Lighting control protocol
Overall update

- DMX512 – first boards are being manufactured, documentation being compiled
- Dali – Implementation in progress on C2000 and MSP430 (no availability date)
- 2.4GHZ wireless – EZ RF demo with TPS62260
- PLC – BPSK demo code and HW available (HW refresh shortly)
- Looking at: LonStack, KNX(-RF), W-DMX…
Dali
Dali lighting schematic
DALI bus system
Dali specifics

• Uses TPS62260, MSP430
• Example code on MSP430 available
• Example HW implementation available:
  – Schematics
  – Gerbers
  – Board availability:
    • TPS62260-EVM338 in stock
    • Dali Phy?
Overview

DALI Controller

PHY

PHY
DALI Controller

- OSRAM DALI MuLTI 3
  - Switch contact input
    - On/Off switch
    - Press and hold for ramp
  - Lighting Regulation
  - DALI Controller
    - Broadcast messaging
    - Direct Arc Level Controls
DALI and MSP430 interface
MSP430 microcontroller
DALI Slave Unit
Dali system prototype

OSRAM DALI controller

TPS62260 EVM with MSP2131

DALI PHY for MSP430
DALI message Format

**DALI Master Message**

**DALI Slave Message**
Table A-1. Standard Commands

<table>
<thead>
<tr>
<th>Command Value</th>
<th>Description</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>Extinguish the lamp without fading</td>
<td></td>
</tr>
<tr>
<td>01</td>
<td>DIm up 200 ms using the selected fade rate</td>
<td></td>
</tr>
<tr>
<td>02</td>
<td>DIm down 200 ms using the selected fade rate</td>
<td></td>
</tr>
<tr>
<td>03</td>
<td>Set the actual arc power level one step higher without fading</td>
<td></td>
</tr>
<tr>
<td>04</td>
<td>Set the actual arc power level one step lower without fading</td>
<td></td>
</tr>
<tr>
<td>05</td>
<td>Set the actual arc power level to the maximum value</td>
<td></td>
</tr>
<tr>
<td>06</td>
<td>Set the actual arc power level to the minimum value</td>
<td></td>
</tr>
<tr>
<td>07</td>
<td>Set the actual arc power level one step lower without fading</td>
<td></td>
</tr>
<tr>
<td>08</td>
<td>Set the actual arc power level one step higher without fading</td>
<td></td>
</tr>
<tr>
<td>10-80scene</td>
<td>Set the light level to the value stored for the selected scene</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Reset the parameters to default settings</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Store the current light level in the DTR</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Store the value in the DTR as the maximum level</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Store the value in the DTR as the minimum level</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Store the value in the DTR as the system failure level</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Store the value in the DTR as the power on level</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Store the value in the DTR as the fade time</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Store the value in the DTR as the fade rate</td>
<td></td>
</tr>
<tr>
<td>40+8scene</td>
<td>Store the value in the DTR as the selected scene</td>
<td></td>
</tr>
<tr>
<td>50+8scene</td>
<td>Remove the selected scene from the slave unit</td>
<td></td>
</tr>
<tr>
<td>60+8group</td>
<td>Add the slave unit to the selected group</td>
<td></td>
</tr>
<tr>
<td>70+8group</td>
<td>Remove the slave unit from the selected group</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>Store the value in the DTR as a short address</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>Returns the status of the slave as XX</td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>Check if the slave is working</td>
<td>YES/NO</td>
</tr>
<tr>
<td>92</td>
<td>Check if there is a lamp failure</td>
<td>YES/NO</td>
</tr>
<tr>
<td>93</td>
<td>Check if the lamp is operating</td>
<td>YES/NO</td>
</tr>
<tr>
<td>94</td>
<td>Check if the slave has received a level out of limit</td>
<td></td>
</tr>
</tbody>
</table>
### DALI special commands

