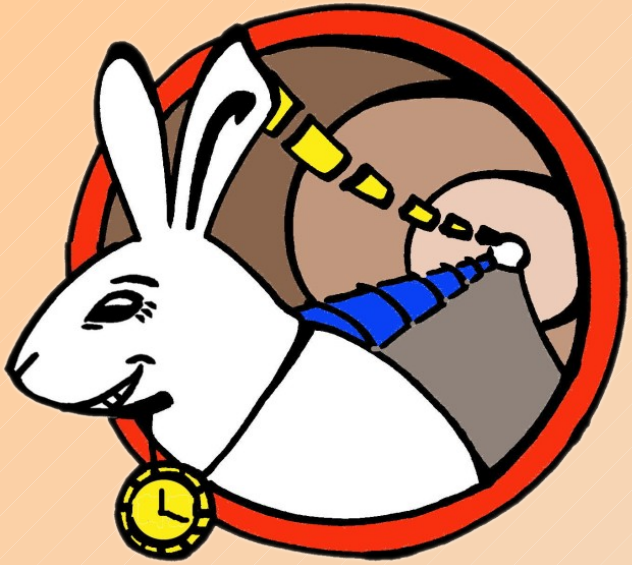


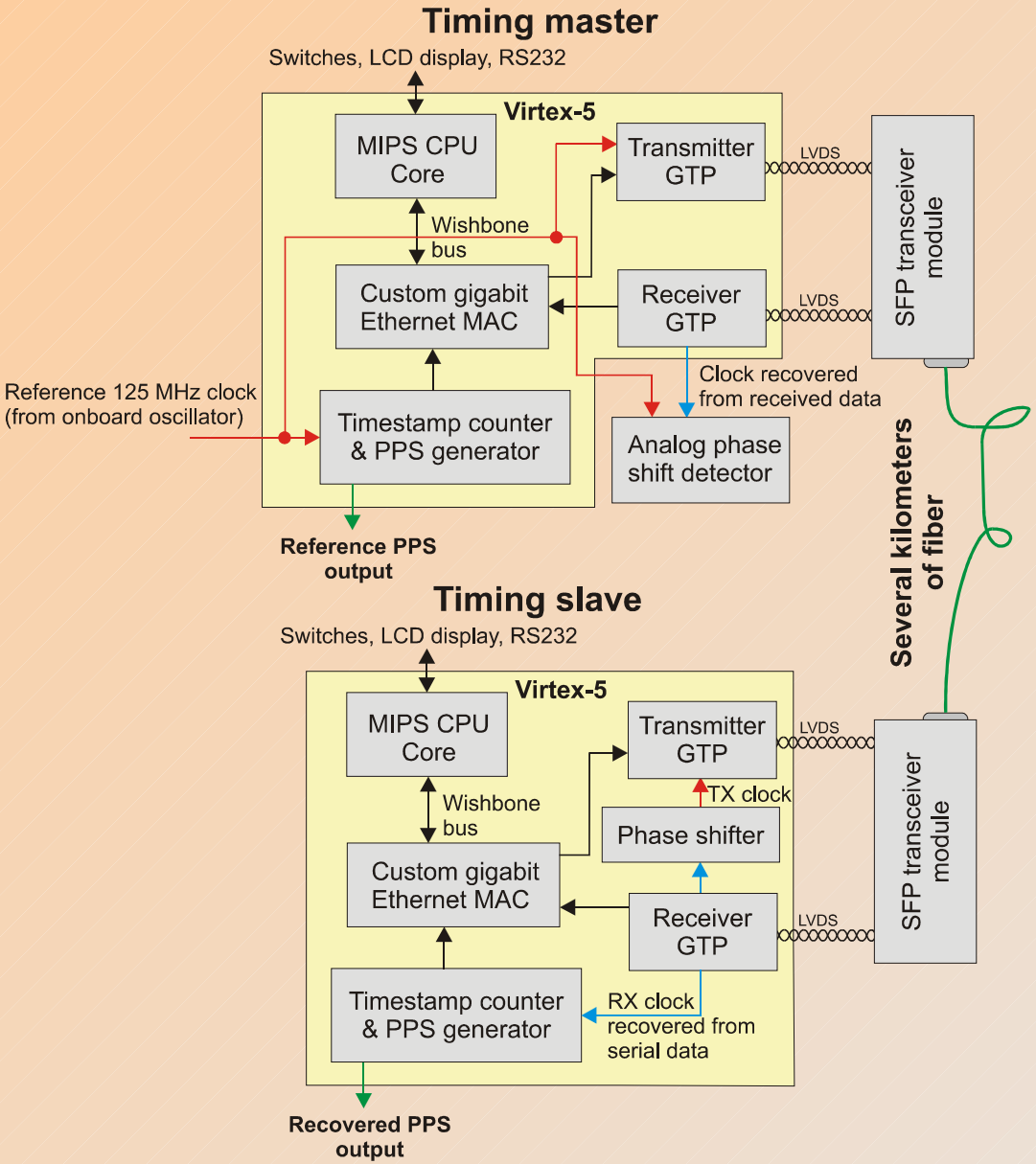
Timing transmission - first tests results

