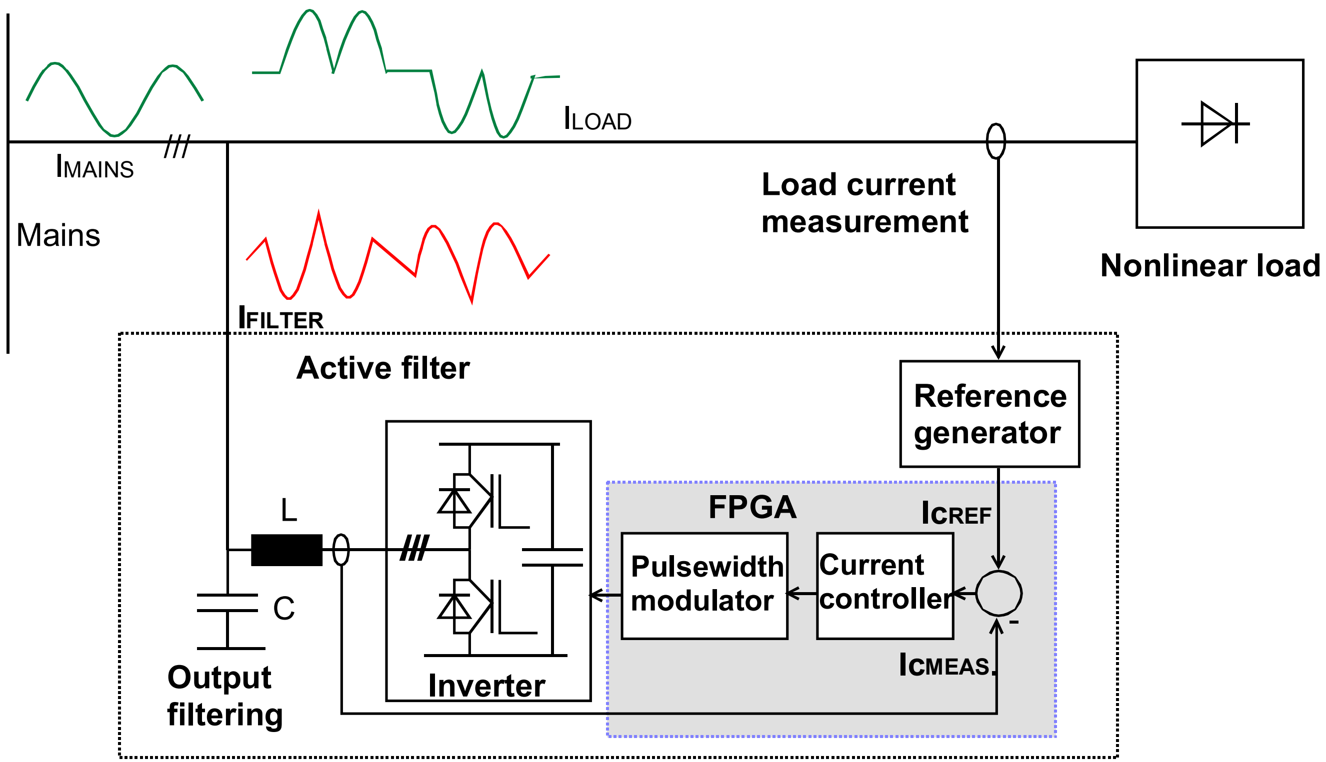
Paper presented at EPE 2003

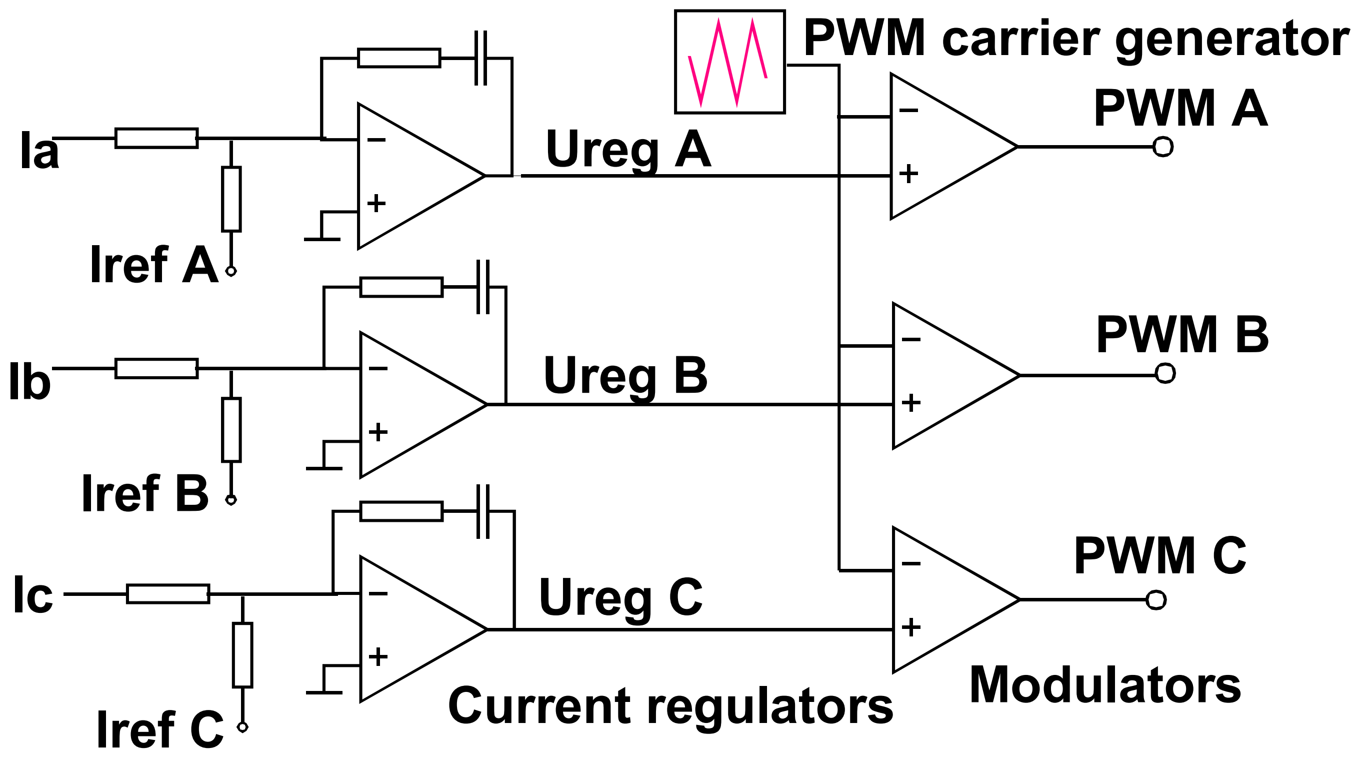
FPGA based digital current controllers

Example case: Active shunt filter.



- Non-linear loads draw distorted current from the mains