<table>
<thead>
<tr>
<th>Special Command Value</th>
<th>Description</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 00</td>
<td>All special mode processes shall be terminated</td>
<td>–</td>
</tr>
<tr>
<td>A3 XX</td>
<td>Store value XX in the DTR</td>
<td>–</td>
</tr>
<tr>
<td>A5 XX</td>
<td>Initialize addressing commands for slaves with address XX</td>
<td>–</td>
</tr>
<tr>
<td>A7 00</td>
<td>Generate a new random address</td>
<td>–</td>
</tr>
<tr>
<td>A9 00</td>
<td>Compare the random address with the search address</td>
<td>–</td>
</tr>
<tr>
<td>AB 00</td>
<td>Withdraw from the compare process</td>
<td>–</td>
</tr>
<tr>
<td>B1 HH</td>
<td>Store value HH as the high bits of the search address</td>
<td>–</td>
</tr>
<tr>
<td>B3 MM</td>
<td>Store value MM as the middle bits of the search address</td>
<td>–</td>
</tr>
<tr>
<td>B5 LL</td>
<td>Store value LL as the lower bits of the search address</td>
<td>–</td>
</tr>
<tr>
<td>B7 XX</td>
<td>Program the selected slave with short address XX</td>
<td>–</td>
</tr>
<tr>
<td>B9 XX</td>
<td>Check if the selected slave has short address XX</td>
<td>YES/NO</td>
</tr>
<tr>
<td>BB 00</td>
<td>The selected slave returns its short address XX</td>
<td>XX</td>
</tr>
<tr>
<td>ED 00</td>
<td>Go into physical selection mode</td>
<td>–</td>
</tr>
</tbody>
</table>
2.4GHz proprietary
SimpliciTI 2.4GHz specifics

- Uses TPS62260, MSP430 and CC2500
- Based on point to point implementation (star network possible)
- Example code on MSP430 and CC2500 available:
  - Point to point
  - Send index information corresponding to a pre-recorded R/G/B dimming value
- Example HW implementation available:
  - Schematics
  - Gerbers
  - Board availability: in stock
SimpliciTI network

- Low Power: a TI proprietary low-power RF network protocol
- Low Cost: uses < 8K FLASH, 1K RAM depending on configuration
- Flexible: simple star w/ extendor and/or p2p communication
- Simple: Utilizes a very basic core API
- Versatile: MSP430+CC110x/2500, CC1110/2510, CC1111/CC2511, CC2430, CC2520
- Low Power: Supports sleeping devices
TPS62260&CC2500 - 2.4GHz
MSP430 Schematic

JTAG Connector

eZ430-RF Connector
TPS62260 Schematic

3x TPS62260
In 300mA Constant Current Source Configuration

3.3V Regulator
EZ430 - RF2500

- Star network stack included
- Includes 2 RF targets & battery expansion board
Product portfolio today
Remote control implementation

- **USITT DMX512-A** is an Asynchronous Serial Digital Data Transmission Standard for Controlling Lighting Equipment and Accessories used almost in all professional light equipment.

- It is designed to carry repetitive control data from a single controller to one or more receivers up to 300m - 455m (1km theoretical maximum).

- Fast data transmission at a typical bit rate of 250 kbit/s, into packets of up to 513 bytes. This enables a refresh rate of 44Hz for a 513-bytes packet.

- Support for up to 512 channels. Up to 32 devices can be connected on a serial data link in a daisy chain scheme.
Data Link Topology

Single active differential line driver

DMX out: XLR female 3-pin connector

DMX in: XLR male 3-pin connector

DMX controlled Device #1

DMX controlled Device #n

Differential line receivers

Line termination
State Machine Execution Time

one DMX byte (0x00) with 2 stop bits

DMX Signal

Cycle for setting the PWM - Longest execution time

State machine execution time
USCI Module Clock Timing

Graph showing 250kBits/sec data rate with a bit time indication in the serial data stream.
DMX512 specifics

• Example code on MSP430 available free of charge (no royalty, no certification required)

• Example HW implementation available:
  – Schematic
  – Gerber
  – Board availability : short supply for now (hand made)
Implementation

Pin 1, 2, 3: +12V
Pin 4, 5, 6: GND
Pin 7: -DMX
Pin 8: +DMX
RF2500T Connector
Male Connector
XLR-DMX512 Connector
Daughter card
RGB-DMX512 Prototype
Female Connector
12V DC Connector
Implementation

- Daisy-Chain Possibility for RGB-DMX512 Prototypes
- RGB-DMX512 Prototype
- XLR-DMX512 Connector Daughter card
DMX512 BOM

- DC/DC CC per LED or LED string (3x TPS62110)
- Shunt voltage reference (3x TL431)
- Commergy AC Adapter Power Supply TBD
- 5V / 3.3V LDO (TPS71550)
- RS485 (SN65HVD3082E)
- DMX512 converter to 3xPWM (MSP430F2274)
Execution time of overflow ISR
Schematics
Schematics
Upcoming development tools

• Same principle as Dali and CC2500

• Using TPS62260/MSP430F2131+PHY board (RS485)
Narrow Band PLC modem solution on TI MCU
Qualify the PLC modem opportunity

• Bit rate targeted? → We focus here on narrow band solution (kilo bits per second).

• Which frequency band will your PLC application use (A, B, C, D, FCC..)