Tomasz Włostowski
CERN AB-Co-HT

Outline:

- **Test system**
- Delay measurement methods
- Results

Test system diagram



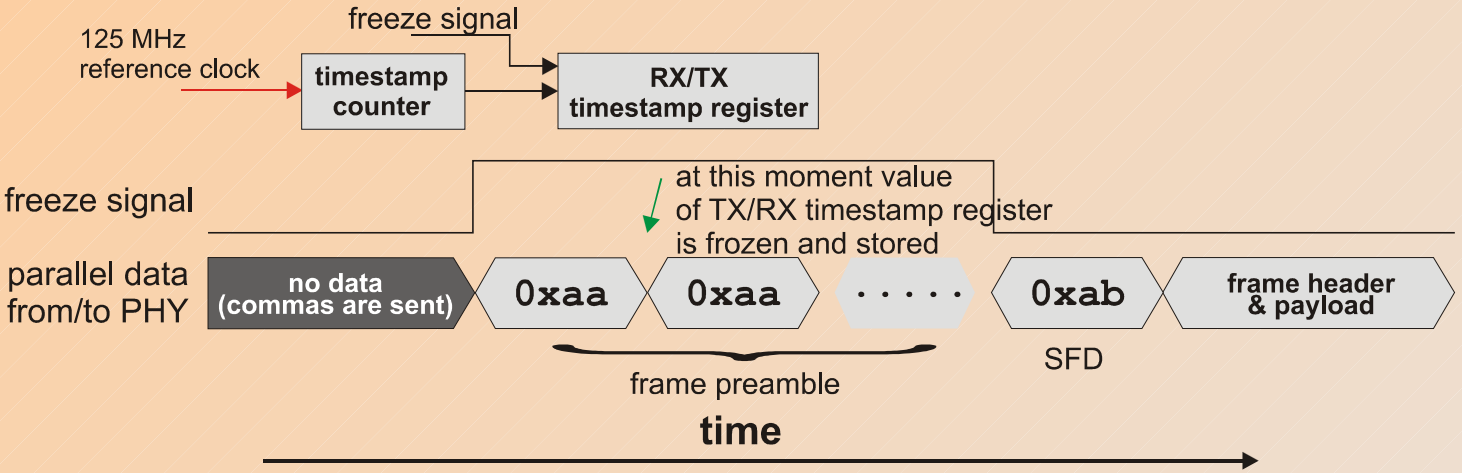
Test system

- Testing point-to-point PPS tranmission with fine (sub-nanosecond) delay compensation
- Based on two Xilinx ML506 kits with Virtex5 FPGA and WDM SFP modules from Optoway
- Additional electronics on small piggy boards
- Test box with several kilometers of optical fiber

