

A new and universal Powerline Communication
Approach
for Industrial Applications based on an FPGA-Solution

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Overview

1 Concept and Basic Idea

- Motivation
- Basic Idea
- Goals
- Concept

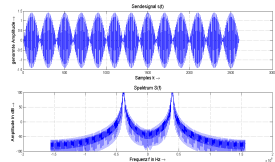
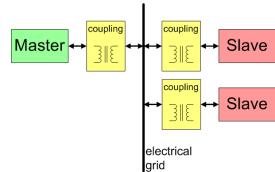
2 Powerline-Communication

- Characteristics
- modulation schemes

3 Implementation

- Hardware Components
- VHDL Design

4 Conclusions



Motivation

Nowadays

- ▶ increasing interest in modern communication systems
- ▶ nearly every modern application needs to communicate with other devices
- ▶ vast majority of industrial applications
- ▶ even more important in the future

Examples

- ▶ intra- and inter-car-communication systems
- ▶ communication between adjacent machines in factories
- ▶ powerful and intelligent communication in independent power grids

Motivation

current communication systems

- ▶ wireless communication systems
- ▶ wired communication systems

Drawbacks of current communication systems

- ▶ Both described communication systems require additional, specific components to work in different locations
- ▶ Examples:
 - ▶ wireless: specific antennas
 - ▶ wired: additional wires like fiber for optical communications
- ▶ Both communication systems have one thing in common:
They need a power supply - more additional wires

Basic Idea of Powerline-Communication

Thoughts

- ▶ Are there any possibilities to eliminate the disadvantages of additional components in current communication systems?
- ▶ If both communication systems have these wires for the power supply, can we use them for the communication?

Powerline-Communication

- ▶ Communication Method called: Powerline-Communication (PLC) or sometimes Digital-Powerline (DPL)
- ▶ A PLC system make direct use of an electric grid within a building or industrial factory
- ▶ Already used in for example the german 230V-AC-main for:
 - ▶ In-House-Network (Internet), Babyfones or talk-back circuits

Goals and Concept of this PLC approach

- ▶ The Concept is to design a new and versatile approach for modern and universal Powerline Communication
- ▶ different goals should be achieved:

versatile and universal PLC Approach

- ▶ applicable in AC- and DC-mains of different voltages
- ▶ cable lengths in the order of several kilometers are applicable
- ▶ frequency range is adapted but not limited to the european standardized range from 3kHz upto 148.5kHz
- ▶ modulation of signals is done with two different PSK modulation schemes on the powerline

Concept

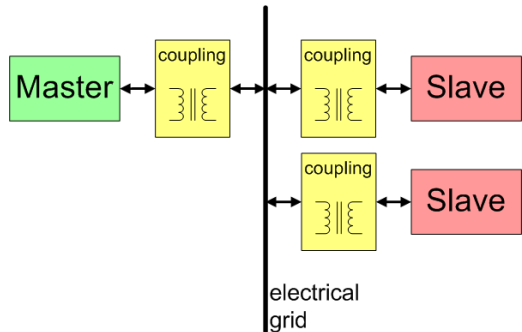
- ▶ The concept of the PLC is based on an FPGA-Solution
- ▶ entire physical layer of the communication implemented in VHDL
- ▶ a powerline modem modulates the signals to the powerline via analog frontend

Additional benefits of the FPGA-Solution

- ▶ Multi user communication with one master and several slave units
- ▶ implementation of fast and reliable protocols for safety and security critical environments
- ▶ bidirectional and parallel communications are possible

Powerline-Communication characteristics

- ▶ adding a modulated carrier signal to the powerline
- ▶ different carrier frequencies used to transmit signals of e.g. multiple nodes in a network
- ▶ signals are modulated on the powerline with coupling circuits
- ▶ the coupling circuits additionally work as a safeguard against voltage glitches from the mains

