Karlsruhe Institute of Technology

Reconfigurable Hardware for Power-over-Fiber Applications

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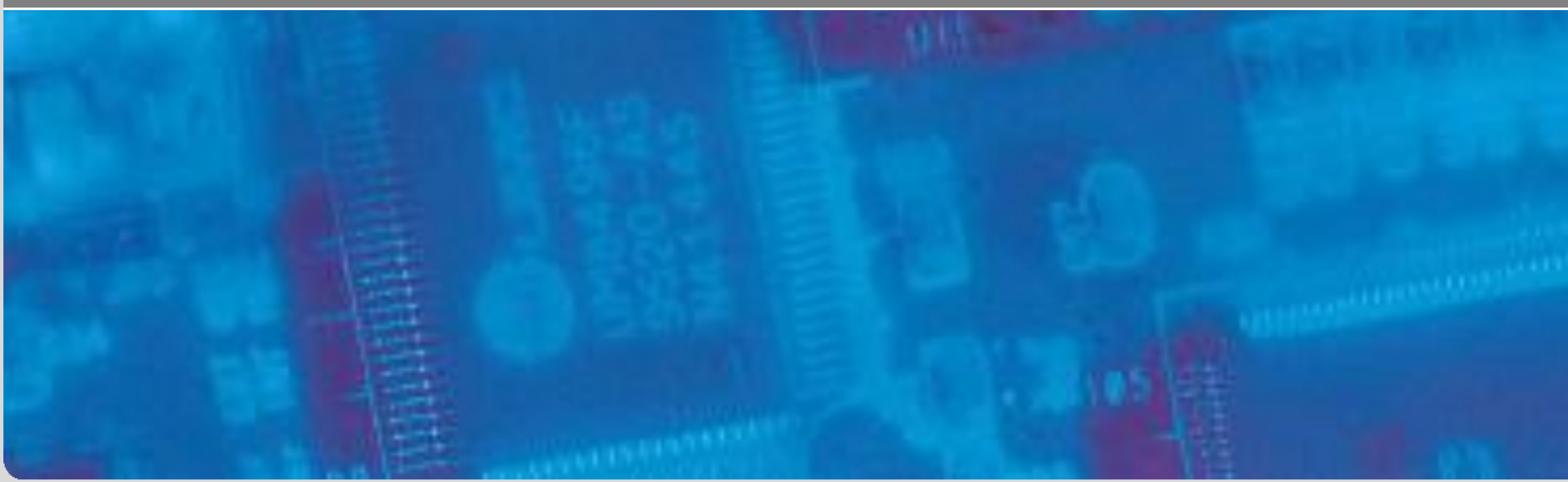
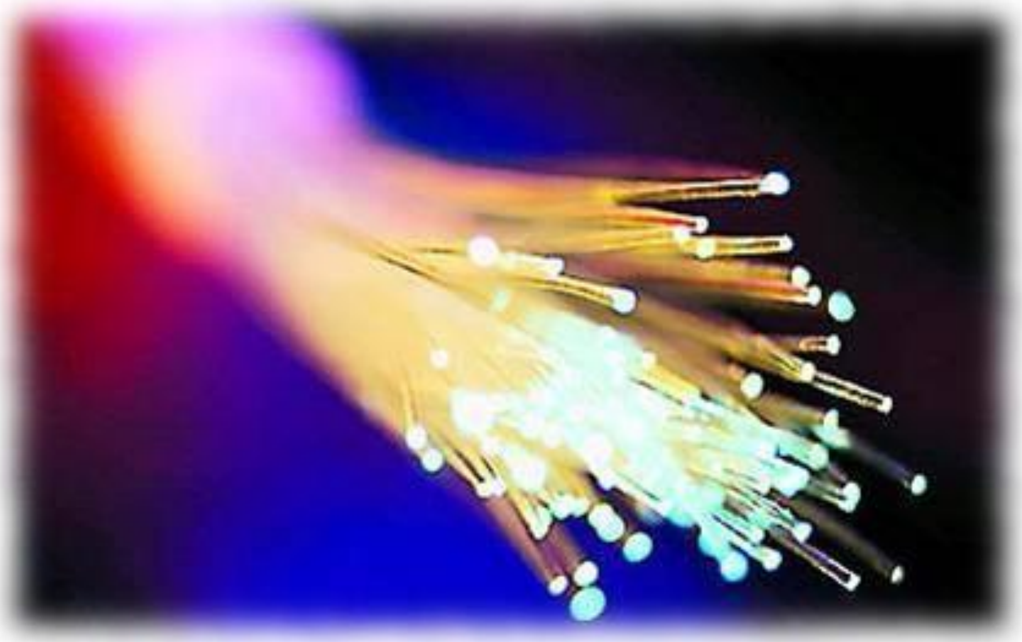


Overview

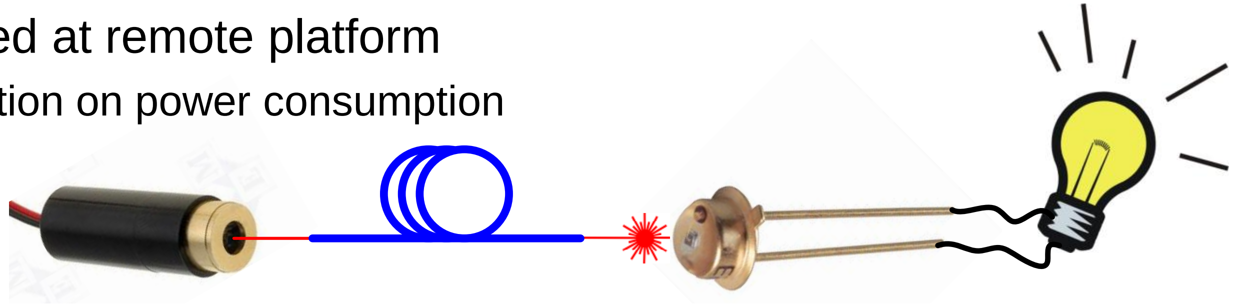
- Power-over-Fiber - Introduction
- Demonstrator
  - Analog Front-End
  - Remote platform
  - Base station
  - Performance
- Conclusions



