Atomic clock stability detector

Dominik Caban, Patrik Horský

CERN Supervisor Ing. Daniel Valúch PhD.

Project goal

- Design a device capable to monitor stability of 6 reference frequencies (10MHz) from CERN accelerators

- Clocks are ultra stable GPS disciplined, or Cesium atomic oscillators

- Measure the phase and frequency slippage between each of the 6 signals

- Display the values on LCD and make the data available through Ethernet for alarm generation and long term logging

How stable an atomic clock is?

- A very simple principle:

- If I have just one clock, I know all the time what time it is

- When I buy a second clock, I am not so sure anymore…

THIS MAKES THE BRAIN EXPLODE

- But what if I have 6 clocks?

D. Caban, P. Horský: Atomic clock
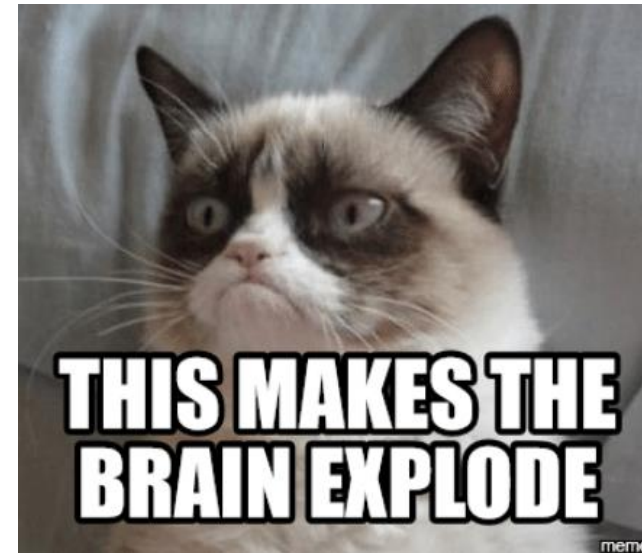stability detector. HSSIP CERN 2019
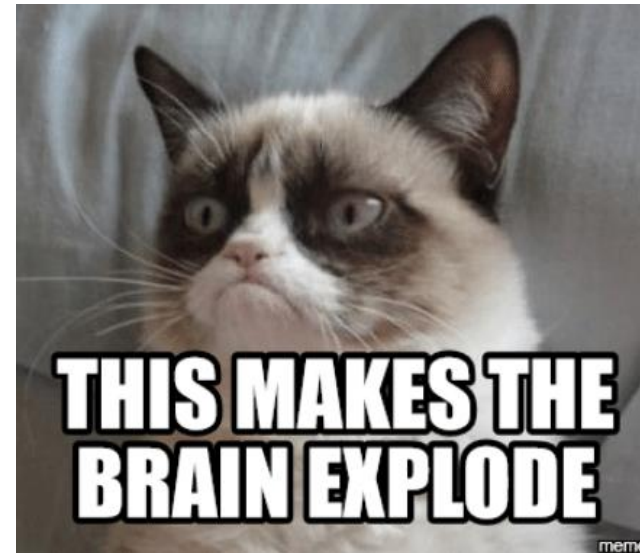
How stable an atomic clock is?

- We cross-compare signals from 6 different clock references.

- If one drifts, or will become unstable, we will see it against the five other

Phase comparison matrix

	2	3	4	5	6
1	$1-2$	$1-3$	$1-4$	$1-5$	$1-6$
2	.	$2-3$	$2-4$	$2-5$	$2-6$
3	.	.	$3-4$	$3-5$	$3-6$
4	.	.	.	$4-5$	$4-6$
5	.	.	.	.	$5-6$

