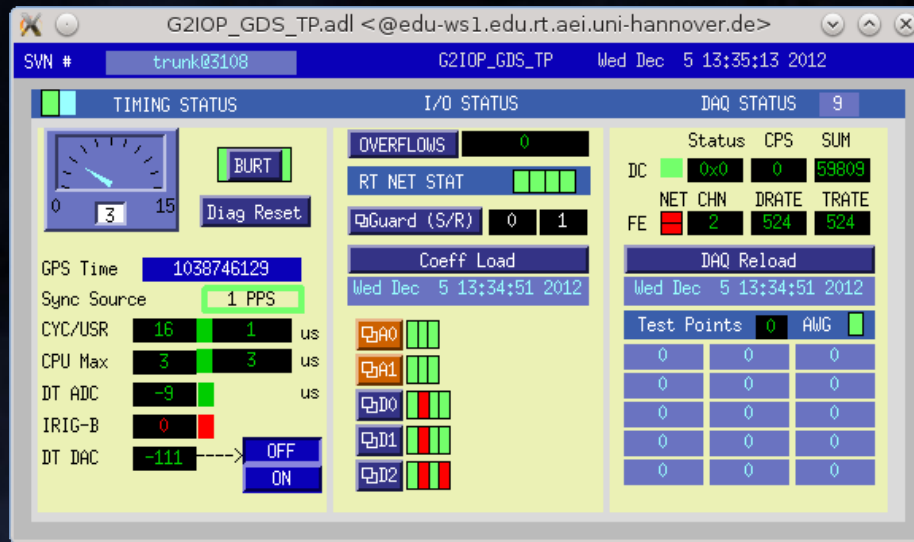
- Data Transfer: ON OFF
- Packets: 4246795,000
- Filter: 0,000
- FB Read Min: 1,000
- FB Read Max: 5,000
- Skipped Packets: 600,000



MEDM screens (2)

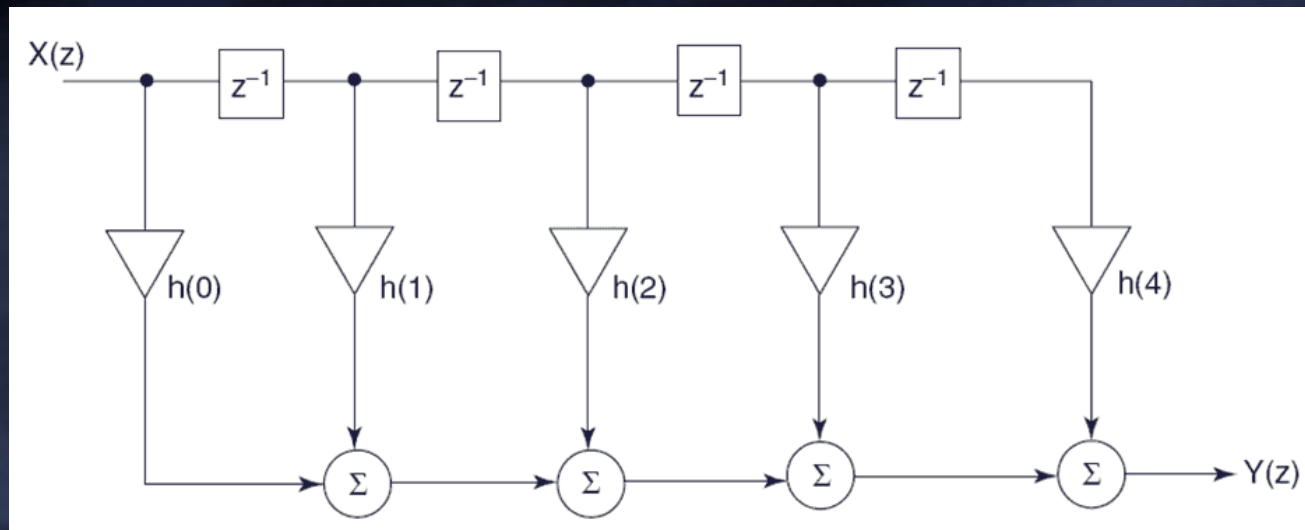


MEDM screens (3)