Power-over-Fiber

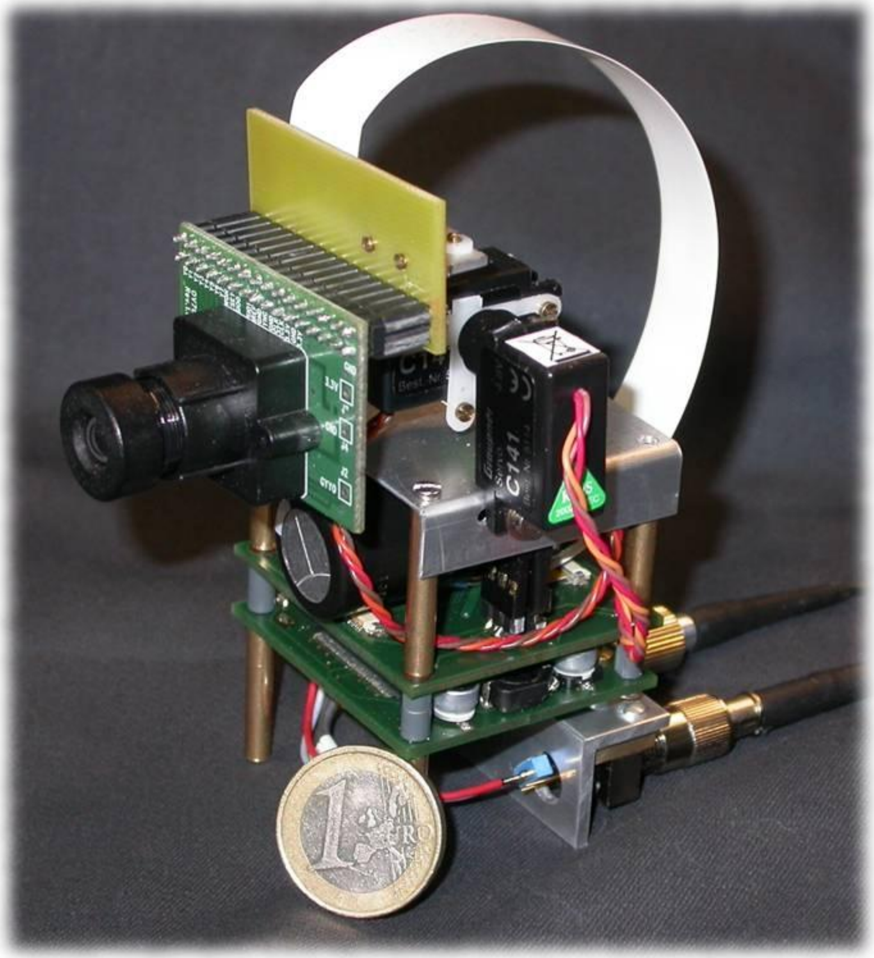
- Transfer of energy through a glass fiber
- Overall efficiency ~ 10%
- Very robust against electromagnetic interference
  - Outdoor equipment (protection against lightning)
  - Medical instruments (e.g. endoscope)
  - Sensors in EMI problematic areas (high voltage / current applications)
- Glass fibers are difficult to detect
  - No electromagnetic radiation
  - Security & Observation system
- Limited power budged at remote platform

  -> Special consideration on power consumption



Demonstrator

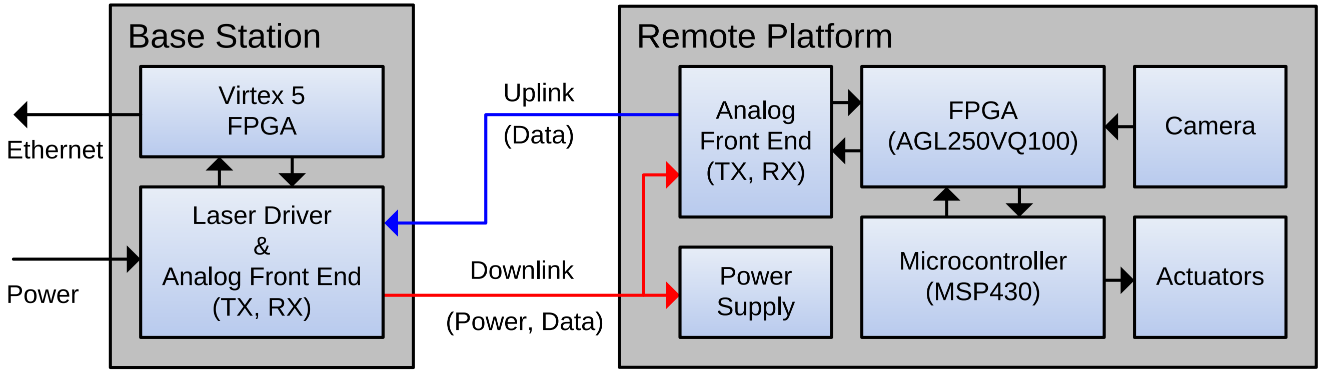
- Video sensor
  - 640 x 480 pixels @ 25 fps
  - Movable (remote controlled)
- Web interface
  - Live video stream (M-JPEG)
- Downlink
  - 100 KBit/s
  - Manchester coded
- Uplink
  - 160 MBit/s
  - 8B10B coded