• Which modulation will you use (BPSK, SFSK, OFDM, OTDM, open to any ) What is the application that you are developing? (metering, street lighting, home automation, solar..)

• Do you need to comply to any standards? (PLAN, PRIME, Home Plug

• Are you OK with a black box solution for PLC modem

• Do you wish to integrate the application on the same device as well?
Agenda

• Power Line Communication definition
• Targeted application
• Implementation the 32-bit F28x MCU
• Software solution roadmap
• Incoming tools
PLC modem applications
What is power line communication?

- Communication without any additional cables, wires or radio links!
- The ‘mains’ i.e. the power-line is used as the communication media.
PLC Modem modulation

Power line communication
- Wired technology
- Use of the electricity networks for data transmission

Indoor
- After the residential counter
- Reserved for in-house communication and maintenance (mid-speed) or internet access within the building

Outdoor
- Last mile access (from transformer to the house)
- Requires the authorization of energy supplier
Frequency bands for PLC in Europe
- defined by the CENELEC:
  - The range of 3 kHz – 9 kHz and band A are exclusively for energy providers.
  - Bands B, C, D are open for end-user applications.
  - Bands A, B and D are protocol free
  - Band C is regulated – CSMA access

Frequency bands for PLC in USA
- Single wide band – from 150 to 450 kHz
- No access protocol
- FFC band 10kHz – 490kHz

Frequency bands for PLC in Japan
- ARIB band 10kHz – 450kHz
32-bit MCU focuses on narrowband

- **Low Speed (bps)**
  - TurtleTech/TWACS
    - <10 Hz modulation, freq division multiplexing, ~3bits/hour data rate.
    - Utility automatic meter reading. Very long reach.
  - X-10
    - Modulate at 120 kHz for 1 msec at 60 Hz zero-cross
    - Aimed at home automation, 120 b/sec.
  - Universal Power-Line Bus (UPB)
    - Pulse position modulation on each half sine wave
    - Aimed at home automation, 240 b/sec

- **Mid Speed (kbps)**
  - FSK (ST7537/ST7538)
  - Konnex (KNX)
  - SFSK
  - ITRAN 800 (CENELEC)
  - CEA-709.2 (Echelon/LonWorks)
  - EIA-600 (CEBus/Intellon)
  - ITRAN 800 (US FCC)
  - OFDM (IEC 61000-3)

- **High Speed (Mbps)**
  - Home Plug
    - Broadband over power lines, 1.8 Mb/s
    - OFDM modulation. Subcarrier frequencies from 4.5 to 20.7 MHz
  - DS2

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**Addressable by TI F28x™ 32-bit MCU**

**Software flexible solution**

**Targeted Application:**
- Home automation
- Smart appliance
- Control Systems
- Electricity meter
- Lighting
- Solar
- Drives
PLC Narrowband applications

In-house communication
• Smart home appliances: monitoring, energy management,…

Outdoor
• Urban facilities:
  – Lighting/streetlighting and ballast system
  – Traffic light
  – Industrial: solar field, drives.
• Automatic Meter Management (AMM):
  – Automatic Meter Read
  – Advanced features: Provider can turn-on/off electricity supply / monitoring, prepaid metering without smart cards
TI offers a complete solution
F28x™ 32-bit MCU PLC solution

• Ready and flexible for future standards:
  – Resources left for evolving, more demanding modulation schemes.
  – New code = new standard with the same hardware!

• Additional functions can be implemented in same processor:
  – PFC, solar, lighting, power monitoring, inverters, motor control,…
TMS320F28x™ 32-bit MCU

• Single chip programmable and flexible solution that supports:
  – PHY layer
  – MAC layer
  – Application layers
  – Security (Data: encryption, IP: flash protection)
  – Same H/W platform for low-cost S-FSK to OFDM migration path

• Flexible software programmable solution:
  – Multi protocol support
  – Field update options
  – Support standards evolution

• Easy interfacing with Metrology and wireless bus
Electricity meter example
Entire PLC/Ballast system uses just 3 ICs: DSP, line driver and low noise amplifier!
Lighting example
End-to-end system description

Control

WWW

Concentrator

AC 85-265 V

AC/DC & PFC
PLC

Isolation

Multi-String LED Drivers

Lighting Control

GPRS
WLAN
ETH
MCU
PLC
TMS320F28x™ 32-bit MCU key benefits

PERFORMANCE
- up to 150 MHz CPU
- new HW Control Law Accelerator on Piccolo
  - 120 MIPS equivalent performance
  - OFDM reduced power consumption (400mW)
- Data security flexibility
- Multi-protocol support

FLEXIBILITY
- SW compatibility across all F280xx
  - Easy migration across device family
  - Leverage investments
- Interoperability via SW