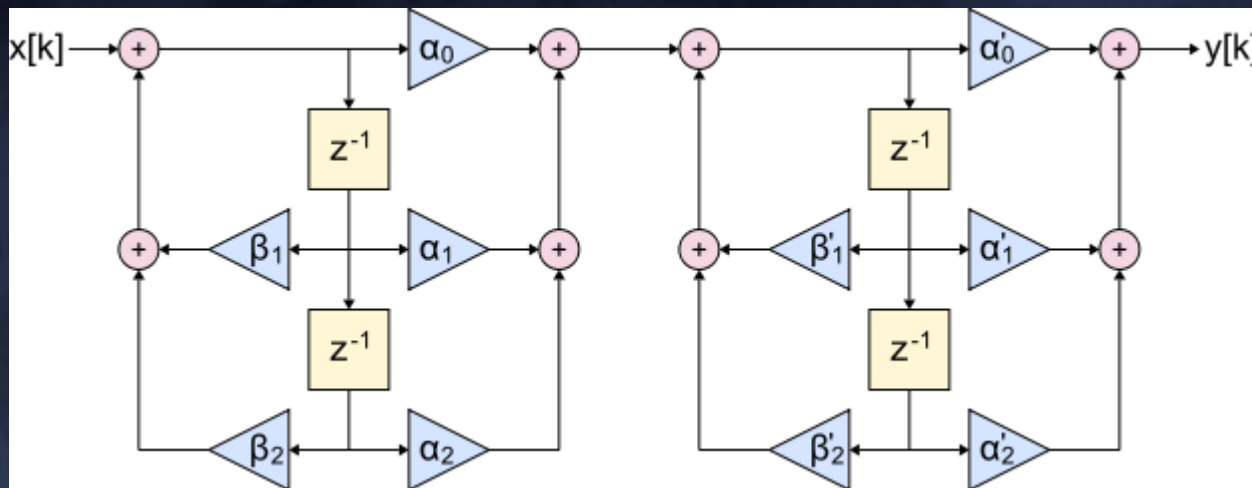
Digital filters: FIR

- CDS: Finite impulse response with ≤ 512 taps
- Computational heavy
- For 2kHz or 4kHz loops
- Coefficients defined in modelName.fir
- Nobody uses it (C-code instead)



Filters: IIR

- Infinite impulse response filter
- CDS implementation: second order sections
- Up to 10 SOS
- Coefficients from z-domain transfer function
- Matlab and tools help