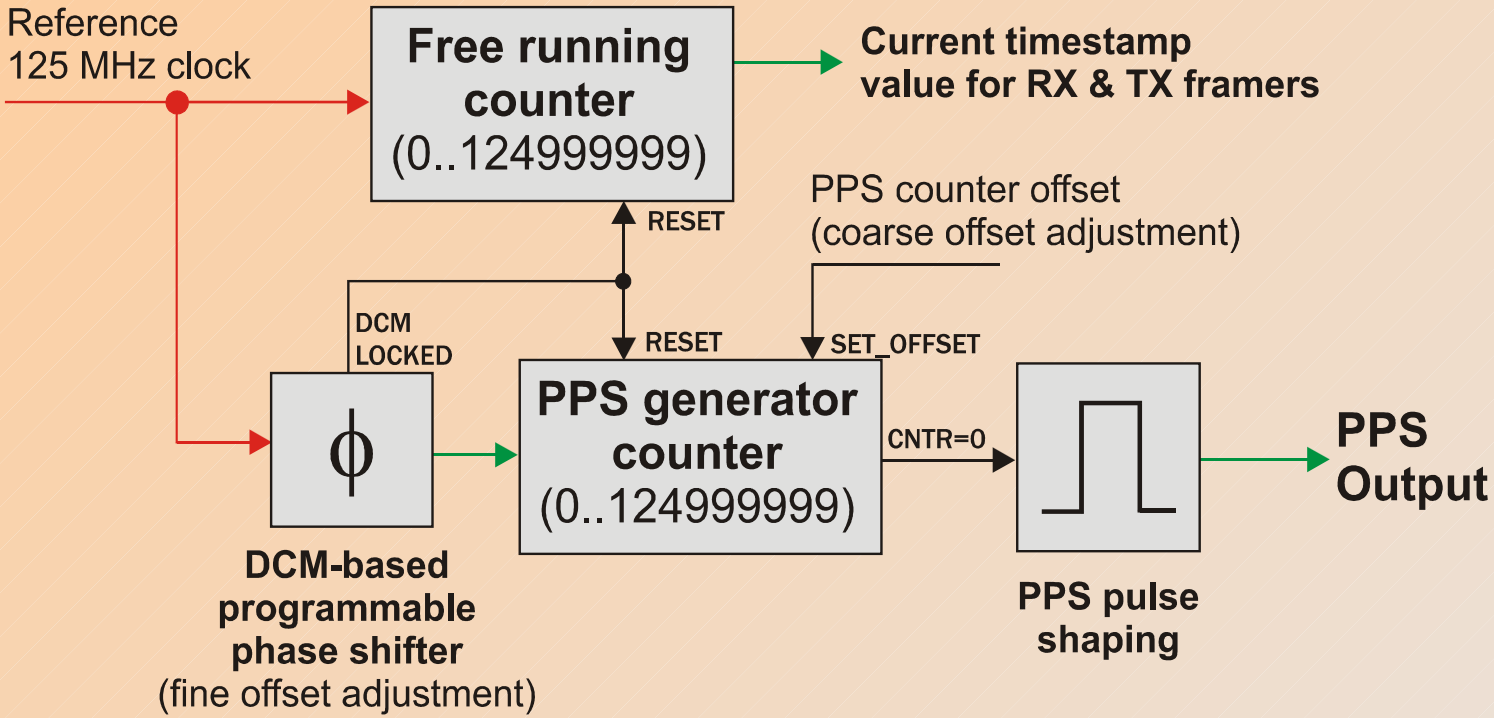
FPGA components

- Custom gigabit Ethernet MAC (not 100% IEEE-compliant) with synchronous mode and timestamping capabilities
- GbE PHY using Virtex GTP transceivers in phase-aligned mode
- Local clock recovery block
- embedded MIPS processor core