THIS MAKES THE BRAIN EXPLODE
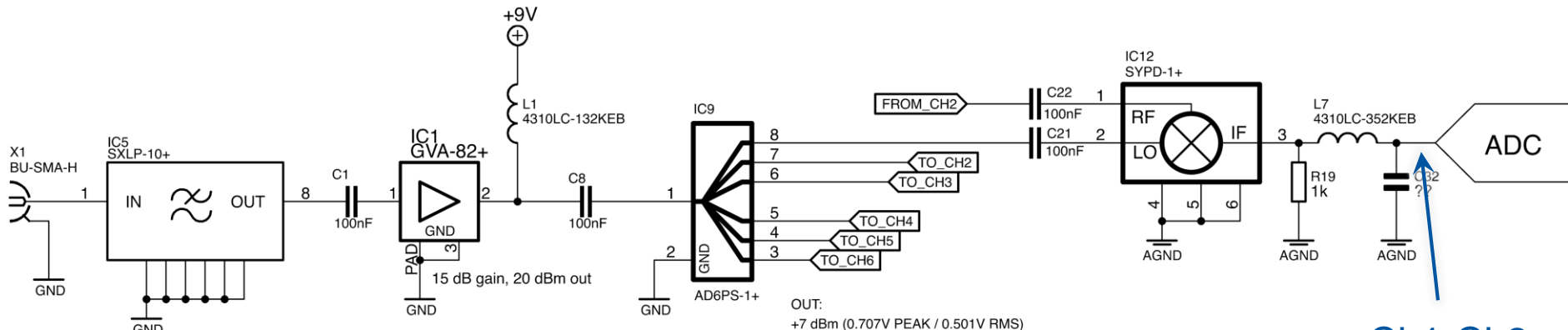
Simplified hardware diagram