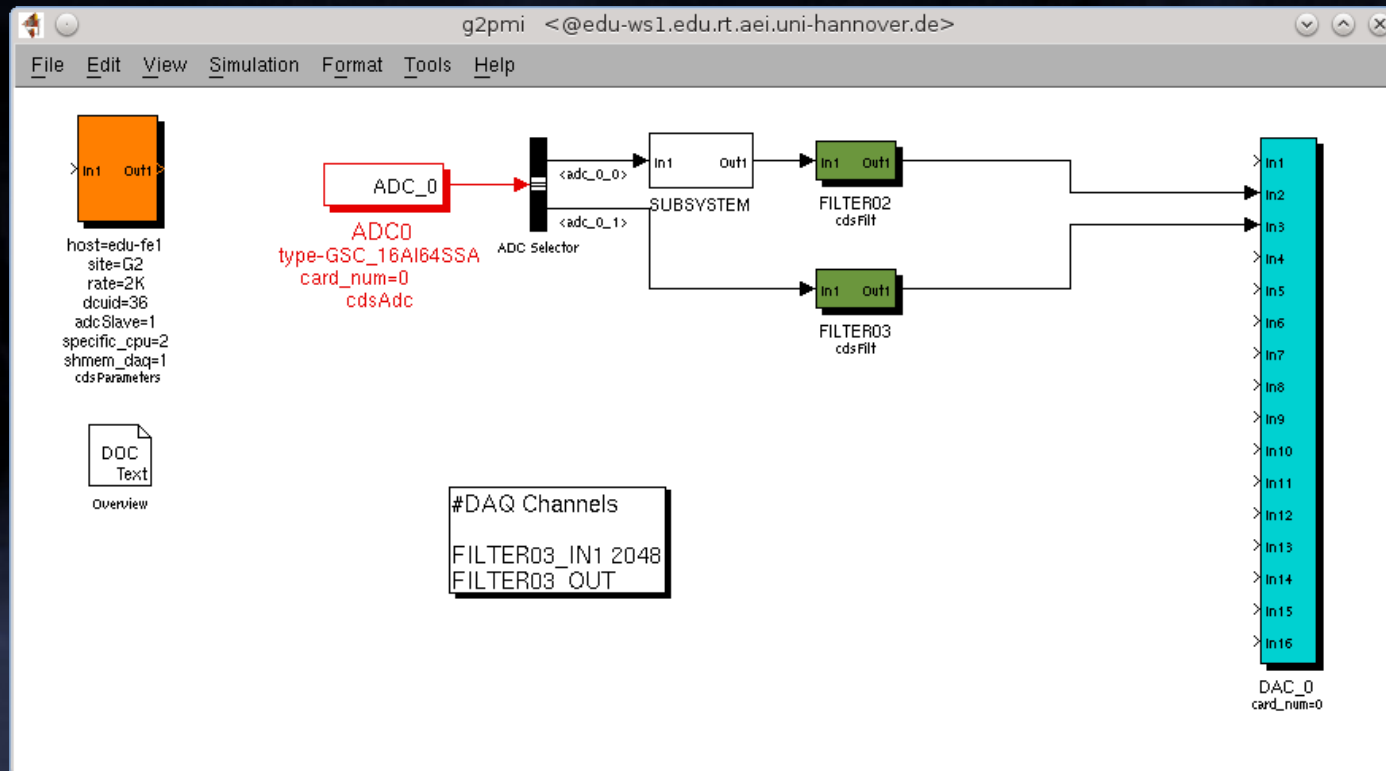


Tools, tools, tools

- Many useful tools – little documentation
- Select channels to record: daqconfig
- Look at time domain data: dataviewer
- Filter development: foton
- Spectrum analyzer: diagnostics test tool (DTT)
– diag / diaggui
- Many tools are part of the global diagnostic system (GDS)
<https://www.lsc-group.phys.uwm.edu/daswg/download/software/source/>
- Many user scripts available

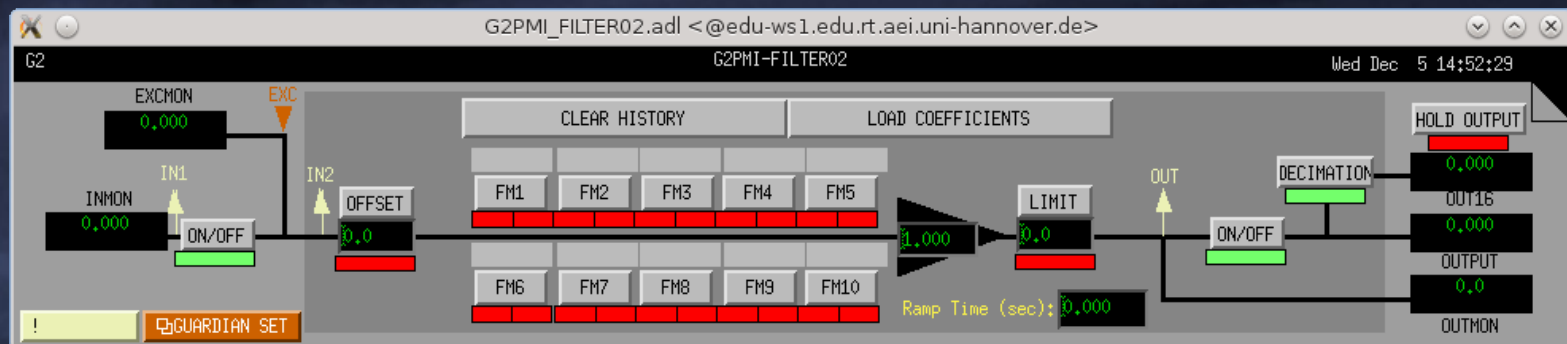
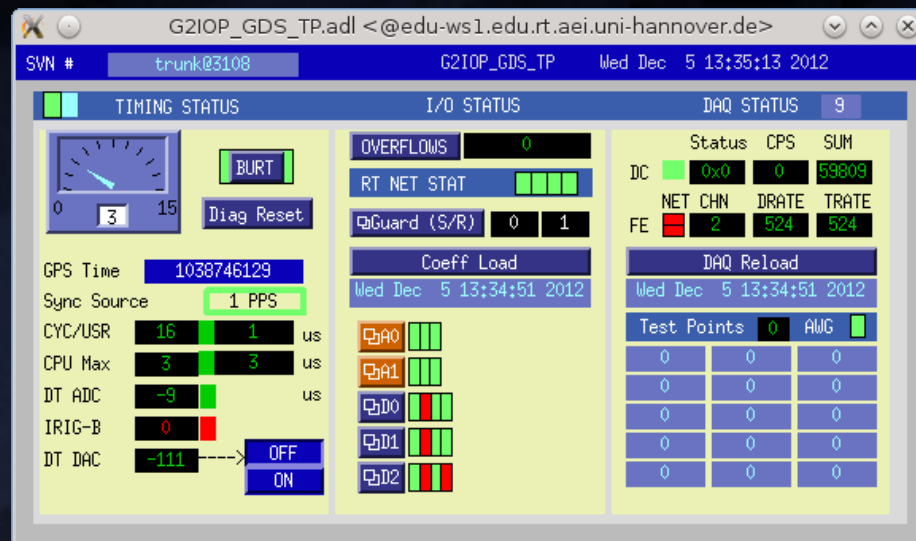
Tutorial (1)