MAC timestamping



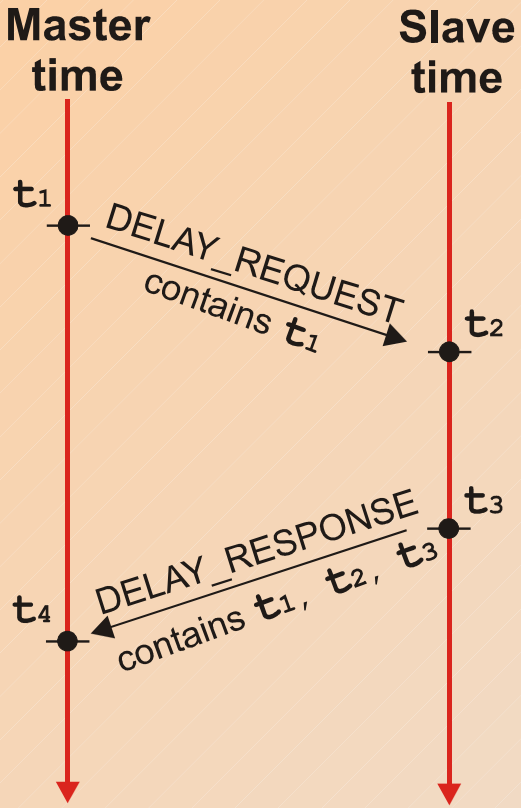
In-phase clock recovery



Outline:

- Test system
- **Delay measurement methods**
- Results

Coarse delay measurement



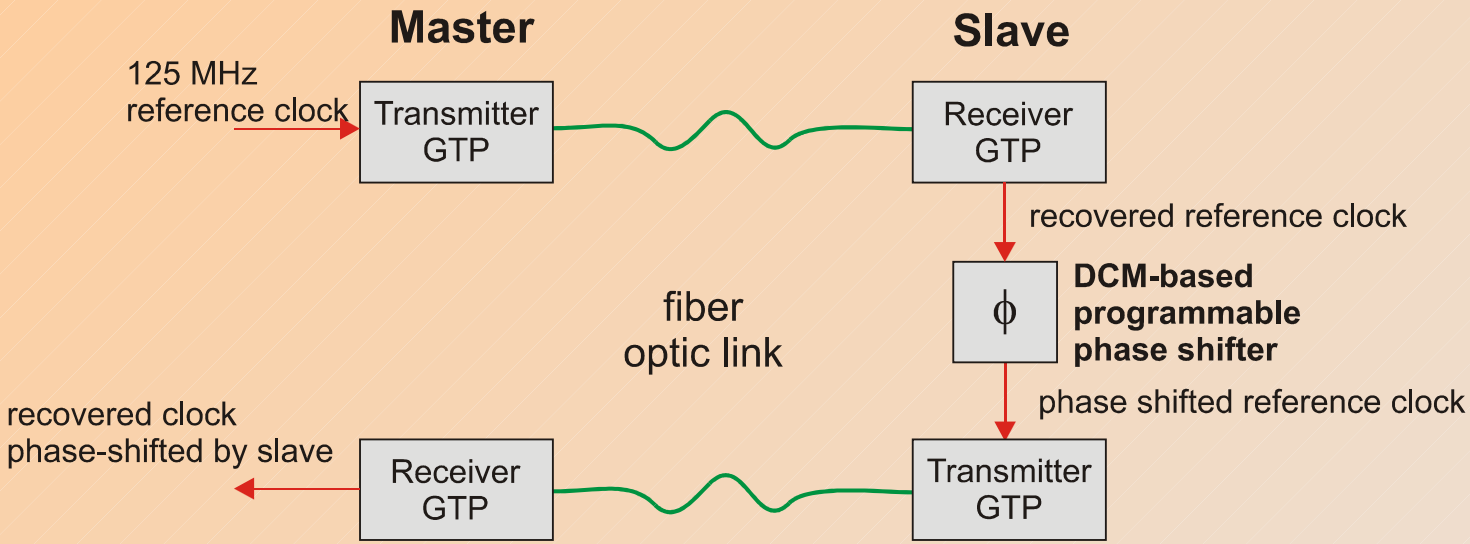
- PTP-like method using hardware timestamps
- Accuracy of single clock cycle (8 ns) taking advantage of synchronous operation

Measuring phase shift

Two methods of phase shift measurement were used:

