A Sensor Network for Buildings Based on the DALI Bus

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Abstract— This paper discusses a method of expanding the standard DALI lighting network into a general purpose sensor network. The DALI (Digital Addressable Lighting Interface) was originally intended for communication between a controller and building lighting devices. It is a two-wire bus which allows control of individual lights on the network. A redesigned DALI controller supports both standard DALI devices and environmental sensors on the same bus, thus providing the economy of using a single bus for building lighting, HVAC and environmental monitoring and control. An IEEE 1451 TEDS and method of interfacing with the more general IEEE 1451.0 protocol is provided.

***Index Terms*— DALI, sensor, protocol, TEDS**

I. Introduction

The DALI bus [1] was designed as a protocol purely for lighting control. It is effective for fading, scene selection and detecting faulty light sources. The DALI system operates in the master-slave mode [2]: one master controller can control up to 64 DALI slave units. The communication is an asynchronous, half-duplex, serial protocol over a two-wire bus. It uses bi-phase encoding and Baud rate is 1200 bps. An advantage is that the power (12+ volts with a 250mA limit) and data for the slaves or remotes, including sensors, are both carried over these two wires.

It is unnecessarily costly to build separate networks for lighting, HVAC, alarm and environmental monitoring systems in the same building (Fig. 1).

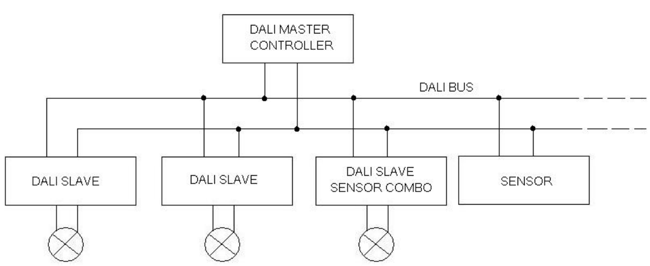

Fig. 1. Block Diagram for the Expanded DALI Bus System

To extend the existing DALI bus and hardware interface to communicate with general purpose sensors, three problems must be taken into account: (1) the communication between sensors and controller must not interfere with the standard DALI devices, (2) the sensor communication protocol utilizing the same hardware must provide more functions than the standard lighting DALI protocol and (3) the standard DALI commands must be compatible with the more universal IEEE 1451 digital transducer format.

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II. Approach

A. *Physical Layer*

Our choice for making the sensor communication compatible with DALI protocol (IEC60929) [3] is to change the bit stream encoding by using faster Baud rate and a different data format for the sensor communication. The pulse width of standard DALI data is either 0.833ms or 1.667ms. If the pulse width of the sensor protocol data is less than 0.833ms, then the standard DALI devices communication will ignore these pulses and thus not be disturbed.

The encoding method chosen is a combination of NRZ (Non Return to Zero) encoding and MPE (Manchester Phase Encoding) at a data rate of 9600 bps. With NRZ, logic '1' bit is sent as a high level and logic '0' bit is sent as a low level. The receiver may lose synchronization when using NRZ to encode a long runs of bit stream in high Baud rate, also the consecutive bits with the same value (no changes in voltage) will generate a wide duration of '0' or '1' pulse in DALI bus which may interfere with standard DALI devices. In our design, bit7 of every byte is encoded in MPE and the rest of the bits are encoded in NRZ. A narrow MPE pulse (bit7) always appears before the NRZ bits (bit0-bit6); this will help the receiver to synchronize every byte and avoid the wide pulse appearing in the DALI bus. An alternative method using MPE for all bits at 4800 bps was also successfully tested.

B. *Data Transfer Layer*

In DALI protocol, the master controller provides power for DALI bus, and thus the remote or slave units. The idle state of DALI bus is in high level voltage ('1') and the DALI interface for slave unit is a current sink. The slave unit pulls the DALI bus to almost 0 for logic '0'. The '0' bit always overrides the '1' bit when '0' and '1' appear in the DALI bus at the same time. The slave unit incorporates both transmission and receive lines which means it can check the state of DALI bus when it is sending out the data bit. By taking advantage of these hardware characteristics (Figs. 2 and 3), it is easy to upgrade the simple master-slave mode DALI protocol to an advanced communication protocol in transfer layer.