Low pass filter   Amplifier   Phase detector
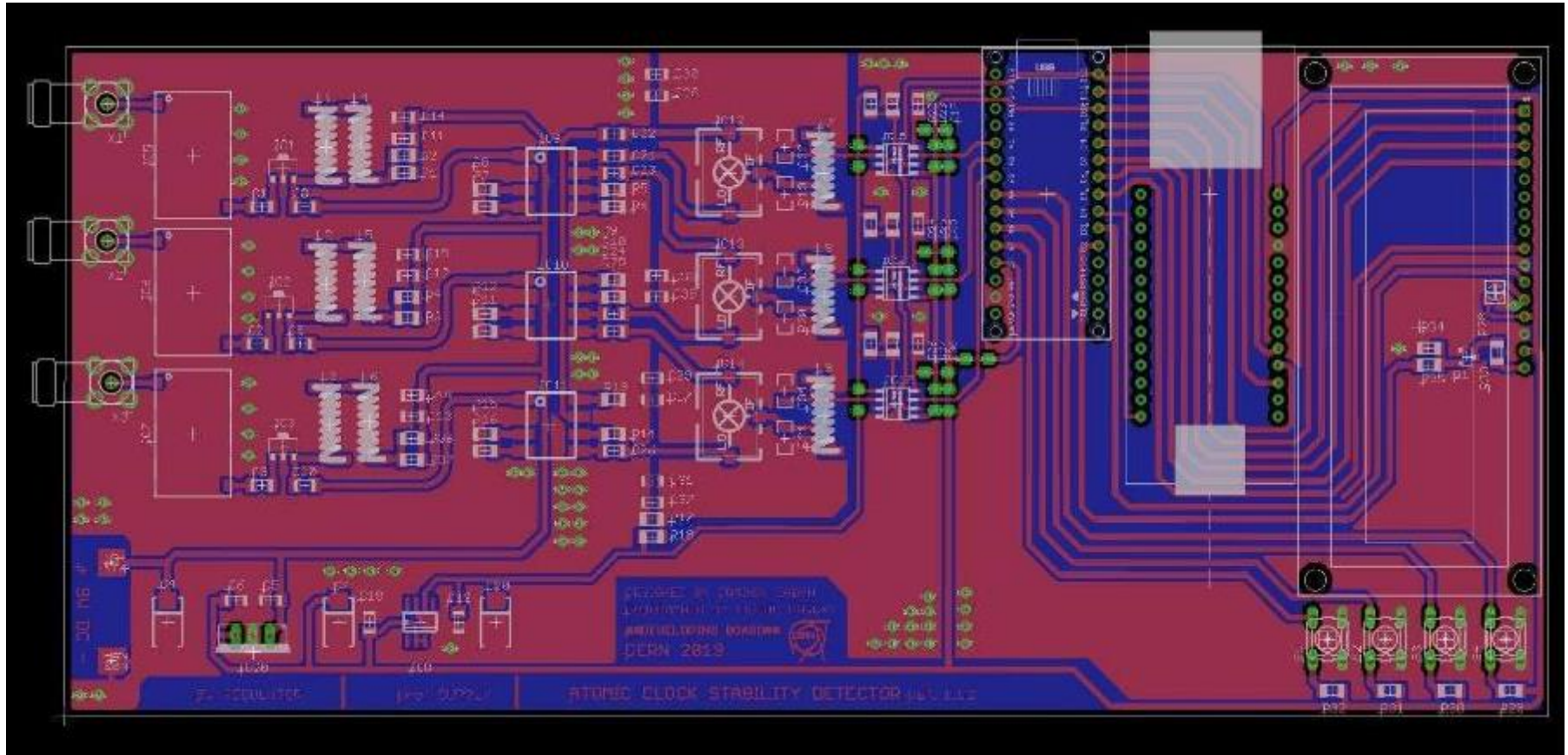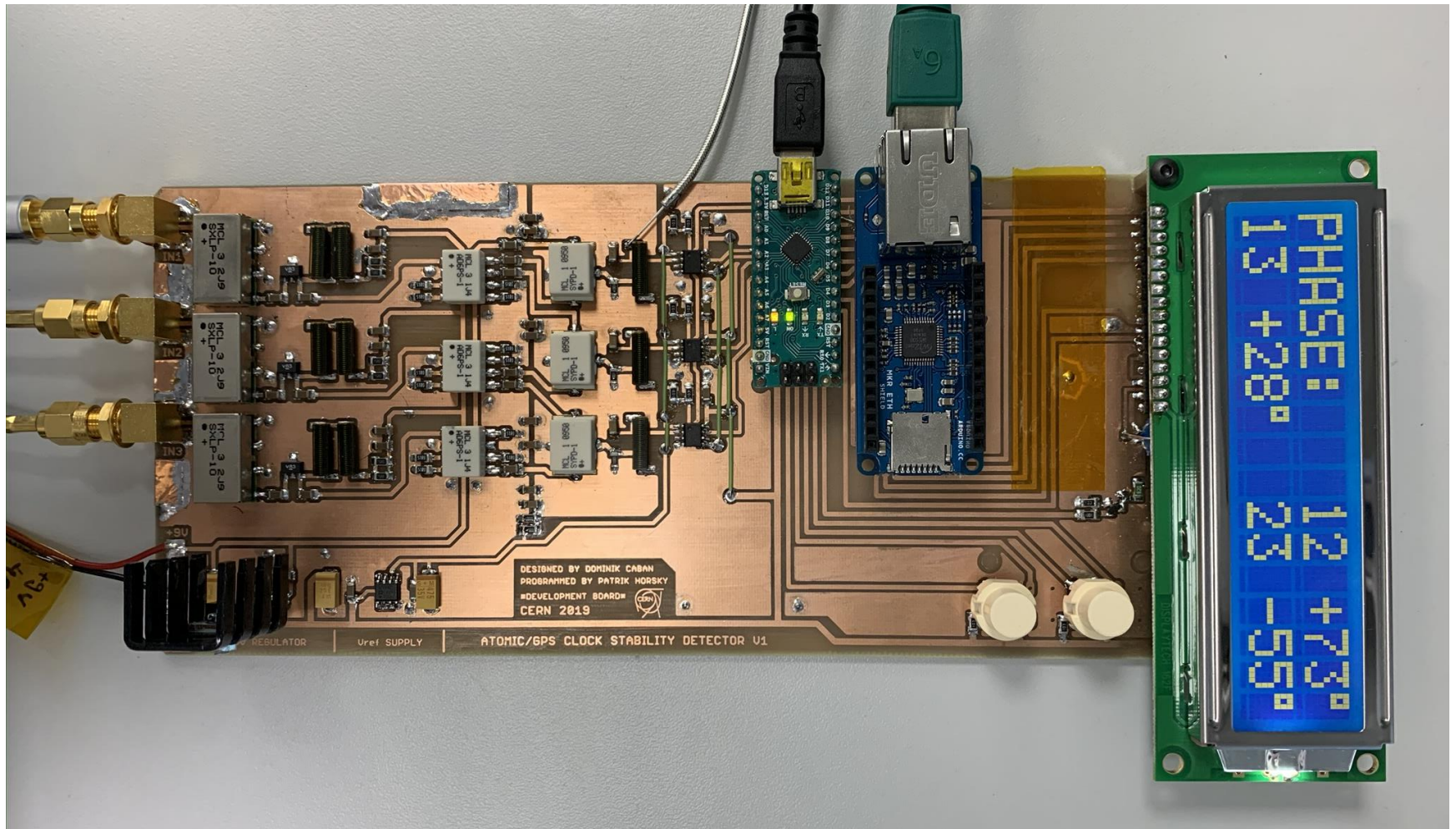
Ch1-Ch2 phase error