- Using programmable phase-shifter
- Using analog phase-frequency detector

Measuring phase using DCM

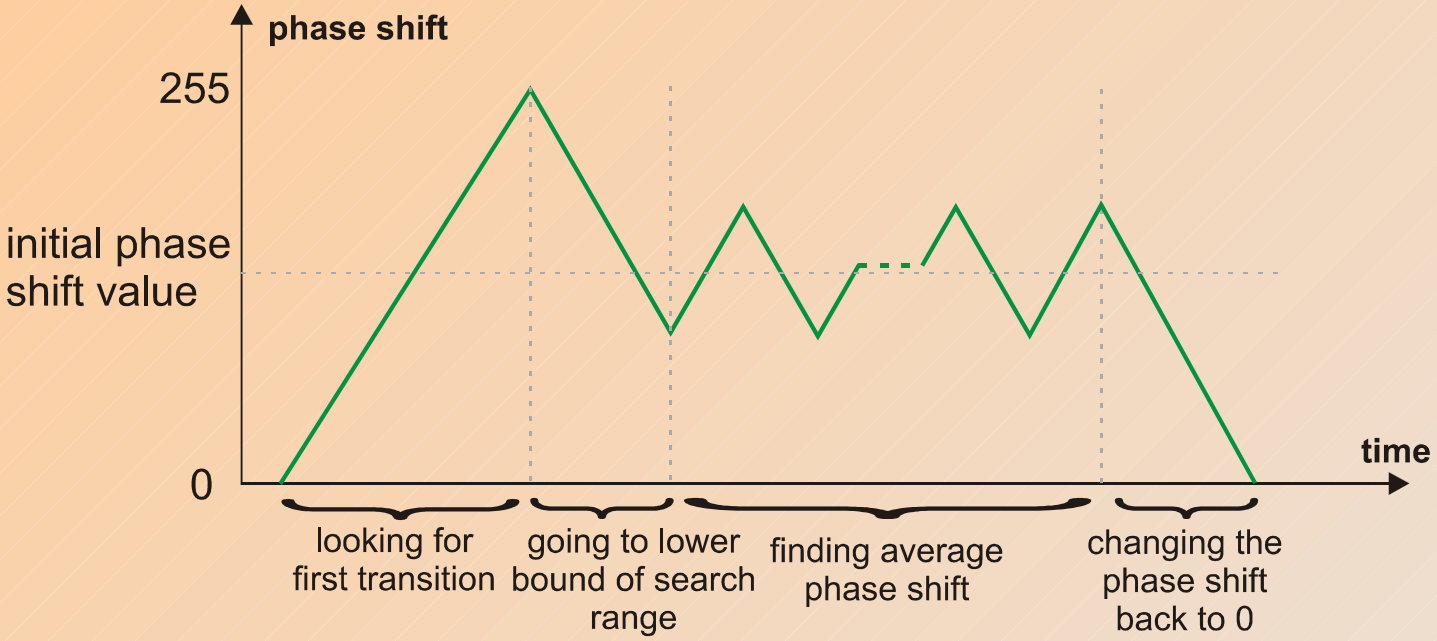


Idea: We are increasing the DCM phase shift ϕ until transition in coarse delay value is observed.