Demonstrator

- Base station
  - Virtex-5 FPGA (ML509)
  - High power laser and driver

- Remote platform
  - High efficiency photovoltaic converter and power supply
  - Energy reservoir: 50 F gold cap capacitor
  - Two servo motors and video sensor
  - Digital signal processing



FPGAs in Power-over-Fiber Applications

- Highly adaptable interfaces
  - Support for many different kinds of sensors and actuators
  - Mostly no additional components required

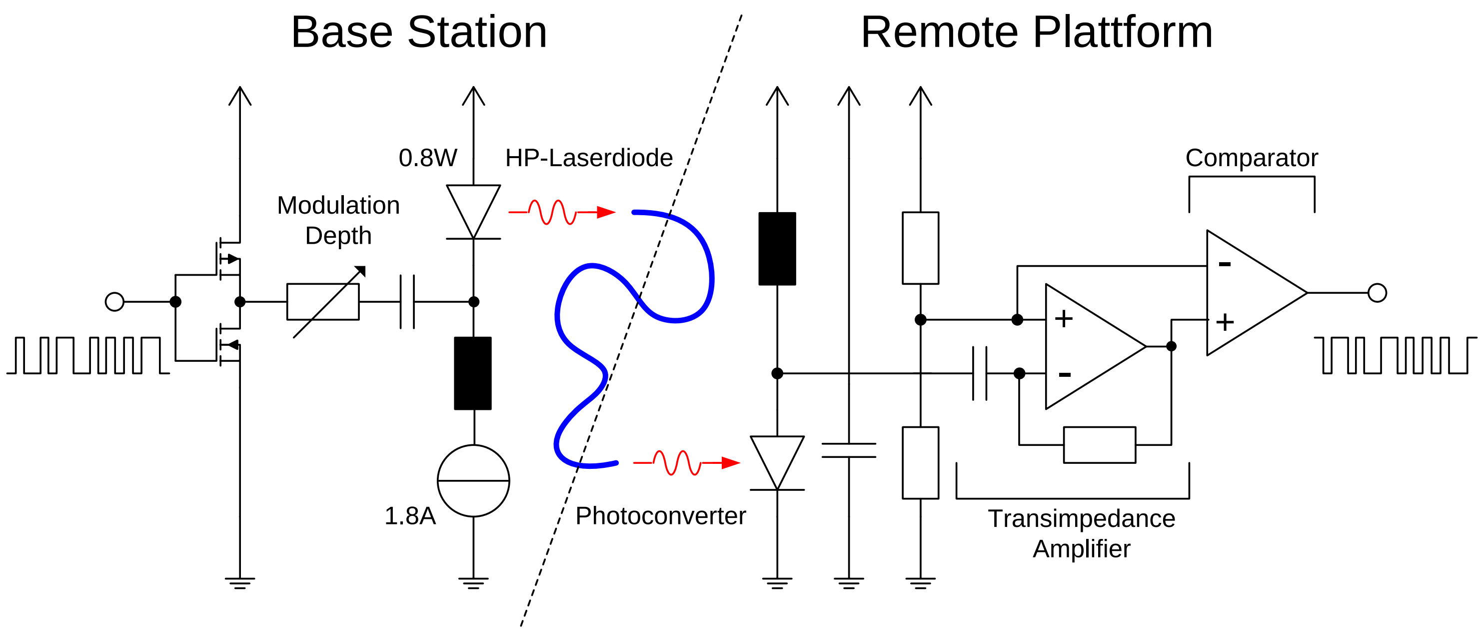
- Fiber communication
  - Communication protocol and line codes adaptable to the requirements of the PoF network
  - Minimal external components

- Power optimized designs
  - Only required modules are configured
  - Clock speed of various modules adaptable -> suitable microcontrollers require more power

- High processing power
  - Data preprocessing at the remote platform to reduce bandwidth