RF input Ch1

⋮

RF input Ch6

Finished Board Design

Final Product

Human Interface

- Analogue phase error signals are sampled by a high resolution ADCs

- Data are processed by an ATMega microcontroller

- The Phase differences and frequency differences are calculated and made available through a human interface and Ethernet interface

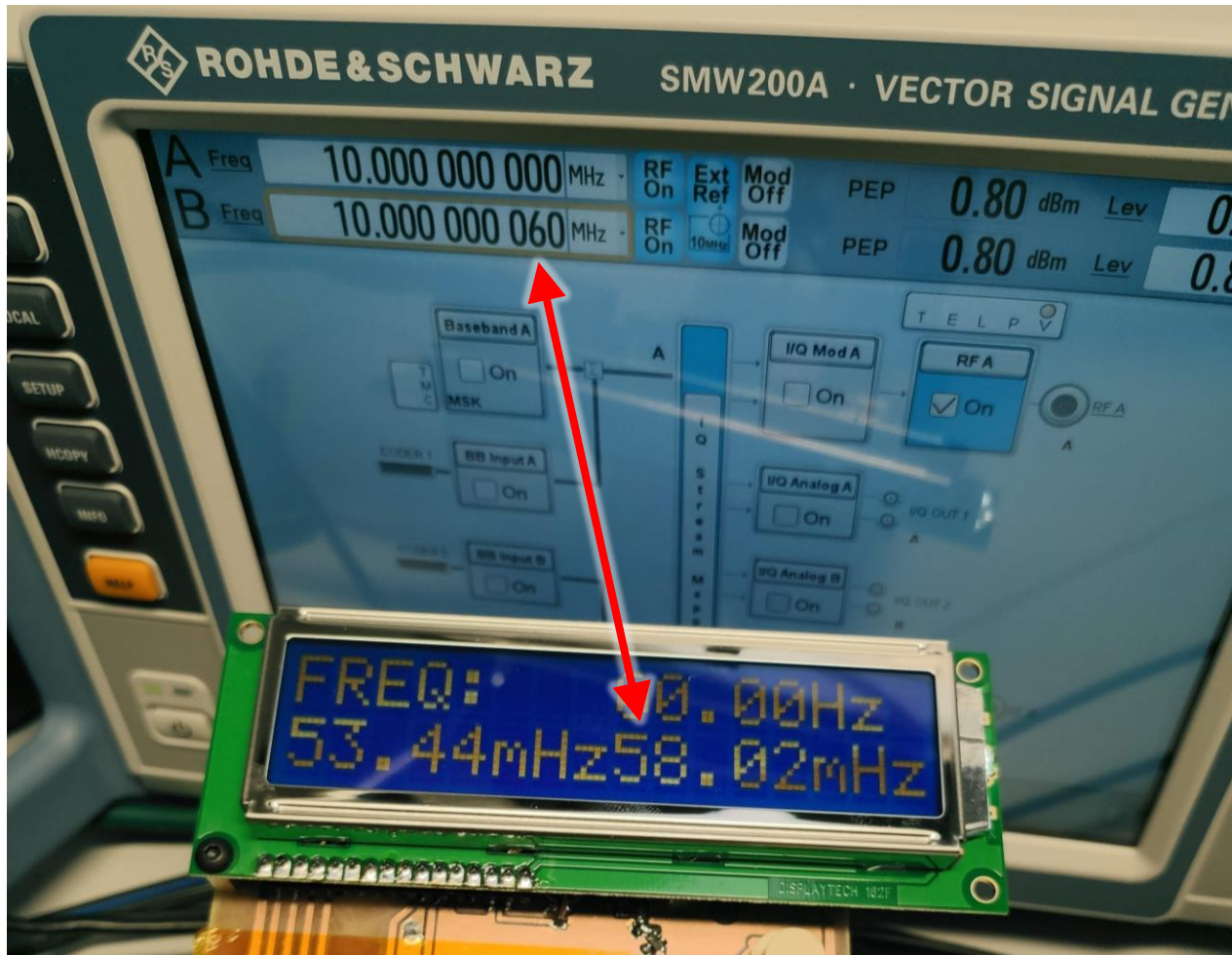$$Slope = \frac{ADC_{max} - ADC_{min}}{\varphi_{max} - \varphi_{min}} \qquad Offset = ADC_{min} - \varphi_{min} * Slope$$