- Active filter injects currents that cancels distortion.

Analogue current controller

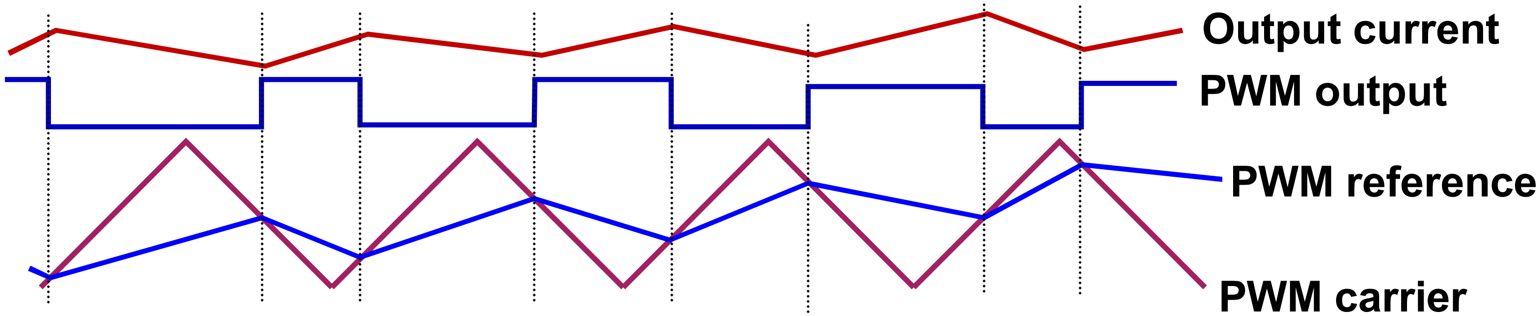


- Analogue circuits works continuously
- Allows high gain, giving good performance.