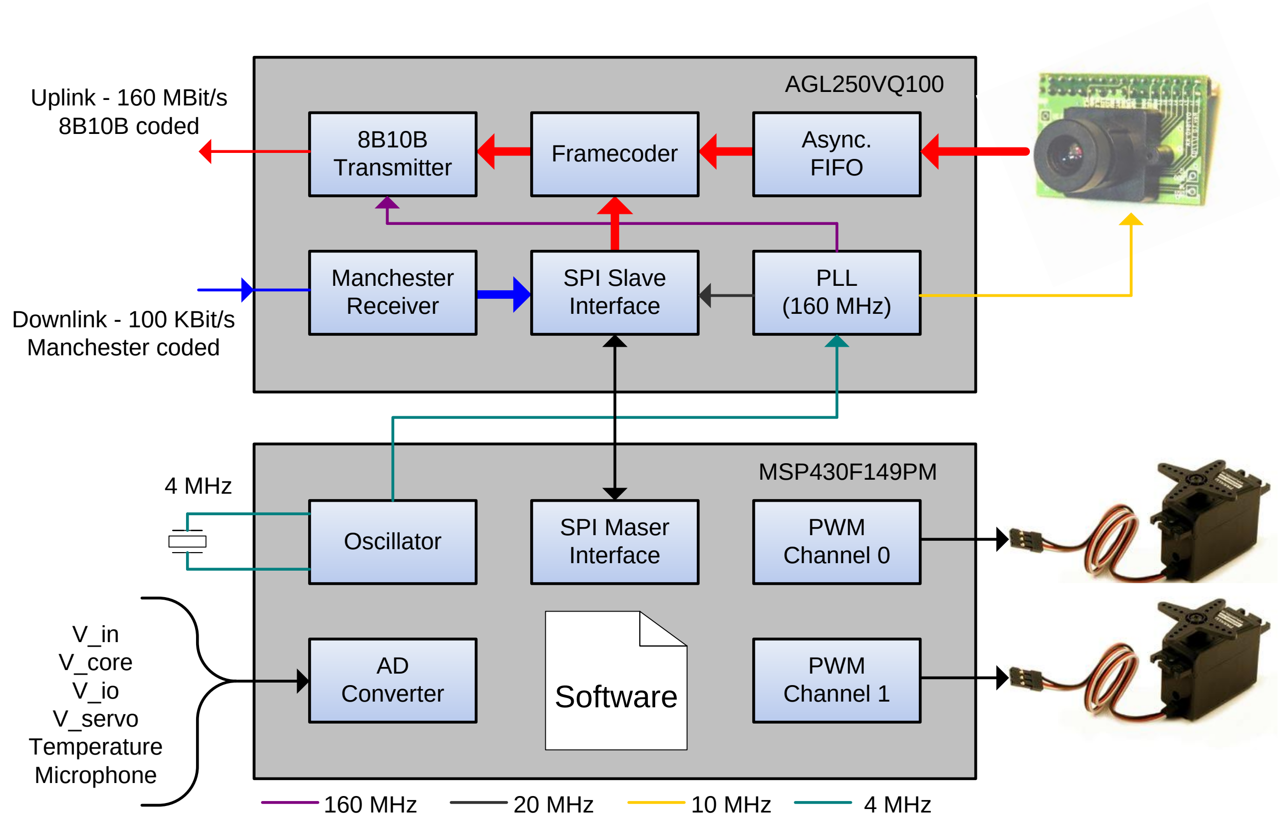
Analog Front-End – Downlink

- High-power laser diode - 0.8 W at 808 nm
- Photovoltaic converter - 40% conversion efficiency
- Available power at remote platform - 320mW
- 100 KBit/s communication bandwidth



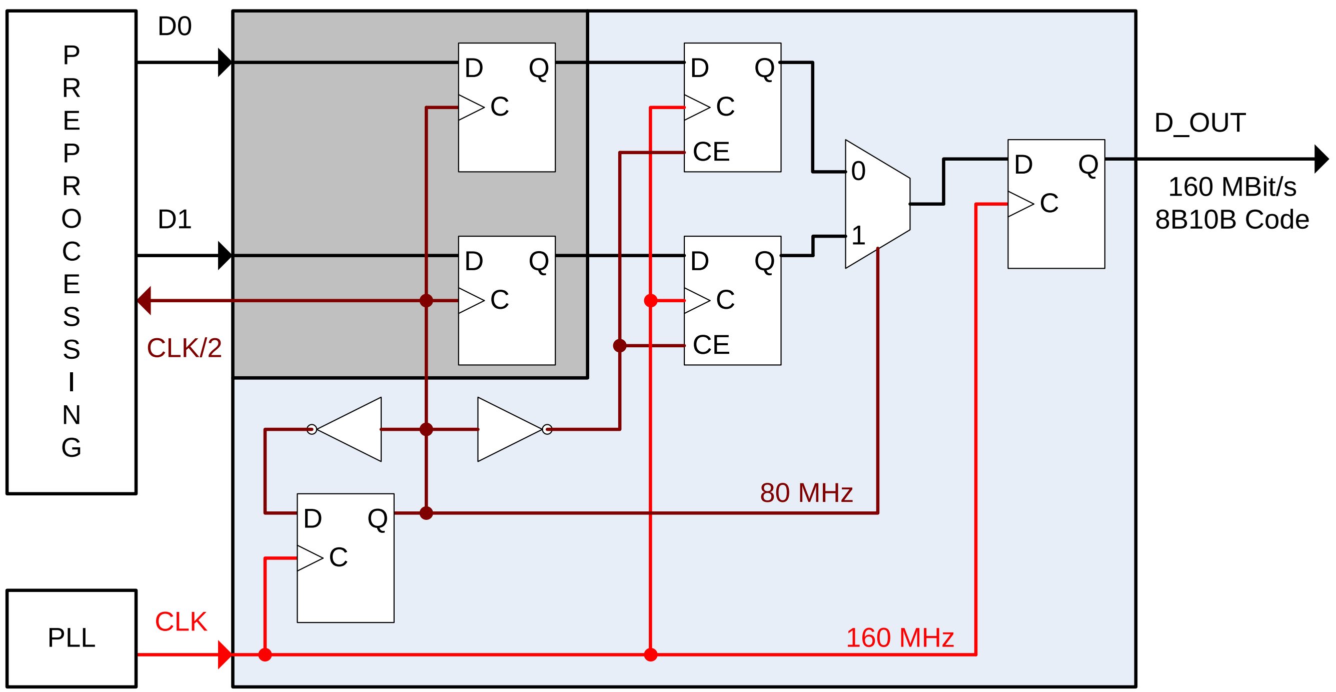
Remote platform

- Combination of FPGA and microcontroller
  - FPGA (Actel Igloo) - High speed data processing
  - Microcontroller (MSP430) - Power management



