Demo: A Programmable High-Throughput Duplex DC-PLC Testbed for Power and Data Integration

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Introduction

- **Existing Wring Method**
  - Separate wires for power supply and data transmission

  → Too many wires in the system
- **DC-PLC (Direct Current Power Line Communication)**
  - Power and data transfer through single pair of power line
  - Simplified and lightweight architecture
  - Lower manufacturing and operational expenses

Prior Works

Technology	PHY Thrp. (kbps)	Duplex	Voltage range	Power consumption	MAC mechanism
IEEE 2847-2021 [1]	9.6	Simplex	0~50 V	Low	None
M-bus [2]	0.3 ~ 38.4	Half duplex	34, 36 V	High	Polling
Yamar SIG100 [3]	~100	Half duplex	10~36 V	High	None
D^2-PLC	**100 +**	**Half duplex**	**12 V**	**Low**	**Programmable**

Table 1. Comparison between prior works and proposed scheme.

System Design

A. Overview

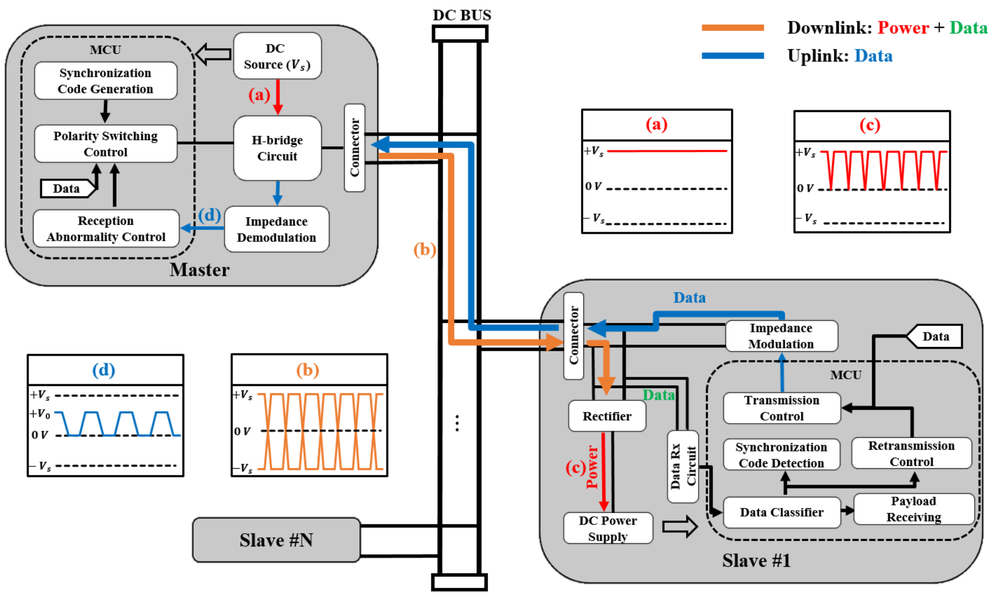

Figure 1. Overview.

B. Downlink – Voltage Polarity Modulation

- H-bridge with 2 PMOS and 2 NMOS
  - Switching polarity with high frequency
  - On-off keying by representing (+) for 1, (-) for 0

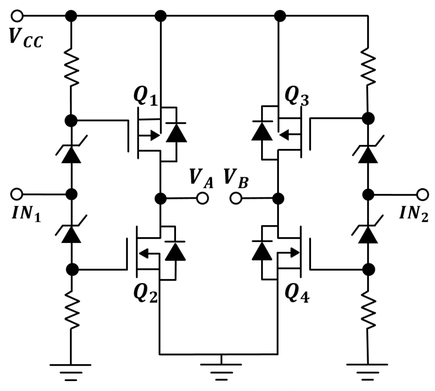

Figure 2. H-bridge.

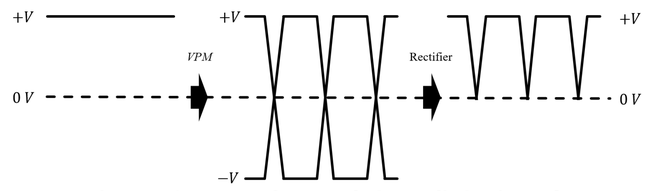

Figure 3. Waveform of downlink signal.

Input		Switch				Output		
IN_1	IN_2	Q_1	Q_2	Q_3	Q_4	V_A	V_B	V_{AB}
0	1	On	Off	Off	On	V_{CC}	0	$+V_{CC}$
1	0	Off	On	On	Off	0	V_{CC}	$-V_{CC}$

Table 2. VPM result after H-bridge circuit.

C. Uplink – Current Amplitude Modulation

- Impedance Modulation
  - Small current injection (10 mA) to power line with high speed
  - Symmetric NMOS inverter at master side

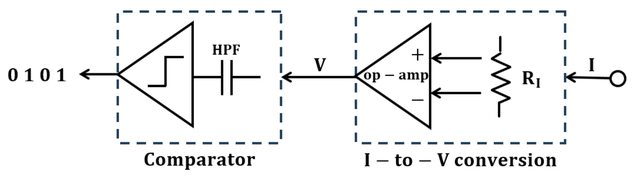

Figure 4. Impedance demodulation.

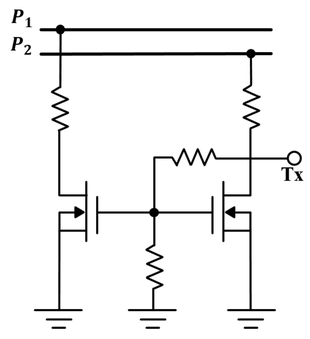

Figure 5. Impedance modulation.