INTEGRATION
- 12-bit ratio-metric ADC with individual channel triggers
  - More accurate resolution - limit drift errors
- 3 Analog comparators with 10-bit reference
  - Zero crossing detection/synchronization
- Dual On-chip oscillators
  - Intelligent clocking system monitoring
- On-chip Flash up to 512kB

COST OPTIMIZATION
- Single 3.3V supply available in the family
  - Cost and board space saving
  - Save 1.8V power and SVS
- Multiple package options down to 32-pin
  - Board space saving

Piccolo device block diagram example
OPA564 – line driver 1.5A, 26V, 17MHz

Features
- Single or Dual Supply: \( \pm3.5V(7V) \) to \( \pm13V(26V) \)
- Large Output Swing: \( 22Vpp \) at \( 1.5A \) (24V supply)
- Thermal and over-current warning
- Adjustable current limit
- Output Enable/Disable Control
- \( 20V/\mu s \) slew rate

Benefits
- Enables design flexibility
- Desirable for demanding applications
- Protects in over-temp and over-current conditions
- Provides accurate, user selected, current limit
- Saves power and protects the load
- Allows 230kHz full-power bandwidth and excellent linearity
PGA112 – RRIO, Single Ended, 2ch mux

Features
• Zero Drift and RRIO
• Binary gain : 1, 2, 4, 8, 16, 32, 64, 128
• 4 internal calibration channels
• Software shutdown (Iq < 4μA)
• AVDD and DVDD supply in 2.2V to 5.5V range
• VCLAMP pin to clamp output
• Low noise, low Ib, low offset, low Iq
• Extended -40°C to +125°C
• 10-MSOP Package w/ SPI interface

Benefits
• Best for low offset, RRIO, wide BW, single supply apps
• Allows for optimum A/D range matching for a wide variety of input signal amplitudes
• Allows easy system calibration for gain and offset
• Ideal for power sensitive applications
• Perfect for mixed voltage systems

Texas Instruments
TI PLC solution roadmap

Solution Status
- Production
- On Development
- Future

Development vectors

Lab demo PLC code
- Open project
- 1.2kps FSK (F2808)
- 5.44kps BPSK (F2812)
- PHY Layer, minimal MAC
- A Band

PLC Production Code
- Up to 76.8kbps OFDM PHY
- Integrated MAC layer
- Compatible with EN 500065, IEC 61000-3

Future

2008
- Cenelec A band SFSK/OFDM – F2808 – June 09
- A and B band F2808 SFSK/OFDM – September 09

2Q09
- Piccolo migration – 4Q09

4Q09
- Cenelec A band SFSK/OFDM – F2808 – June 09
- A and B band F2808 SFSK/OFDM – September 09
- Piccolo migration – 4Q09

2010
- Cenelec A band SFSK/OFDM – F2808 – June 09
- A and B band F2808 SFSK/OFDM – September 09
- Piccolo migration – 4Q09

PLC Production Code
- PRIME
- OFDM/SFSK
- Minimum Application layer available

Industrial PLC

PLC Production Code
- Open project
- Multi modulation, Multi band
- OFDM, FSK, DCSK, others
- API Packages for PHY Layer
- Enables application layer development
- Optimized AFE and board
- Full F28x product family support

Texas Instruments
PLC Modem development Kit (PLC-DK) – comes with
- 2 Modem s
- 2 PLC System On Module
- Cables (USB and power)
- GUI and documentations
- Plastic cover box
- Part # TMDSPLCKITV1
- SRP $450
- Available end of June

PLC System On Module (SoM)
- TMS320F280x 32-bit Micro-controller based
- I2C, SPI, SCI ports available for Host controller
- Gerber and Schematics available

- Robust Narrowband communication over low-voltage power line
- OFDM and S-FSK
- Data rates up to 76.8 kbps for one phase
- Phase selection provided
- Encapsulated libraries solution with interface to host controller (I2C, SPI, SCI)
- Compatible to standards EN50065 (Cenelec), IEC 61000-3
- Operating frequency range 24-94.5kHz (Cenelec A band)
- B band support under development
- Easy integration into end-point or network devices of AMR/AMI systems
- Easy integration in industrial application (lighting, solar..)
- NRE and Royalties FREE
TI PLC development path

Prototype Phase

- **Experience and demo on the PLC-DK**
- **Interface with application**
  - Interfaces available for host controller using serial port (I2C, SPI, SCI)
- **Integrate into the final application**
  - Option 1: Plug PLC SoM in application (interface definition provided)
  - Option 2: Merge SoM in application (schematic and Gerger File Available)