- Matlab: g2pmi.mdl



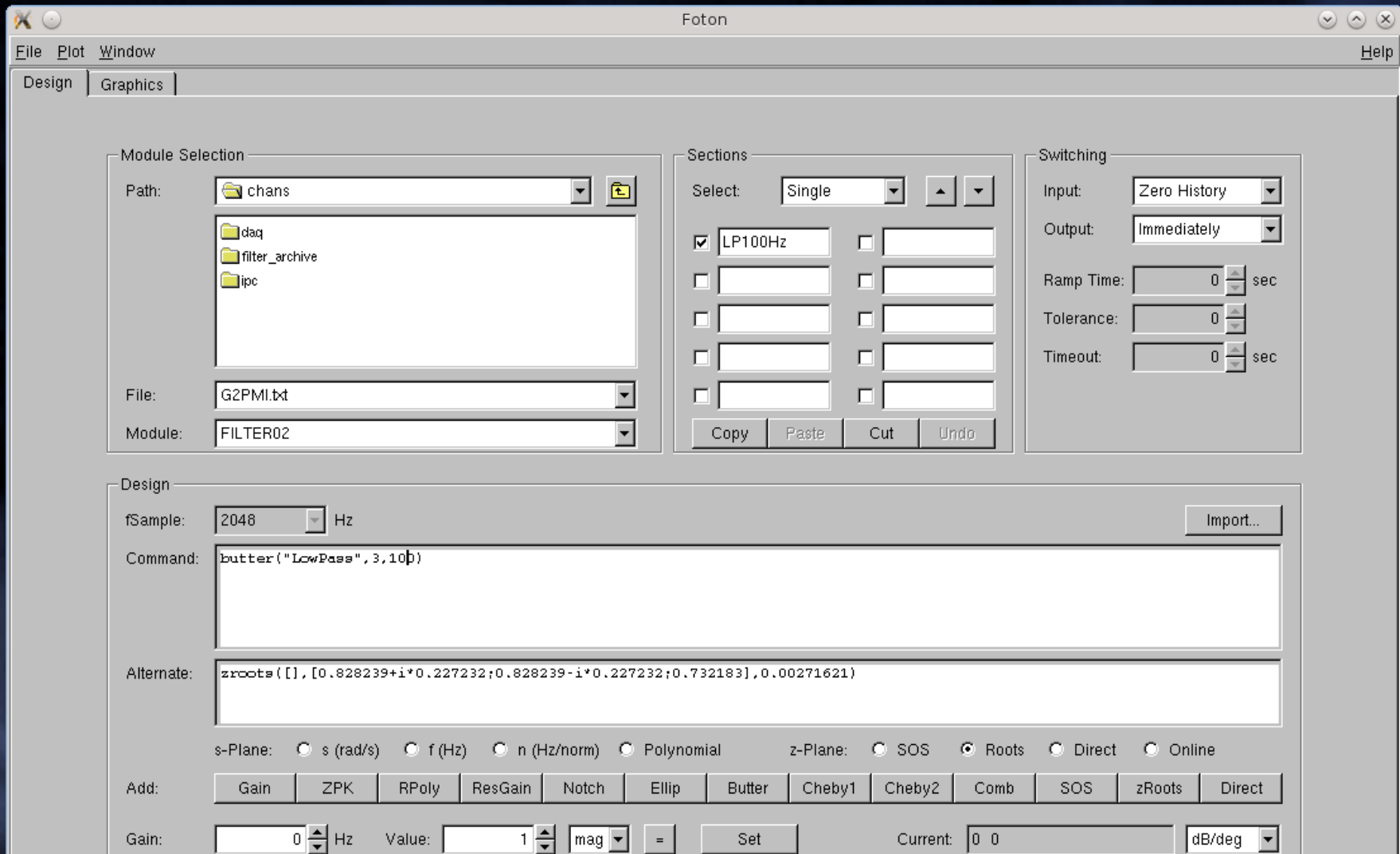
Tutorial (2)