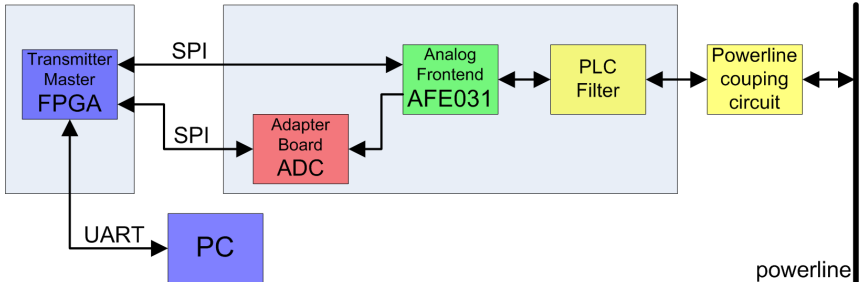


modulation schemes

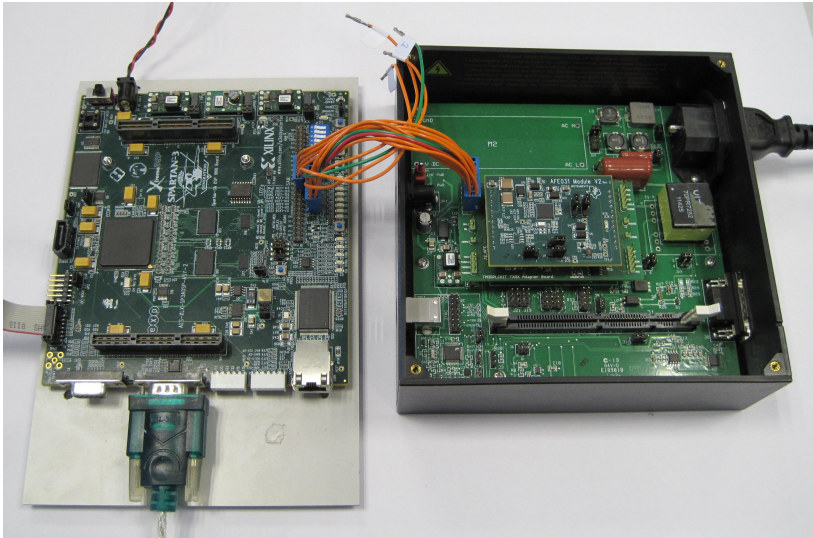
- ▶ two different PSK modulation schemes implemented
- ▶ both robust modulation schemes:
 - ▶ enable a reliable communication despite the channel effect on the powerline
 - ▶ have their own Carrier Phase Recovery to get rid of
 - ▶ a constant phase shift caused by imprecise oscillators
 - ▶ a phase error caused by the synchronization of the quadrature demodulator
- ▶ major difference is the mapping of the phase-shift-keying (PSK) modulation:
 - ▶ standard Q-PSK (quadrature)
 - ▶ $\frac{\pi}{4}$ -PSK
- ▶ the $\frac{\pi}{4}$ mapping eliminates 180° phaseshifts between adjacent symbols which are bad for the signal transmission

Hardware Components

- ▶ hardware components used for the PLC can be divided into two major parts
 - ▶ FPGA (Xilinx Spartan 3A DSP 1800A)
 - ▶ PLC modem with the AFE031 and an ADC on the Adapter Board
 - ▶ Texas Instruments TMDSPCKIT-V3, Texas Instruments Analog Frontend Module V2, ADS7947



Hardware Components

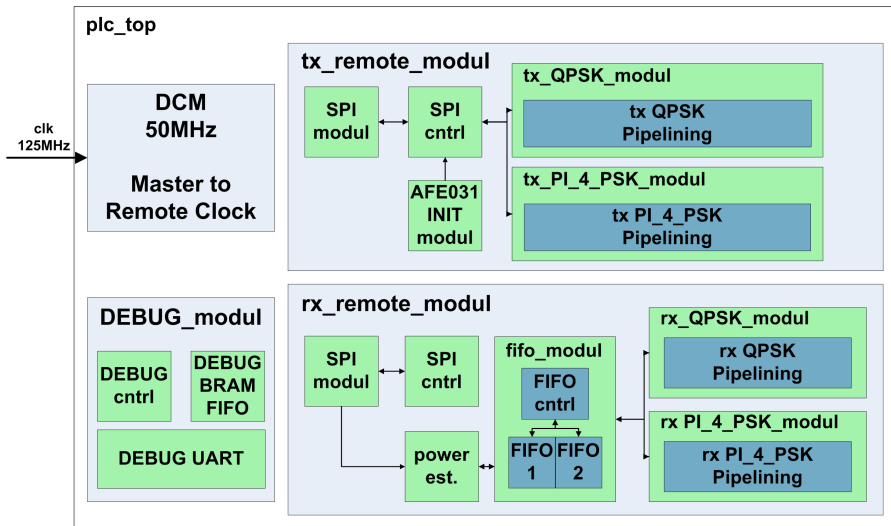


VHDL Design

VHDL implementation characteristics

- ▶ structure of transmitter- (TX) and receiverdesign (RX) are identical
- ▶ there is a basic VHDL implementation structure for master and slave units
- ▶ SPI-interfaces from the FPGA to the PLC modem (TX and RX)
- ▶ UART-interface from the FPGA to a PC as debug- and control-interface
- ▶ clock decoupling from higher to lower clock frequencies
- ▶ maximum design speed after synthesis is achieved
- ▶ general interfaces to modular implemented VHDL functions

basic VHDL implementation structure



Conclusions

- ▶ Proof of concept done by loop-back tests (TXRX pin)
- ▶ all algorithms tested and simulated in Matlab
- ▶ no errors in 34 Byte packets

- ▶ Device Utilization of the Spartan 3A DSP 1800A FPGA:
 - ▶ 21% Slice Flip Flops
 - ▶ 19% input LUTs
 - ▶ 31% occupied Slices
- ▶ smaller and low cost FPGA feasible
- ▶ FPGA usage allows further PLC extensions

- ▶ highly versatile FPGA-Solution for PLC
- ▶ modulation schemes with Carrier Phase Recovery opens a wide range of applicability and reliability

Thank You!

Any Questions?