LCD Human Interface

- The calculated values are shown on the LCD display in two modes:
    - 1. Phase difference
    - 2. Frequency difference
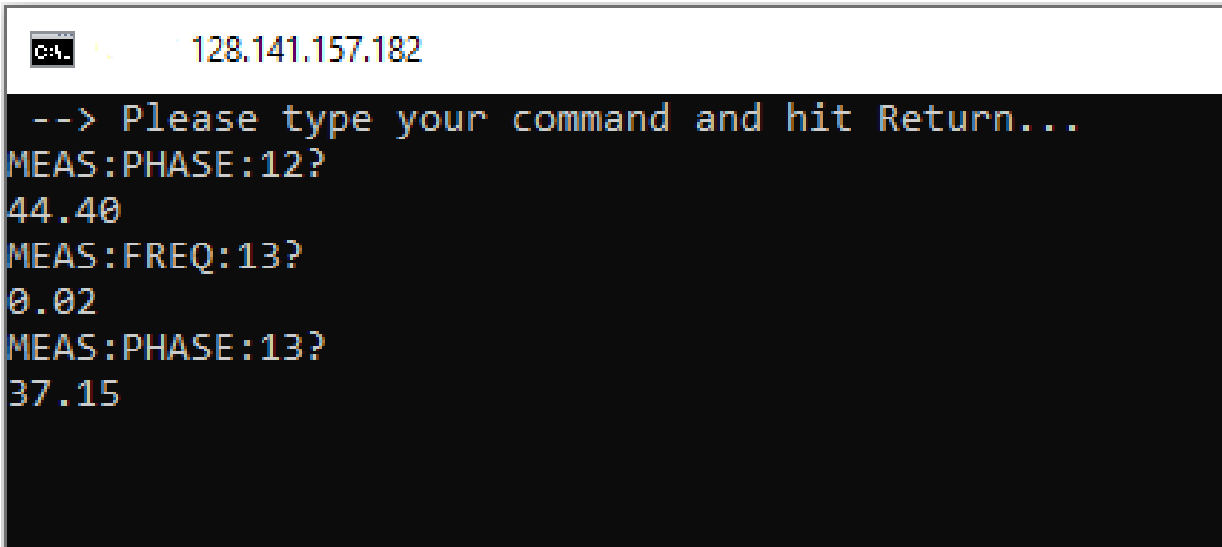- The modes change with a button press.

Validation with real signals

Ethernet control

- The device has ethernet connectivity and data can be accessed from anywhere in CERN using SCPI commands.


```
C:\.          128.141.157.182

 --> Please type your command and hit Return...
MEAS:PHASE:12?
44.40
MEAS:FREQ:13?
0.02
MEAS:PHASE:13?
37.15
```

Conclusion

- During the last two weeks we have designed and built an Atomic clock stability detector

- We have greatly improved our skills in the fields of electronics and programming

- Thanks to our supervisor Daniel Valúch we have learned a lot about RF electronics and much much more

- We have gained an invaluable experience working in a team, designing an electronic device and delivering results

Thank you for your attention