Measuring phase using DCM

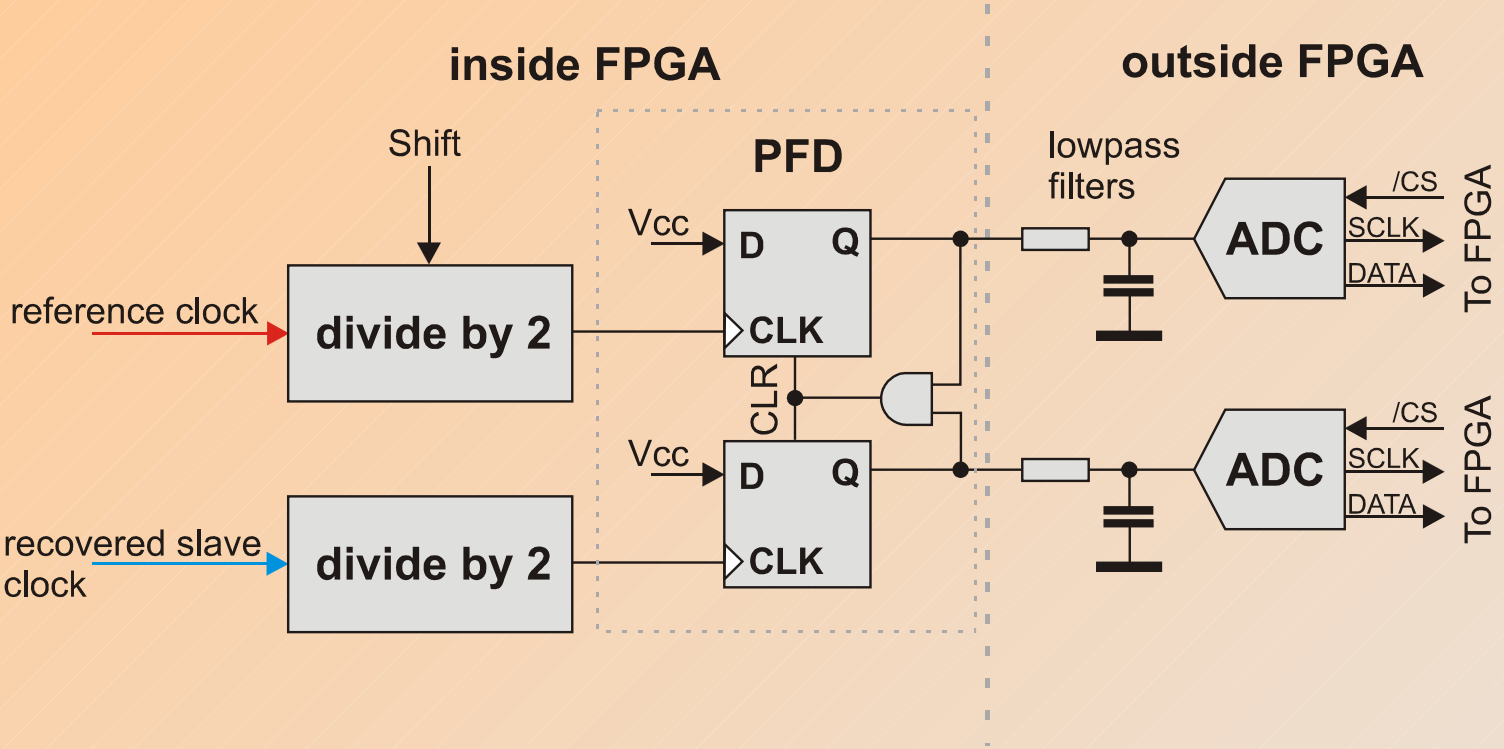
- Very simple method, no need for additional hardware
- Accuracy up to single DCM step (~30 ps)
- Reference method (most linear)
- We need to perform many of coarse delay measurements if we want high accuracy → high network throughput
- Slow due to strange GTP behaviour (GTP CDR can de-lock itself if we change phase too often)
- There are special cases where phase shift is close to 0 or 2π, which require additional calculations

Measuring phase using DCM



- Initially, a full-range scan is performed to determine rough value of phase shift
- Then the neighbourhood of initial value is scanned and results are averaged to find accurate phase shift