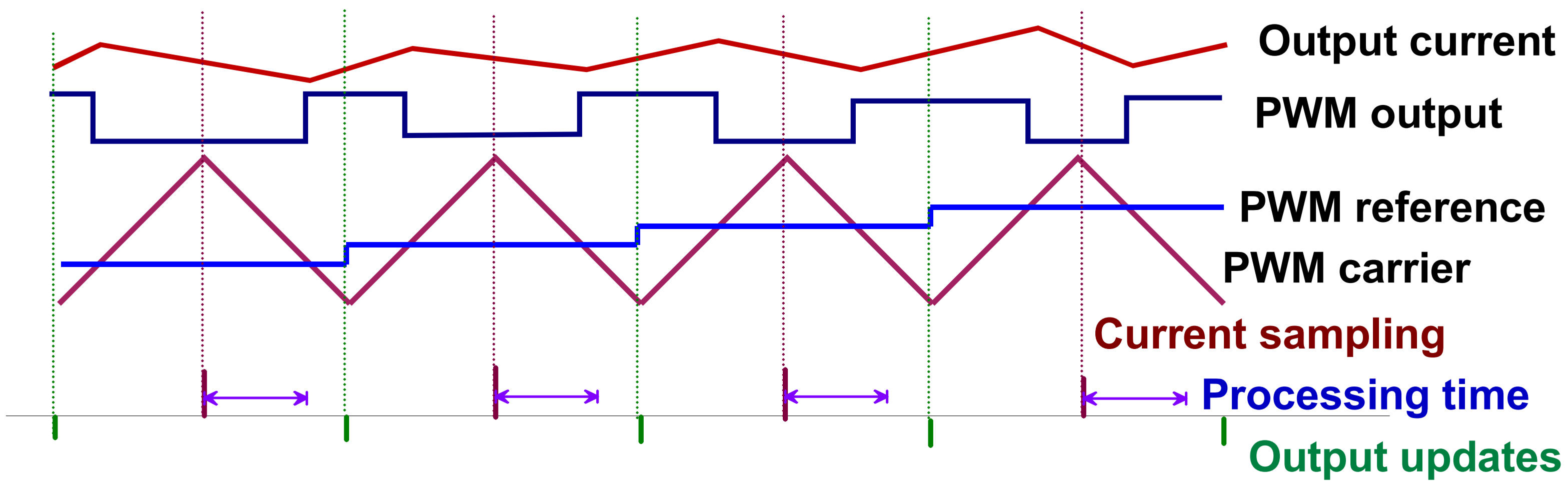
Design target

- Digital uP/DSP’ based controllers has inferior performance compared to analogue controllers due to delay introduced by sampling.
- The challenge: To make a digital control system that is fast enough to give almost continuous signal processing, similar to an analogue circuit.
- Our approach: Use a FPGA based parallel signal processing system, with data rates much higher than the switching frequency, to obtain almost continuous signal processing.

