Agenda

- PL Communications – General Requirements
- Echelon overview
- LONWORKS® Power Line Communication (PLC)
  - General overview
  - 4 generations of PLC products – maturity and cost
- Summary
Power lines are designed for delivering power not data

- Common issues facing PL communications
  - High noise
  - High attenuation
  - Signal distortion

- It takes a sophisticated device to communicate reliably
Attenuation is caused by

- Voltage dividers
  - Wiring inductance
  - Shunt loads
  - Panel loading
  - EMC capacitors

- Phase coupling loss

$$\text{Attenuation (dB)} = 20 \times \log_{10} \left( \frac{V_{\text{transmit}}}{V_{\text{receive}}} \right)$$
Power Line Attenuation in Homes – Reference Data

- World wide in-home attenuation data
  - 169 houses, apartments and condos in 5 countries
  - 1,889 randomly selected socket pairs

But, attenuation is only part of the story...

- 96% are ≤54dB Attenuation
- 99.9% are ≤78dB Attenuation
Importance of Impulse Noise Cancellation

- Digital Signal Processing can overcome impulse noise limitations of narrow band systems

Conventional PLL based Narrow Band Receiver

DSP Receiver with:
- Dual Carrier Operation
- Impulse Noise Cancellation
- Distortion Correction
Other Noise Sources

- Dimmers
  - Triac controlled lights
  - Produce large impulses at 100Hz or 120Hz

- Switching power supplies
  - Fundamentals at 20kHz to >1MHz
  - Rich in harmonics

- Power line communicating devices
  - $3V_{pp}$ to $7V_{pp}$ from 150kHz to 400kHz

- Universal series wound motors
  - Vacuum cleaners, kitchen appliances, drills
  - High repetition rate impulses
### Competing Technology Performance Summary

<table>
<thead>
<tr>
<th>Impairment Type</th>
<th>Conventional Narrowband</th>
<th>Spread Spectrum</th>
<th>Echelon PL 31x0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimmers</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Motors</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Switching Supplies</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Intercoms</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>TV’s</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
</tr>
</tbody>
</table>

Echelon PL 31x0 Series performs well with all impairments!
Regulatory Considerations

- North American Regulations:

- CENELEC Regulations (Europe):
Echelon – Well Established Supplier

- Founded 1988
- Over 300 employees
- 10 offices worldwide
- NASDAQ listed: ELON
- Invented the LONWORKS platform
- Multi-industry, multi-national standard
- Millions of devices installed
  - Thousands of manufacturers
  - Integrators
  - Educational and Governmental institutions
Echelon Power Line (PL) Communications Heritage

- Pioneer in power line (PL) communications for over 20 years
- Designed to work in industrial environments with tough noise sources including dimmers, switching power supplies & variable frequency drives
- Millions of LONWORKS PLC devices installed worldwide
  - Home automation
  - Utilities
  - Street lighting
  - Transportation
  - Industrial applications
- Over 35 million meters around the world using Echelon power line
- 100 thousand homes in Korea using Echelon power line devices
- Home energy solutions in several countries in Europe
- Core technology for McDonald’s kitchen equipment networking
- One of the largest US utilities - Duke Energy
- Philips, LGE, Landis+Gyr in various applications
Echelon’s Narrow Band Power Line Transceiver

- ANSI/CEA 709.2 compliant power line transceiver
- Reliable power line technology
  - Unique dual carrier operation
  - Patented low-overhead error correction
  - DSP based noise cancellation and distortion correction
  - Two high power amplifier options

Worldwide power line acceptance
- Complies with FCC, Industry Canada, Japan MPT, Korean, Chinese, Taiwan and European CENELEC regulations
- Unique dual carrier frequency mode
  - Automatically switches to a secondary frequency when primary frequency is blocked by noise
  - Frequencies chosen to prevent harmonics from blocking both primary and secondary frequencies
  - Ensures that packets are received reliably even in the presence of noise
Echelon PL Technology Coexistence

- Operates in 110-140KHz bands (C-band)
  - Completely separate from BPL technologies that communicate in the MHz frequency band
- Complies with EN 50065-1 for signaling on low-voltage electrical installations in the frequency range 3 kHz – 148.5 kHz
  - Specifics include adherence with frequency bands, electromagnetic disturbances and other requirements to coexist with other technologies
- Coexists with spread spectrum BPL technologies like HomePlug AV
- Coexists with wireless technologies - Wi-Fi and 802.15.4
Echelon PL Technology Maturity & Cost