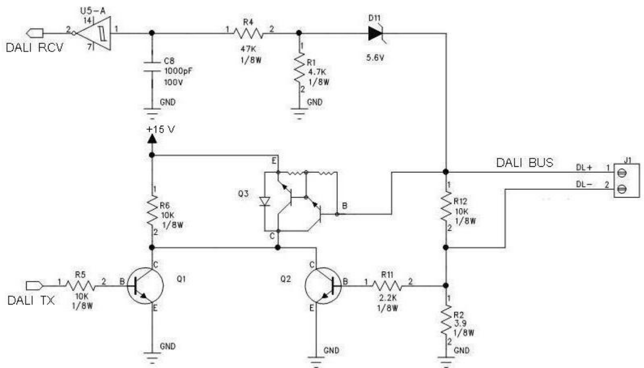

Fig. 2. DALI TX/RCV Circuit on Master Controller

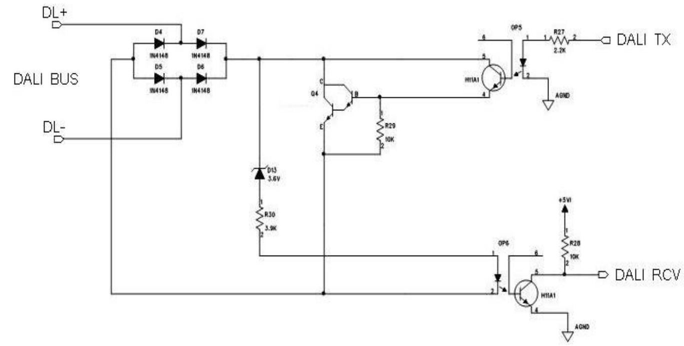

Fig. 3. DALI TX/RCV Circuit on Slave Unit

Table 1: Message Frame Format in the Sensor Communication Protocol

Control Field		Data Field		CRC Field	ACK Filed
Arbitration (1-byte)	Description + Length (1byte)	Slave ID (1 byte)	Command/Data (N bytes)	CRC (2 bytes)	FF hex (1 byte)

Table 2: Master Requests Illumination and Temperature from Slave

Data Field			
Slave address	0x01(inquiry Command)	Illumination code	Temperature code

Table 3: Slave Response (Illumination and Temperature Data to Master)

Data Field					
Slave address	0x01(Answer Inquiry)	Illumination code	Illumination Data	Temperature code	Temperature Data

The transfer layer of the sensor communication protocol has these functions:

- Arbitration
- Acknowledgment
- Error Detection
- Message Validation
- Message Framing

The message frame in the sensor communication protocol has four fields: (Table 1). Bit7 of the arbitration byte is the start bit and bit6-0 are used for bus arbitration (priority level) The unit can monitor the state of bus and detects bus collision, and if so, stop sending for a random time and resend the message. A standard DALI message has the highest priority on the bus because its start bit (0.833ms low level voltage pulse) is longer than the duration of the arbitration byte for a sensor message.

The second byte in the control field contains the description and length information. The description bits indicate whether the frame has an active or passive message. The length here is the byte number of the data field, which is less than 64. The data field format may be ASCII or HEX. If a CRC error is detected, the data is ignored. The ACK byte also acts as the “end of frame” flag.

Examples of the Data field for a sensor read are shown in Tables 2 and 3.

C. *IEEE 1451 TEDS*

The sensors have a TEDS (8 bytes) with the Basic IEEE 1451.4 (Dot 4) format. This is referenced by a specific command. The master is able to convert into Dot0 format (TEDS and data) and thus is compatible with the general IEEE 1451.0 format [4].

D. *Applications Examples*

Examples of sensors tested include a temperature (-20 ^{o}C to 100 ^{o}C) and illumination sensor (Fig. 4). A CO_2 sensor is under development.

The DALI master controller board has an RS232 interface connected to a PC. For testing, commands in standard DALI format (Table 1 & 2) are transmitted from the PC to the master. Returned data (Table 3) is displayed on the PC screen.

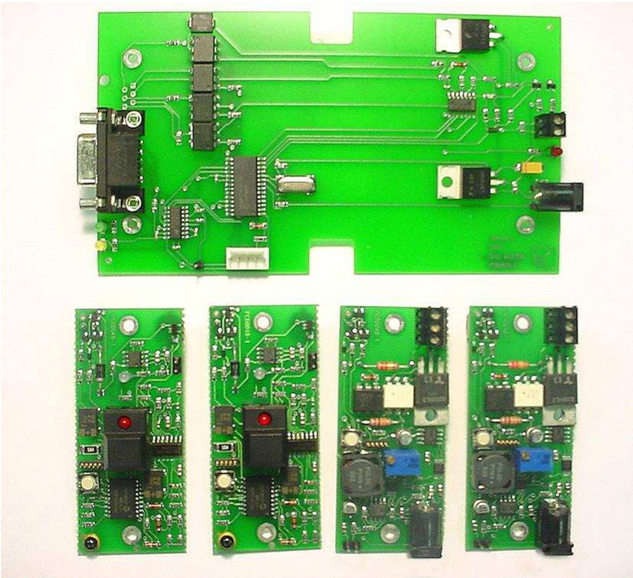

Fig. 4. DALI Master and Slave boards

E. *Future*

Wireless sensor/switch systems based on 433 MHz point to point (Chipcon) and mesh (Zigbee) are being tested. These use the DALI commands and convert to IEEE 1451 format for communication with the master (NCAP) [5].

III. Conclusion

The enhanced DALI network protocol was successfully tested with a variety of sensors with a mix of sensors and standard lighting devices. We expect it to be useful for building monitoring and control applications.

References

[1] DALI user organization http://dali-ag.org/
[2] "Digitally Addressable Lighting Interface (DALI) Unit Using the MC68HC908KX8 Designer Reference Manual" Motorola
[3] DALI INTERNATIONAL STANDARD: IEC 60929 Annex E
[4] IEEE 1451 information: http://ieee1451.nist.gov/
[5] Darold Wobschall, "An IEEE 1451 NCAP Prototype with Multiple Serial Ports and Internet Access," Proc. Sensors Expo (June 2003)