- MEDM: GDS_TP screens
- MEDM: pmi FILTER02, FILTER03



Tutorial (3)

- Filter design with foton



Tutorial (4)

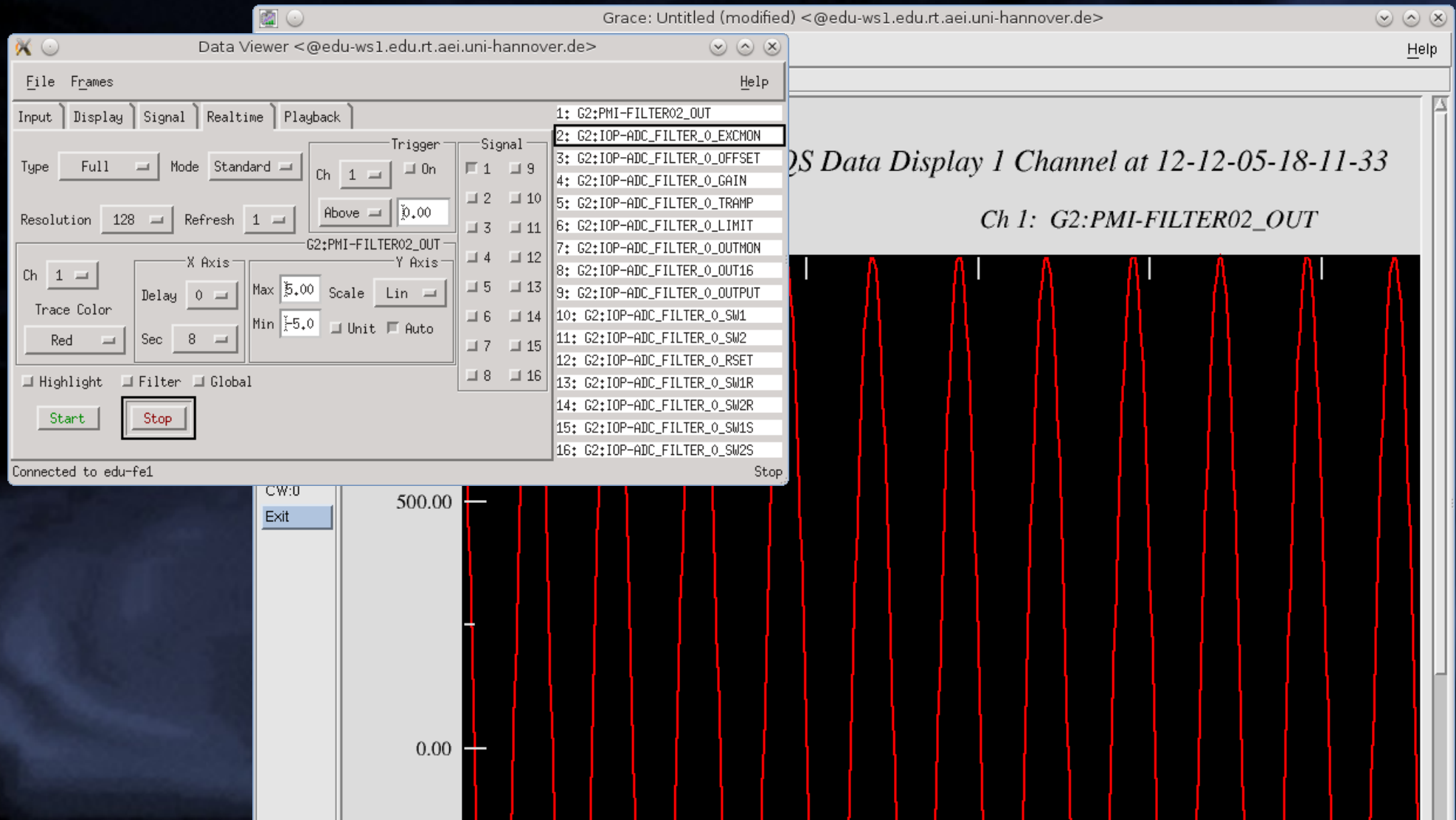
- Measuring transfer functions with diaggui
- Old manual: LIGO T990013-v1