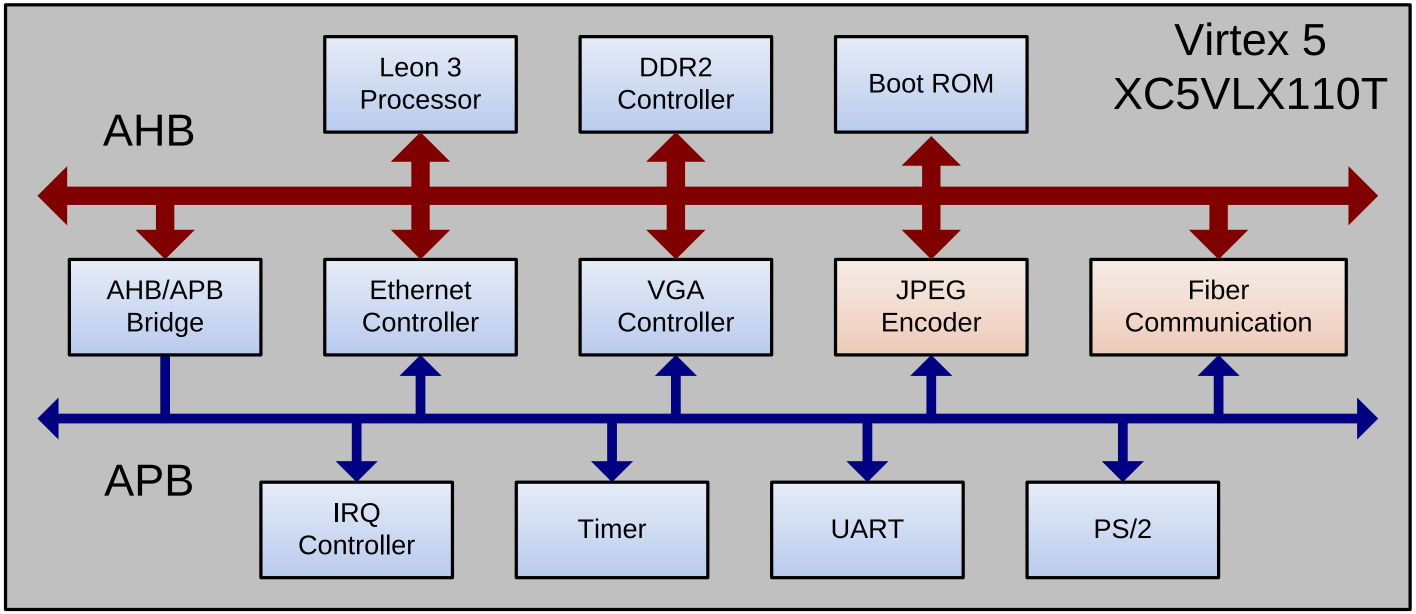
Remote platform – Uplink transmitter

- 8B10B encoding and CRC generation
- Data frame size up to 65536 bytes
- Preprocessing @ 80 MHz
- Final serialization @ 160 MHz



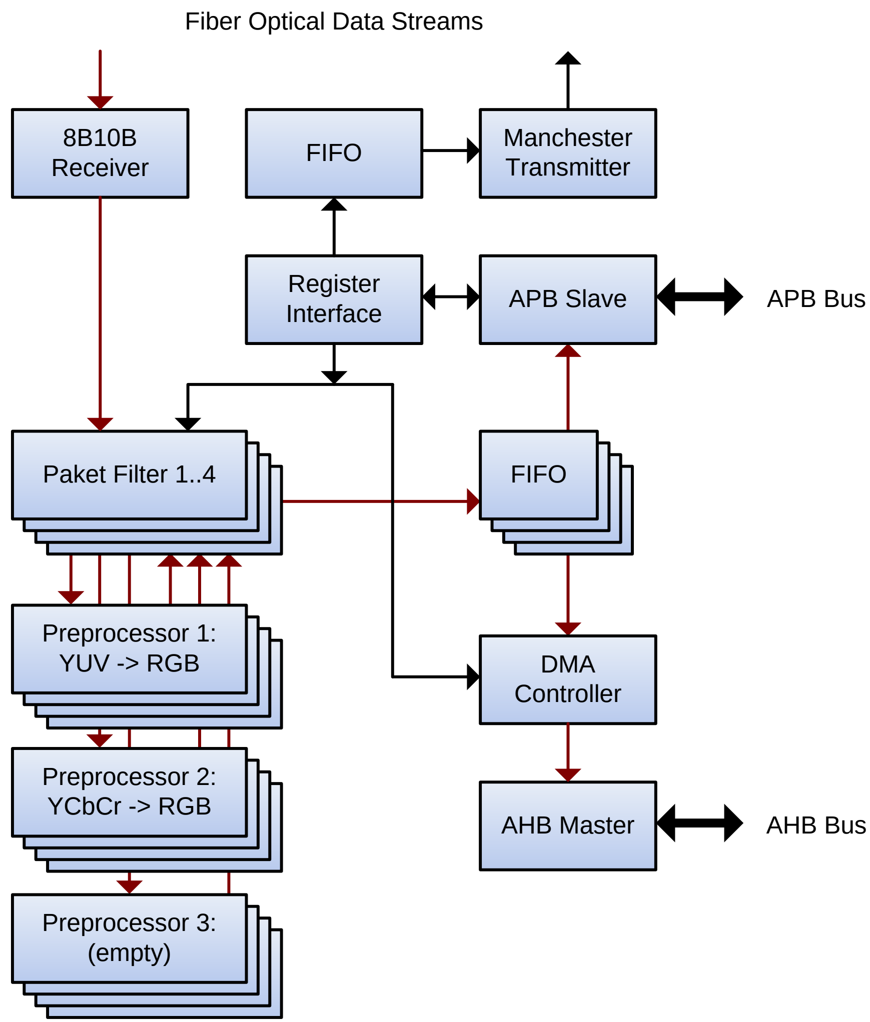
Base station

- Virtex 5 FPGA (ML509 board)
- LEON-3 system-on-chip (Gaisler Research AB)
- Linux operating system
- Additional hardware modules for glass fiber communication and JPEG compression