PLT-10A/PLT-30
PLT-20 / 21
PLT-22

< $10
< $15
< $5

1993
1999
2003
Future

PL 31x0
4th Generation
PLC Solution
from Echelon

All PL transceivers (except PLT-10A/PLT-30) backward compatible with older transceivers

Next Generation PLC chip (further cost reduced)
PL Smart Transceiver Overview

- Works on any AC/DC powered or even unpowered wires
- Integrated microcontroller for application program
- Optimal speed for reliable controls - 5.4Kbps (~14 packets/sec)
- Communication Protocol included in system firmware
- Unique low-overhead error correction
- Digital signal processing (DSP) based noise cancellation and distortion correction
- High power amplifier leading to high signal-to-noise ratio (SNR)
PL 31x0 Power Line Smart Transceivers

Neuron® core with 3 CPUs
- MAC processor
- Network Processor
- Application Processor

Memory For
- Application program
- Network management
- ANSI-709.1 compliant protocol
- Unique 48-bit Neuron ID

Proven Power Line Technology
- Installed base (millions)
- Backward compatible with previous generation PLT-20/21/22 transceivers
PL 31x0 Smart Transceivers - Overview

**PL 3120 / PL 3170 IC**
- 38 pin TSSOP package
- 4K Embedded EEPROM for modest programs
- Can be network processor for optional host processor

**PL 3150 IC**
- 64 pin LQFP package
- 0.5K Embedded EEPROM
- External memory bus for larger programs

Features
- 2K Bytes embedded RAM for variable storage and packet buffering
- Full Duplex hardware UART SPI serial interfaces
- 12 I/O pins with 38 programmable standard I/O modes
- Advanced DSP-based narrow band power line technology
PL 3170 Smart Transceiver – Main Features

• PL 3170 IC
  □ CENELEC C-band operation only
  □ Includes Interoperable Self Installation (ISI) functions built into the firmware stored in ROM
  □ Full 4KB EEPROM is available for user application
Echelon PL Technology Speed

- Speed optimal for reliable controls
- 5.4Kbps
- ~14 packets/second
- Includes all higher layer headers, address and CRC information
Same Advanced Technology Supports Two Bands

- Utility Applications
  - A-Band

- Consumer Applications
  - C-Band

**A-Band**
- Secondary 75kHz
- Primary 86kHz

**C-Band**
- Secondary 115kHz
- Primary 132kHz

PL 31x0 chips include selectable C-Band CENELEC access protocol.
Reliable power line communication requires:

- A sophisticated transceiver
- A well crafted solution
- Applicable system architecture
A complete power line solution consists of:
- PL 31x0 chip
- Reference design
- Coupling circuit
- Power supply
- Application electronics

Correct design practice is imperative to achieving the high communication performance of the PL 31x0 Smart Transceiver.
PLC System Cost Components

- PLC transceiver
- Microcontroller (for protocol & application)
- Coupling circuit
- External components
- Protocol development

Node with PL Communication
## Echelon PL Node Cost - Cost Effective Solution

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Non Isolated Coupling</th>
<th>Isolated Coupling</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLC Transceiver + Microcontroller (Echelon PL 3120)</td>
<td>$4.50</td>
<td>$4.50</td>
<td>Higher level of integration</td>
</tr>
</tbody>
</table>
| Coupling Circuit (to 110VAC – 240VAC Mains)** | $0.37 | $0.57 | Supports non-isolated coupling that could be useful with the J1772 connector. 

Most other PLC technologies do not support non-isolated coupling |
| External Components | $0.50 | $0.50 | Minimize external components (less than 50) 

Compared to over 100 external components required by other PLC technology |
| Protocol | (Included) | (Included) | Highly reliable protocol embedded in each device |
| ** High Volume Pricing  
** Coupling to DC is less expensive |

| Total | $5.37* | $5.57* |
Echelon PL Solution Benefits - Cost Effective & Highly Reliable

- Complete protocol comes embedded in each chip
  - Saves protocol development effort/cost
  - Straightforward & easy to use device interoperability model
- Features in the protocol that make communication very reliable
  - CRC error checking
  - Error correction
  - Collision avoidance
  - Acknowledged or repeated messaging
- Minimized maintenance cost due to increased reliability
Pre-verified PL 31x0 discrete external circuit designs (DSK)

8 versions available covering variations in:
- Number of printed circuit board layers
- Single or 2-sided component mounting
- PCB size and aspect ratio
- PL 3120, PL 3150 or PL 3170 Smart Transceivers
- Standard 1A p-p or optional 2A p-p TX amplifier

Each reference design includes
- Schematic (OrCAD and PDF formats)
- Bill of material (Word and PDF formats)
- Layout files (Gerber, P-CAD, OrCAD, PADS, Altium, DXF, and PDF formats)
Example PL 31x0 Reference Designs