Measuring phase using PFD

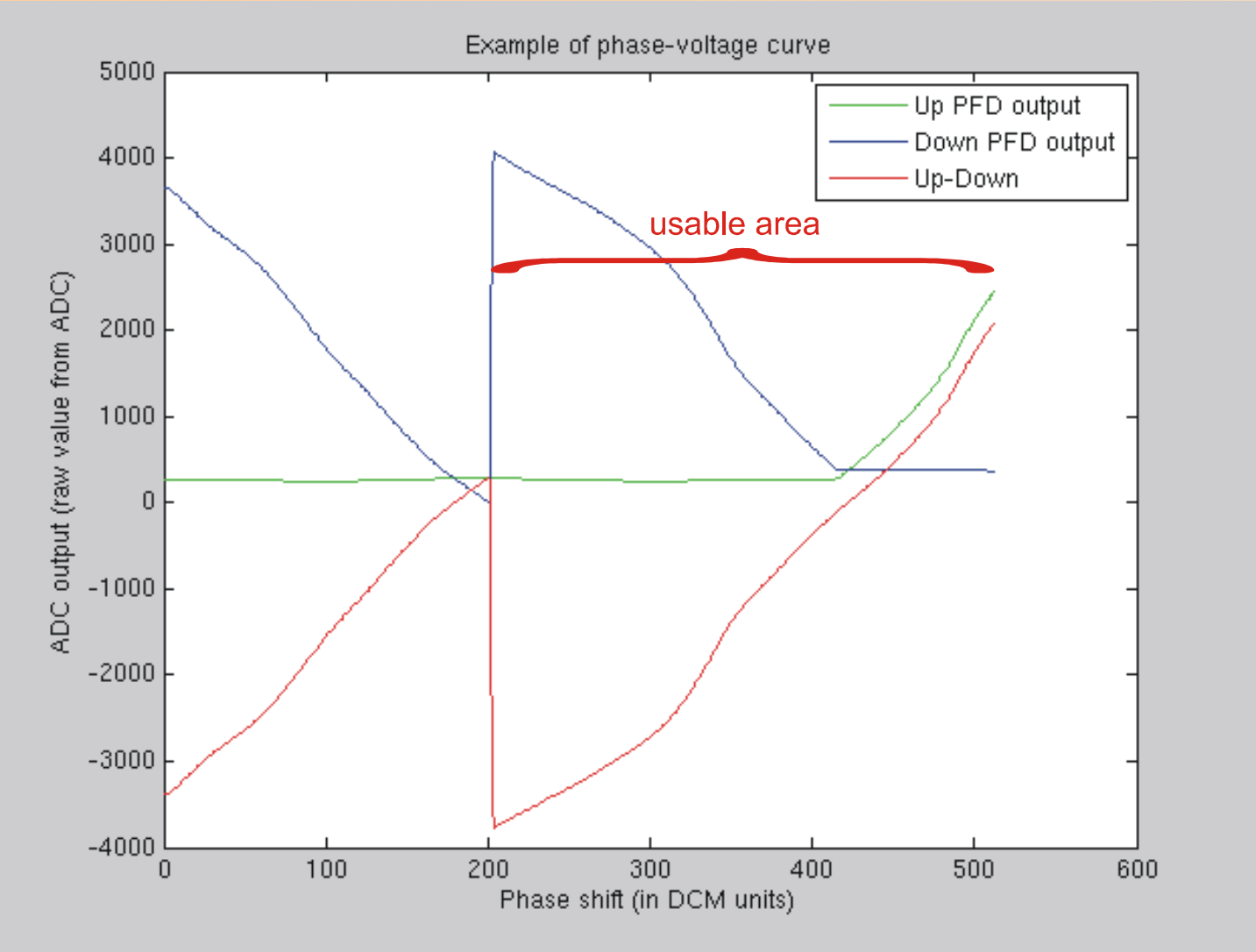


- Classic phase-frequency detector with extended range
- Hybrid analog/digital design
- ADCs on small piggy-board outside FPGA

Measuring phase using PFD

- Direct measurement of phase shift between clocks
- Very fast, only a few ADC reads per measurement
- No additional network throughput
- A bit less accurate than DCM-based method (~80 ps observed in test link)
- PFD is slightly nonlinear – autocalibration procedure is performed periodically using DCM-based method
- Some tricks are also required to obtain full 2π linear range

PFD transfer function



Comparison of both methods

Field of comparison	DCM-based method	PFD-based method
Hardware	No additional parts required, purely digital method	Requires external analog stuff (ADC and filters)
Measurement time	Very long (0.3 sec)	Depends on filter used in phase detector and amount of low frequency phase noise in measured signals. Supposedly can be very short (dozens of micro- seconds)
Calibration	Not required	Required (can be done automatically upon device startup)
Software	Complicated	Simple measurement, compli-cated calibration
Network traffic	Very high	Only during calibration