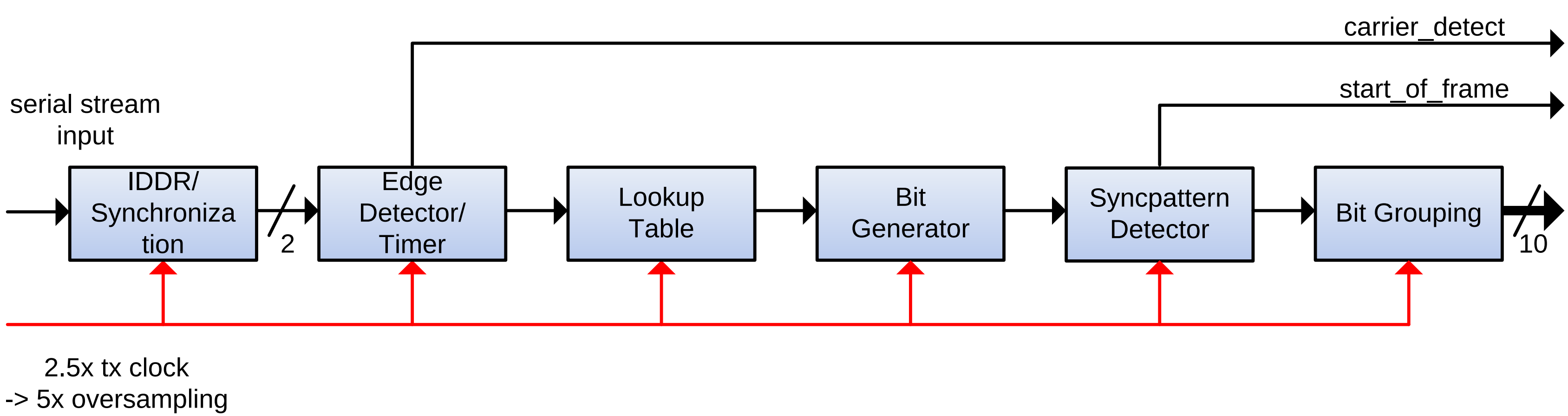
Base station – Fiber communication

- 8B10B receiver (uplink) and Manchester transmitter (downlink)
- Packet filter and demultiplex based on type information
- Up to three data preprocessing modules
- Highly flexible DMA controller



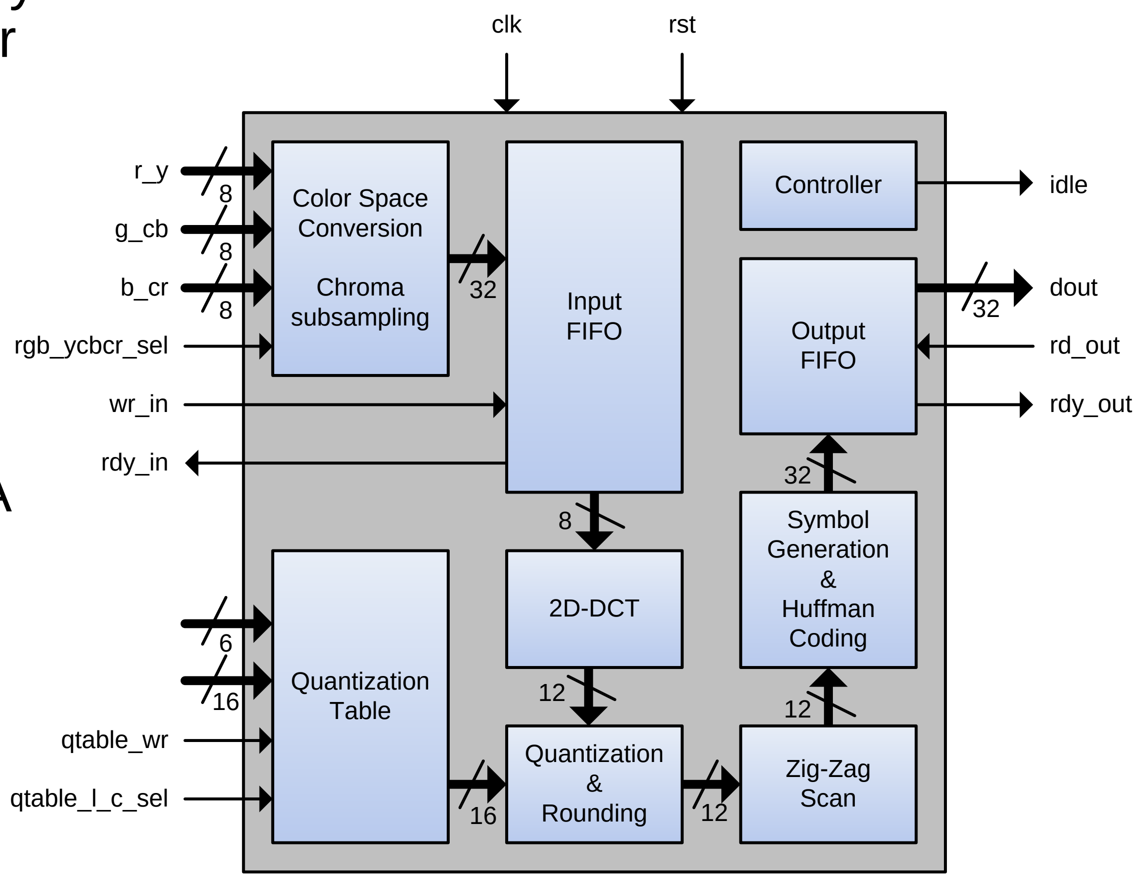
Base station – Uplink deserializer

- Five times oversampling required - 800 MS/s
- Usage of double data rate input register
- Operating frequency – 400 MHz
- Excessive usage of pipelining