The screenshot shows the 'Diagnostics test tools' application window. The interface is organized into several sections:

- Measurement:** Radio buttons for 'Fourier Tools', 'Swept Sine Response' (selected), 'Sine Response', and 'Triggered Time Response'.
- Measurement Channels:** Radio buttons for channel groups: 'Channels 0 to 14' (selected), 'Channels 15 to 29', 'Channels 30 to 44', 'Channels 45 to 59', 'Channels 60 to 74', and 'Channels 75 to 89'. Below are 15 rows of channel selection, each with a checkbox and a dropdown menu. Channel 0 is checked and set to 'G2:PMI-FILTER02_OUT'.
- Swept Sine Response:** Parameters for the sweep: Start (1 Hz), Stop (900 Hz), Points (61), Settling Time (10.0 %). Measurement Time (10 cycles), Averages (10), Harmonic Order (1). Window (Hanning), Power Spectrum (unchecked), Number of A channels (0). Sweep Direction (Down), Sweep Type (Logarithmic), Format (Freq./Ampl.).
- Start Time:** Radio buttons for 'Now' (selected), 'In the future', and 'In the past'. 'Now' is selected. GPS time (1038765564 sec, 0 nsec) and Date/time (5/12/2012, 17:59:09 UTC) are also shown. Buttons for 'Time now' and 'Lookup...' are present. A 'Slow down' parameter is set to 0 sec/avg.