Signal delay

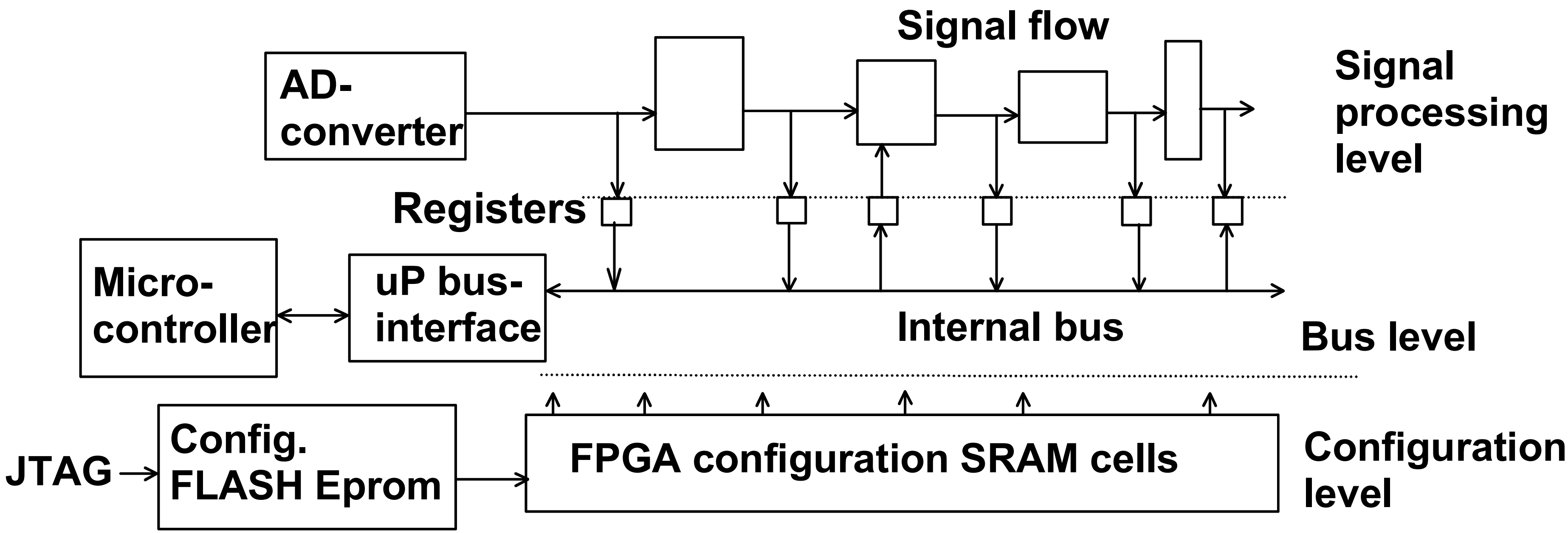


Analogue current controllers



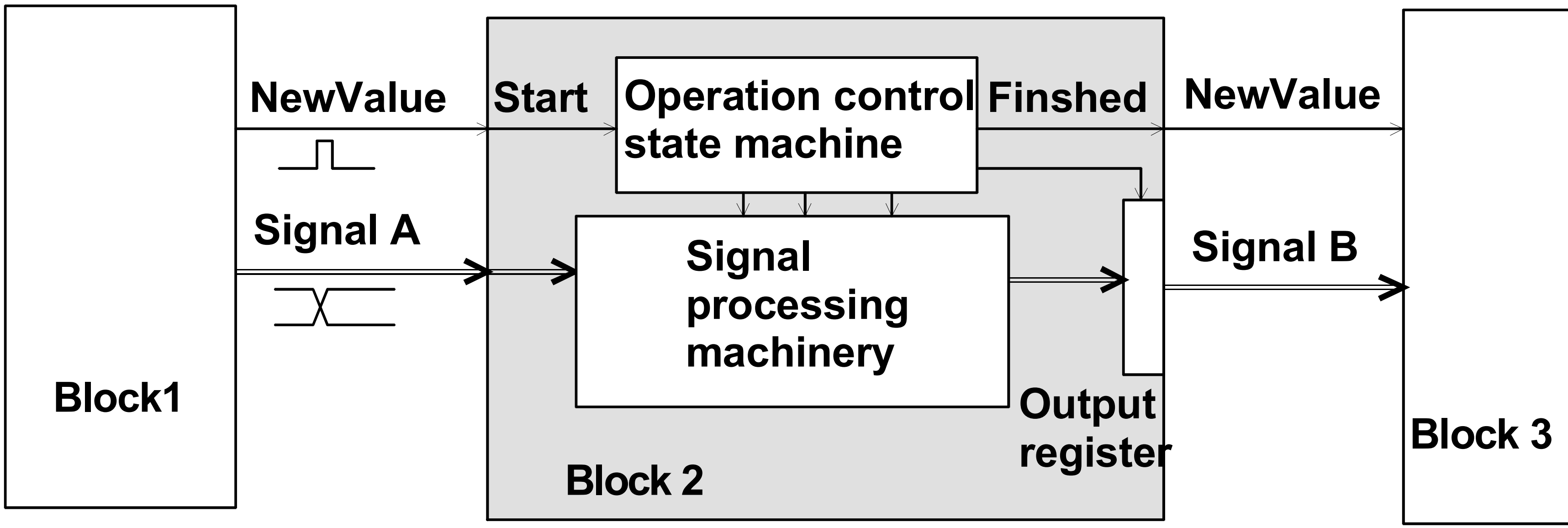
DSP based digital controllers

FPGA design structure



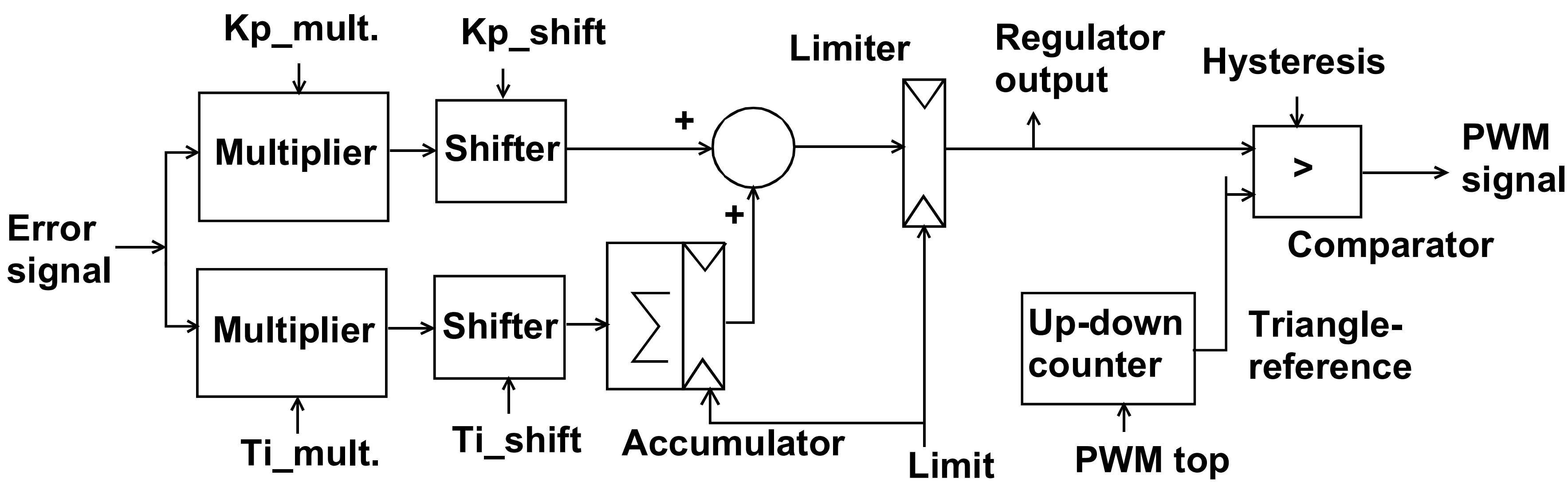
- Several processing blocks in the signal processing chain.
- AD converter drives the signal flow. Updates values every 0,67ms.
- Signals inside the FPGA are available on the processor data bus.