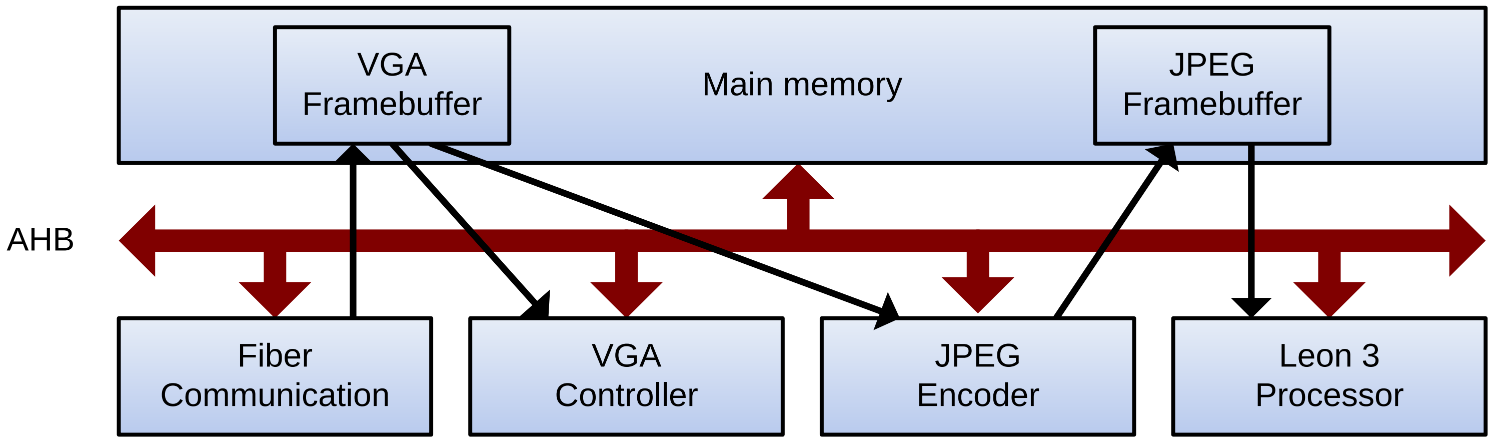
Base station – JPEG

- Complete compression of an image of arbitrary size without processor intervention to JFIF conform JPEG file
- Input format RGB or YCbCr
- Data transfer via DMA



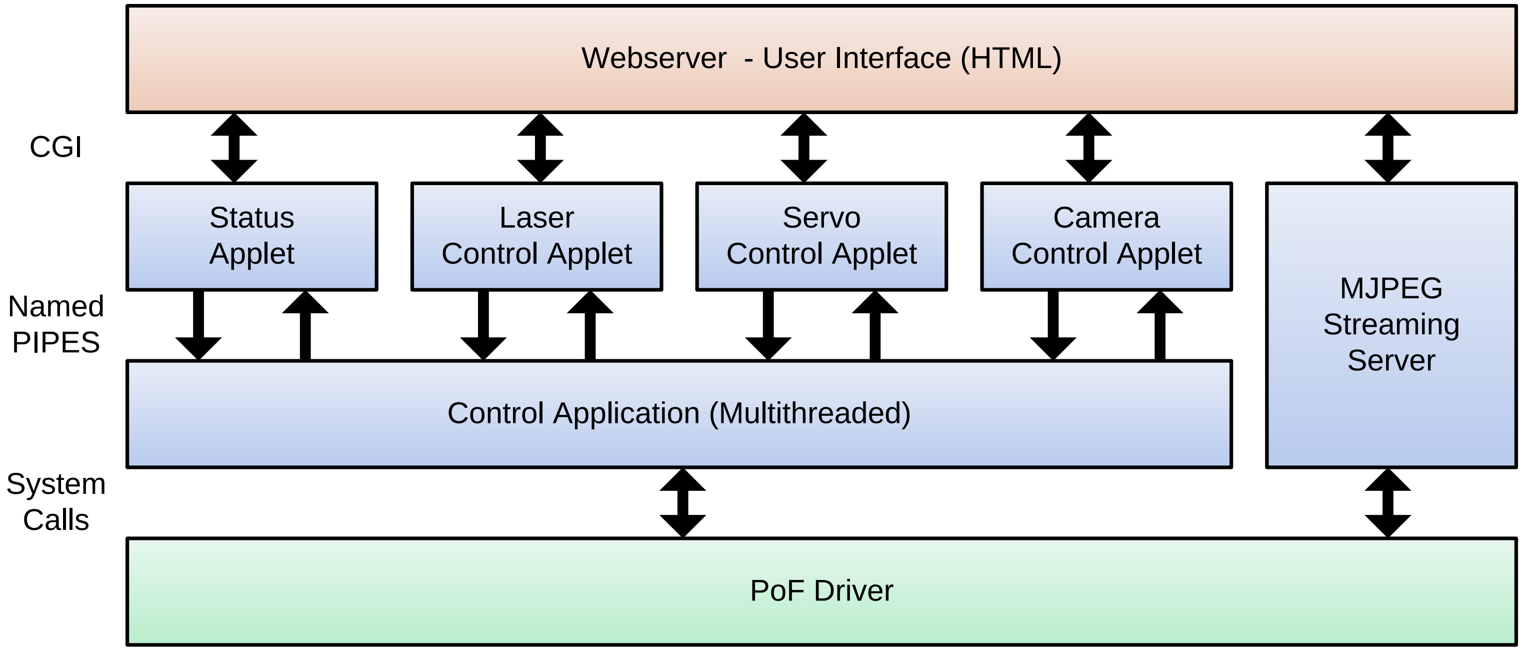
Base station – Image data processing

- Incoming video data is placed in VGA framebuffer
- VGA controller & JPEG encoder read input data from VGA framebuffer
- JPEG encoder writes encoded JPEG data to JPEG framebuffer
- Processor reads encoded JPEG data from JPEG framebuffer and sends it to the internet