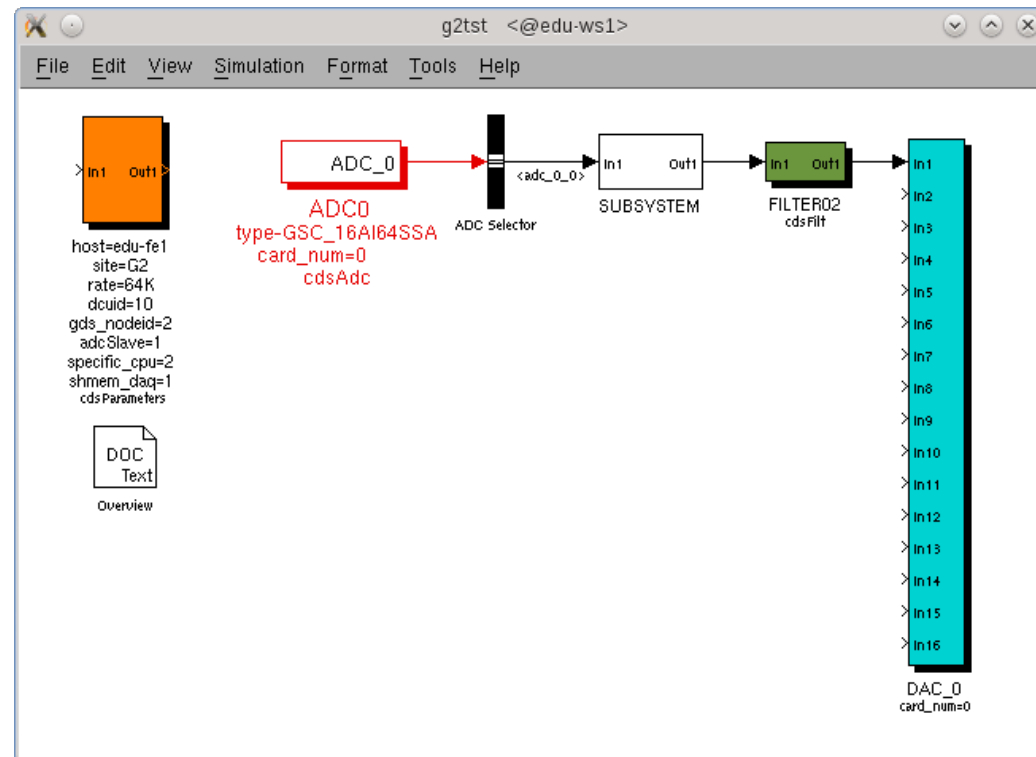
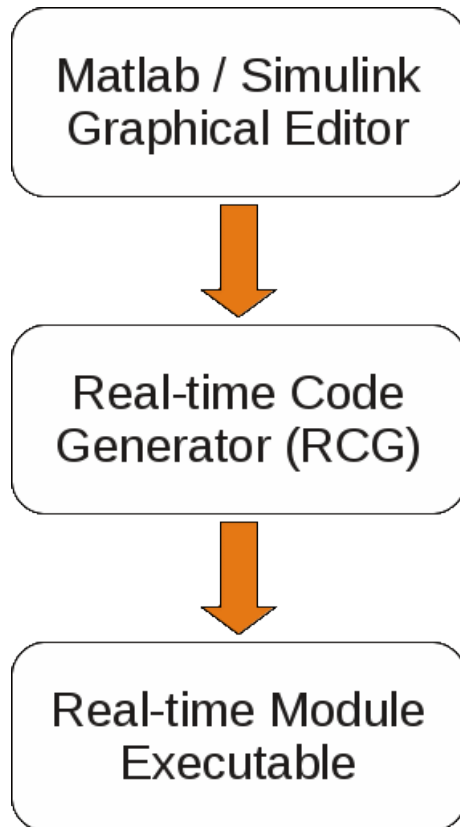
Tutorial (5)

- Viewing live data with dataviewer



Thank you

CDS: from model to module



- Simulink is used just as a graphical editor
- RCG: mdl file → C code → Kernel module

The CDS_PARTS library

- CdsParameters specific to the CDS



```

host=edu-fe1
site=G2
rate=64K
dcuid=10
gds_nodeid=2
adcSlave=1
specific_cpu=2
shmem_daq=1
CdsParameters
    
```

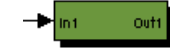
- ADC/DAC channels for analog input/output



```

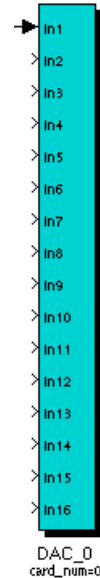
ADC0
type-GSC_16A164SSA
card_num=0
CdsAdc
    
```

- Filter with online changeable transfer functions



```

FILTER01
CdsFilt
    
```



- Logic elements (switch, add, ...)

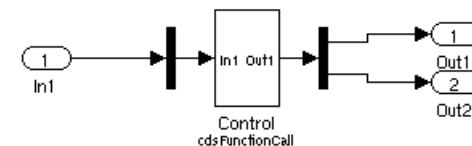
- External control with EPICS GUI



```

TH2
CdsEpicsIn
    
```

- CdsFunctionCall for custom C code



- LIGO-T080135-v4 RCG Application Developer's Guide

Digital vs. analog filters

- Digital: reproducible, no aging, changeable on the fly, system scalable
- Con: limited bandwidth, system complexity
- Cost (10k€+), P[W], your metric