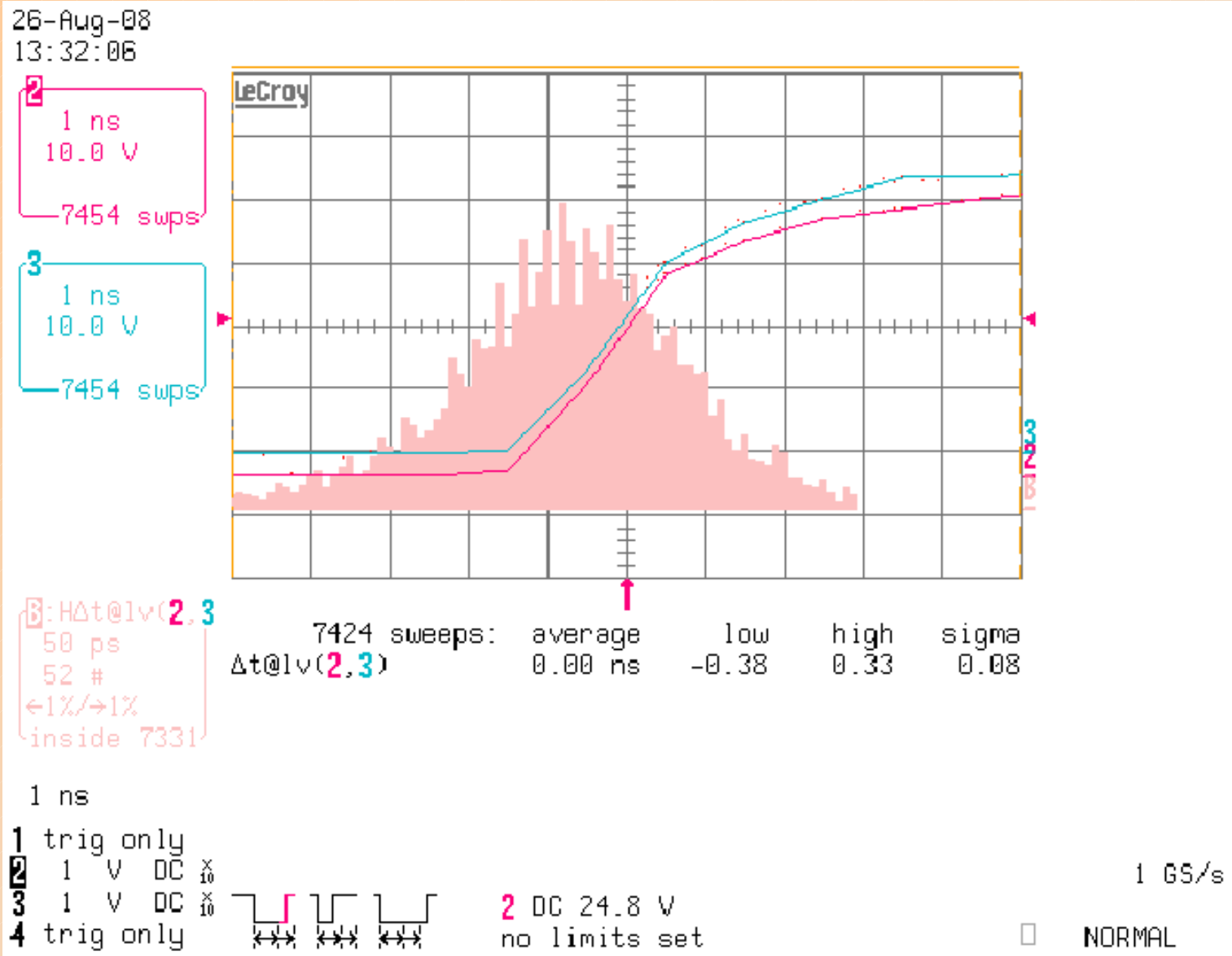
Outline:

- Test system
- Delay measurement methods
- **Results**

Test results

- Tests were conducted for different lengths of fibers, varying from few meters to few kilometers
- Test time – several hours
- Results – PPS's are in-phase with accuracy less than 0.2 ns regardless of fiber length! No manual calibration required!

Phase shift histogram



Questions?