Signal flow between blocks



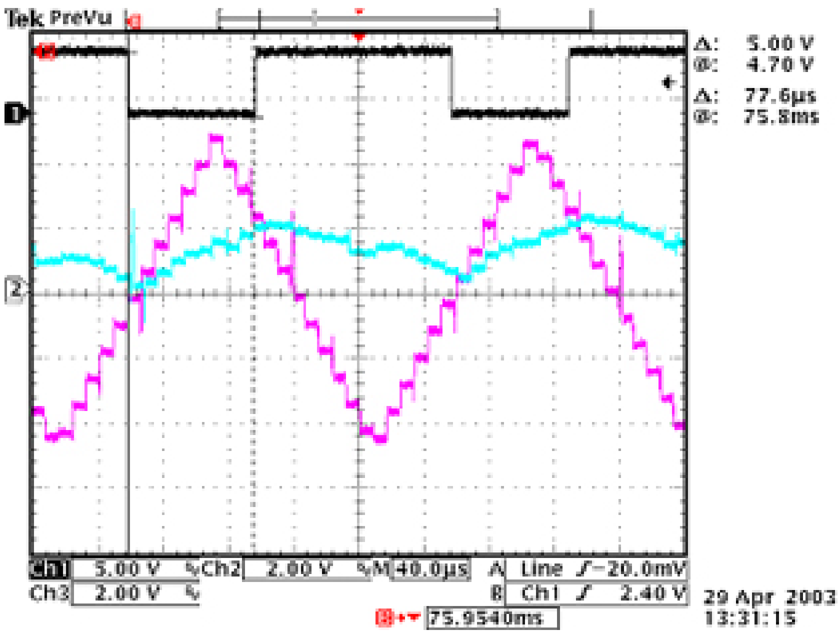
- A new processing sequence trigged by a NewValue flag
- When finished, outputs are updated, and NewValue flag pulsed.
- The block enters idling state, while the next block starts processing.

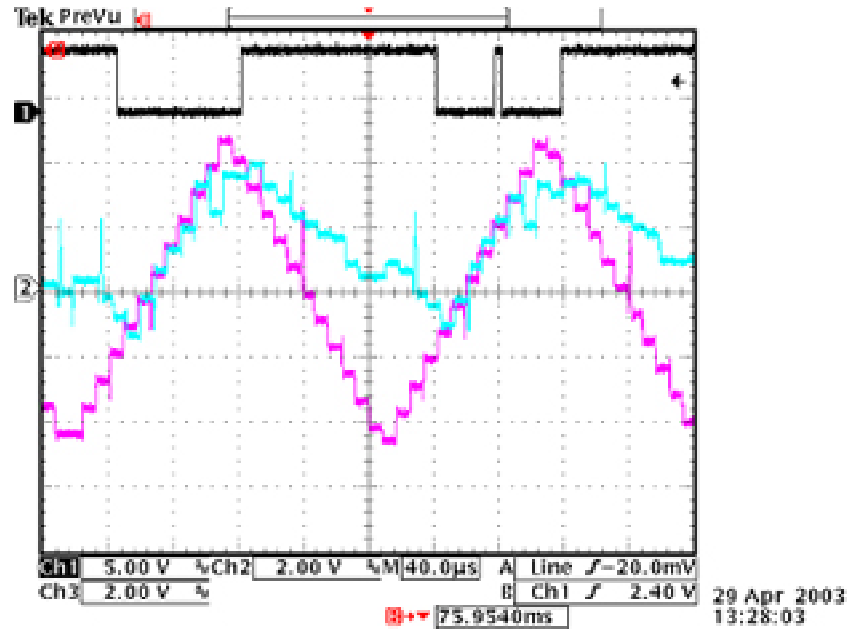
PI controller



- Two stage signal scaling: multiplier and a shifter.
- An accumulator performs integration.
- Limiters on accumulator and the output signal.
- Modulator consists of a up-down counter and comparators.

Pulse modulator.





Normal gain.