Implementation

- **Common Component**
  - 12 V DC power
  - 22-AWG copper line
  - Bus topology
  - Nuvoton N76E003 MCU
  - UART interface
- **Master Node**
  - H-bridge for VPM
  - I-to-V converter for CAM demodulation
- **Slave Node**
  - Power line connector
  - Rectifier for power reception
  - Impedance modulator for CAM (10 mA current injection)
- **Frame structure**
  - Downlink: 5 Bytes header + 11 Bytes payload
  - Uplink: 5 Bytes preamble + 5 Bytes header + 6 Bytes payload
  - Header information: number, type, address, size, CRC

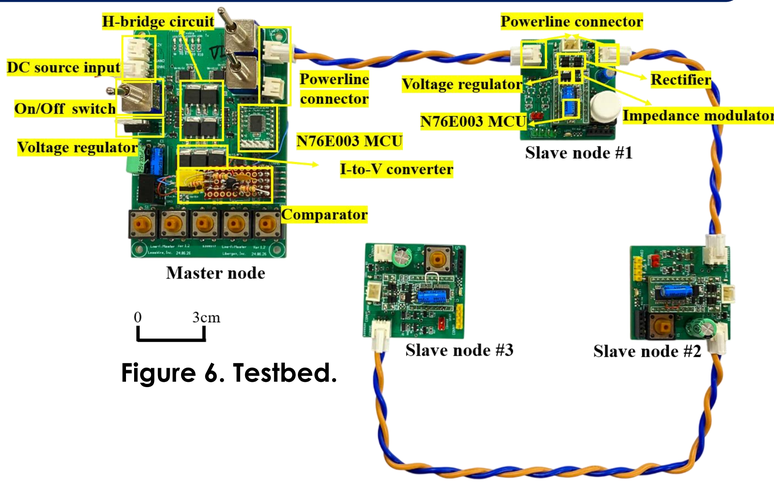

Figure 6. Testbed.

Experimental Results

A. Observed Waveform

- Oscilloscope: PicoScope 2000 Series
- Approximately over 100 kbps throughput

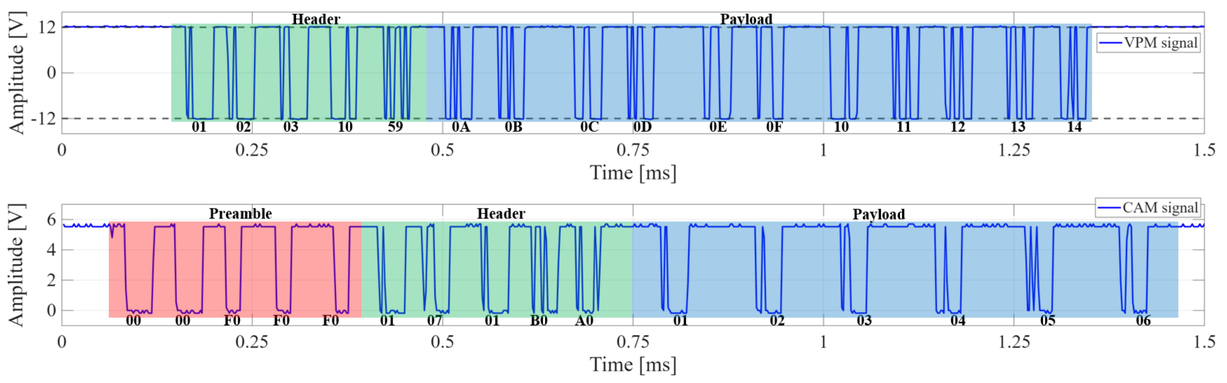

Figure 7. VPM and CAM waveform.

B. Communication Logs

- Frame Exchange (Polling)
  - Request frame by Master to Slaves in order
  - Uplink by Slave only when receiving request with right address

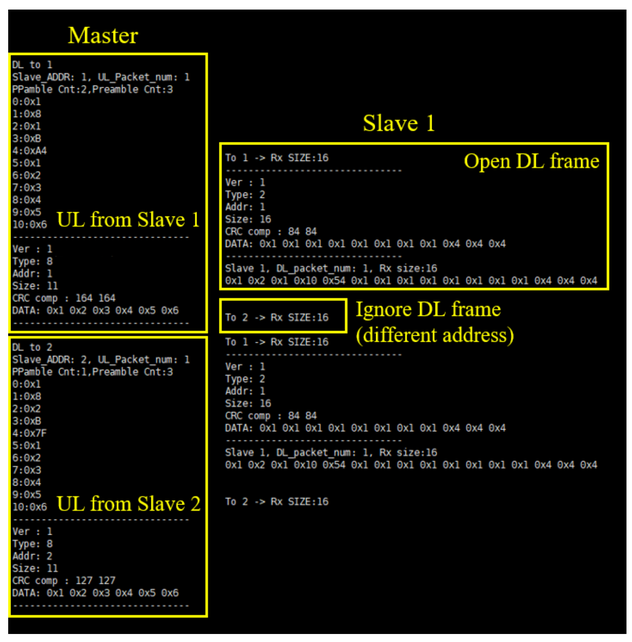

Figure 8. Frame logs from Master and Slave 1.

Reference

[1] IEEE, "IEEE Standard for DC Power Transmission and Communication to DC Loads," IEEE Std 2847-2021, 2021.

[2] Communication systems for meters and remote reading of meters– Part 2: Physical and link layer, European Committee for Standardization (CEN) Std. EN 13757-2, 2004.

[3] Yamar Electronics, "SIG100 Evaluation Board Manual — SIG100 IC- Yamar," 2025.

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