Parts on 1 side, 2 layer PCB, TX=1Ap-p
Parts on 2 sides, 4 layer PCB, TX=1Ap-p
Parts on 1 side, 2 layer PCB, TX=1Ap-p

(Available in SIP and embedded versions)

Design using PL 3150 Chip
Parts on 1 side, 2 layer PCB, TX=1Ap-p
Parts on 2 sides, 4 layer PCB, TX=1Ap-p
Parts on 2 sides, 4 layer PCB, TX=2Ap-p

Also available, but not shown, is a PL 3150, 2Ap-p, 4 layer design
## PL Reference Designs List

<table>
<thead>
<tr>
<th>Reference Design Number</th>
<th>PL Smart Transceiver Model</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td>3120 or 3170</td>
<td>23x63mm</td>
</tr>
<tr>
<td>1201</td>
<td>3120 or 3170</td>
<td>20x38mm</td>
</tr>
<tr>
<td>1204</td>
<td>3120 or 3170</td>
<td>33x38mm</td>
</tr>
<tr>
<td>1205</td>
<td>3150</td>
<td>36x49mm</td>
</tr>
<tr>
<td>1209</td>
<td>3120 or 3170 (2Ap-p)</td>
<td>31x53mm</td>
</tr>
<tr>
<td>1217</td>
<td>3120 or 3170</td>
<td>17x38mm</td>
</tr>
<tr>
<td>1218</td>
<td>3150 (2Ap-p)</td>
<td>48x66mm</td>
</tr>
<tr>
<td>1255</td>
<td>3120 or 3170</td>
<td>17x28mm</td>
</tr>
</tbody>
</table>
Value of Reference Designs

- Each reference design implements
  - A high sensitivity circuit that is as layout sensitive as RF circuits
  - An amplifier capable of driving $\geq 1$App – by using careful thermal design and low impedance traces
- Each reference design has been thoroughly checked
  - Hundreds of hours of testing at temperature and voltage extremes
  - Characteristics of PCB traces calculated and checked
  - Monte Carlo simulation of thousands of instances covering production, temperature and voltage variation

Customers can avoid lengthy design cycles by porting the reference design into their application
PL Security Support

- Authentication built into LONWORKS platform
  - Each device within a LONWORKS network includes authentication

Sender
Key used to transform challenge

Authenticated Message

64 bit Random Challenge

Receiver
Key used to compare response to value transformed locally

Challenge Response

Acknowledgement

- Encryption, can be added into application layer if needed
Proper product design is imperative to maintain the high communication performance of the PL 31x0 transceiver

- Faulty products can work in typical environments but fail to communicate under worst-case conditions in the field
- Cost incurred for design review can offset costly failures later on

Design of ALL PL 31x0 based products must be verified

- Incorporate a precise copy of one of the PL 31x0 Reference Designs
- Verify the checklist in Smart Transceiver data book Appendix B
- Submit pre-production design for a confidential design review
- Check performance using the procedure given in Chapter 7 of the Smart Transceiver data book
Design Review Service

- Pre-production design review service available for any design using Echelon parts
  - Includes review of schematics, layout, and B.O.M.
- Helps get the design correct the first time and reduces the chances of expensive mistakes
- Hundreds of design reviews done for customers over last 8 years
Value of Design Review Benefits

- Reduced time-to-market.
  - We can identify potential problems that customers may not find until the product is in the field
- Helps each customer “get it right the first time”
  - We have reviewed many designs and can help to avoid costly mistakes
<table>
<thead>
<tr>
<th>Resource</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini EVK Evaluation Kit</td>
<td>Best tool for evaluating the LONWORKS platform</td>
</tr>
<tr>
<td>NodeBuilder Development Tool</td>
<td>Fastest, simplest, and most economical way to create new LONWORKS devices and plug-ins</td>
</tr>
<tr>
<td>PLCA-22 Communication Analyzer</td>
<td>Measures packet error rate, noise on the channel, signal attenuation, and many other variables</td>
</tr>
<tr>
<td>Development Support Kit (DSK)</td>
<td>Variety of reference designs in PL DSK includes schematics and layouts for external discreet circuitry</td>
</tr>
</tbody>
</table>
Availability

- PL 31x0 Smart Transceivers shipping for ~ 8 years
- Successfully tested and implemented in industrial, commercial, utility, residential and transportation applications around the world
Summary - Echelon PL Smart Transceivers

- A highly integrated, low-cost solution
- Proven technology with unmatched reliability
- Huge global installed base (Millions of Nodes)