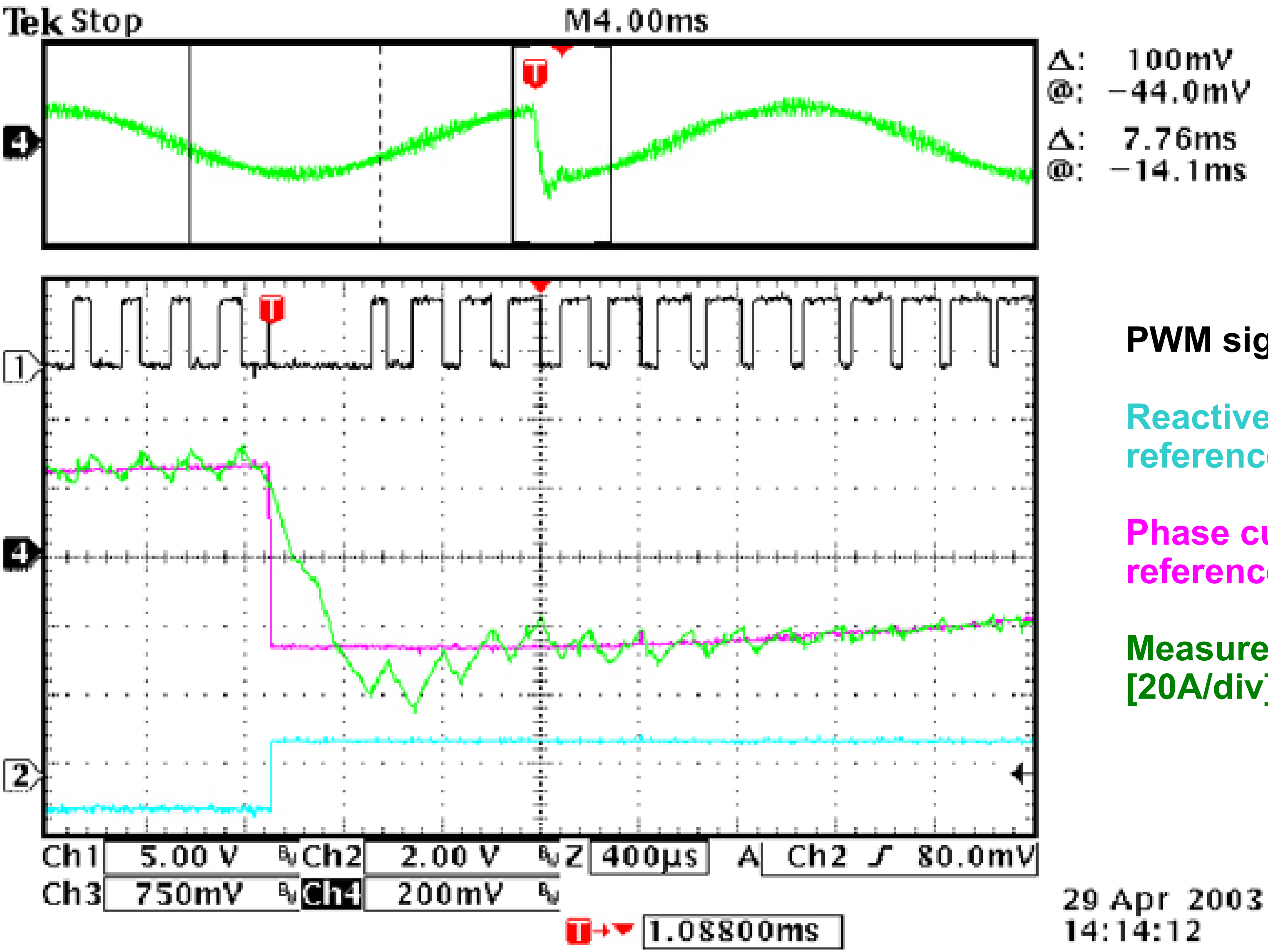
Too high gain. Extra pulses.

PWM output signal (black), Controller output signal (blue), Modulator carrier wave (pink).

Switching frequency: 10 kHz.
Sampling rate: 1,5 MHz.

Note: DA-converter running at 8 µs update rate causes steps and glitches.

Step reversal of reactive current reference



PWM signal

Reactive current reference

Phase current reference

Measured current [20A/div]

Experiences

- The FPGA based digital system behaves as its analog counterpart.
- FPGA based parallel signal processing allows very high data rates.
- Using a FPGA gives immense flexibility.
- Many other circuit variants and extensions are possible.
- AD converter speed and noise may in some applications limit achievable performance.
- Development work in VHDL for a FPGA is substantially heavier than doing a similar job in C for a microcontroller.