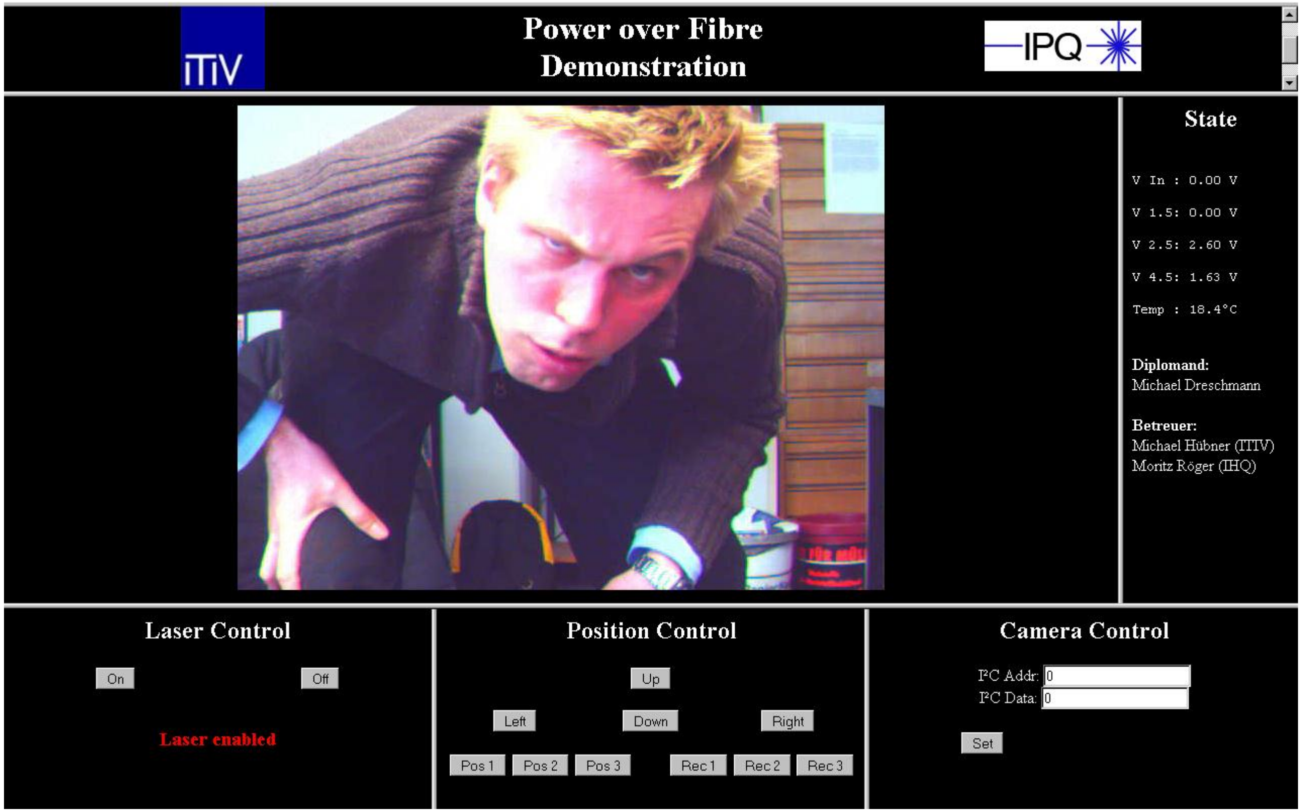
Base station – Software stack

- PoF kernel driver gives access to fiber communication and JPEG hardware
- JPEG encoded video frames are transmitted as Motion-JPEG stream
- Several applets allow remote control of remote platform



Base station – Web interface

- Access via HTTP
- Display of M-JPEG video stream
- Remote control of camera position and further parameters



Performance

Power consumption
Remote platform

MSP430	1 mW
Analog Front End (RX)	0.5 mW
Actel Igloo	80 mW
Video sensor	50 mW
Analog Front End (TX)	20 mW
Servo motors (max)	1800 mW
Total (motors inactive)	160 mW

Performance

Downlink	100 KBit/s
Uplink (effective)	128 MBit/s
Uplink (line)	160 MBit/s
Video frame rate (actual)	12.5 Frames/s
Video frame rate (max)	25 Frames/s
LEON-3 SoC operating frequency	120 MHz
JPEG Encoder (@ 120 MHz, 640x480)	173 Frames/s

Conclusions

- Power-over-Fiber Demonstrator transferring live video
  - 640 x 480 @ 25 fps (12.5 fps)
  - Two servo motors
  - Energy reservoir for short-time high power output
  - Adaptable to many different kinds of sensors and actuators

- Combination of microcontroller and FPGA
  - Low power consumption, very low standby power consumption
  - High processing power
  - High flexibility

- Wide potential for improvement
  - Reduction of power consumption of remote platform
  - More complex optical powered networks

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Thank you for your attention

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