NEC

Application Note

78K0 Series

8-bit Single-Chip Microcontrollers

OpenTherm Data Link Layer Implementation

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NOTES FOR CMOS DEVICES

① PRECAUTION AGAINST ESD FOR SEMICONDUCTORS

Note:

Strong electric field, when exposed to a MOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop generation of static electricity as much as possible, and quickly dissipate it once, when it has occurred. Environmental control must be adequate. When it is dry, humidifier should be used. It is recommended to avoid using insulators that easily build static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work bench and floor should be grounded. The operator should be grounded using wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions need to be taken for PW boards with semiconductor devices on it.

② HANDLING OF UNUSED INPUT PINS FOR CMOS

Note:

No connection for CMOS device inputs can be cause of malfunction. If no connection is provided to the input pins, it is possible that an internal input level may be generated due to noise, etc., hence causing malfunction. CMOS devices behave differently than Bipolar or NMOS devices. Input levels of CMOS devices must be fixed high or low by using a pull-up or pull-down circuitry. Each unused pin should be connected to V_{DD} or GND with a resistor, if it is considered to have a possibility of being an output pin. All handling related to the unused pins must be judged device by device and related specifications governing the devices.

③ STATUS BEFORE INITIALIZATION OF MOS DEVICES

Note:

Power-on does not necessarily define initial status of MOS device. Production process of MOS does not define the initial operation status of the device. Immediately after the power source is turned ON, the devices with reset function have not yet been initialized. Hence, power-on does not guarantee out-pin levels, I/O settings or contents of registers. Device is not initialized until the reset signal is received. Reset operation must be executed immediately after power-on for devices having reset function.

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Introduction

This document should give some information about the OpenTherm™ Communication Protocol.
Furthermore, it illustrates the communication protocol, the hardware (peripherals) and the software which is used.
As example, an implementation of the Data-Link-Layer on a general purpose NEC microcontroller is described. In this case, the µPD78F0148H on the demo-board “Play-it2” is used.
Two units are used to send and receive some simple data using the so called “OT+” protocol.

Legend

Symbols and notation are used as follows:

Weight in data notation	:	Left is high-order column, right is low order column
Active low notation	:	$\overline{xxx}$ (pin or signal name is over-scored) or /xxx (slash before signal name)
Memory map address:	:	High order at high stage and low order at low stage
Note	:	Explanation of (Note) in the text
Caution	:	Item deserving extra attention
Remark	:	Supplementary explanation to the text
Numeric notation	:	Binary... xxxx or xxxB Decimal... xxxx Hexadecimal... xxxxH or 0x xxxx

Prefixes representing powers of 2 (address space, memory capacity)

K (kilo): $2^{10} = 1024$

M (mega): $2^{20} = 1024^2 = 1,048,576$

G (giga): $2^{30} = 1024^3 = 1,073,741,824$

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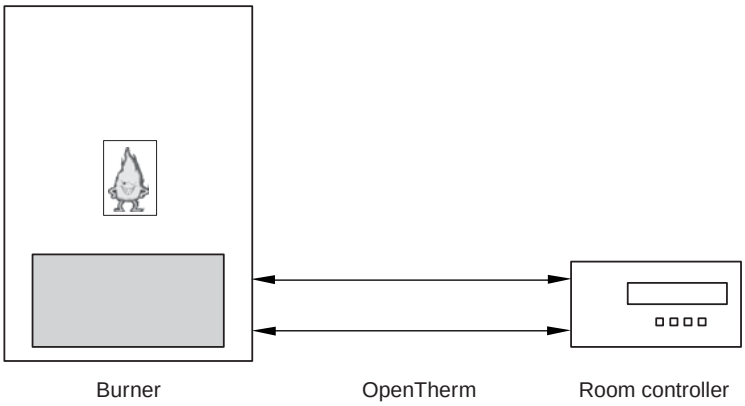
Chapter 1 OpenTherm Description

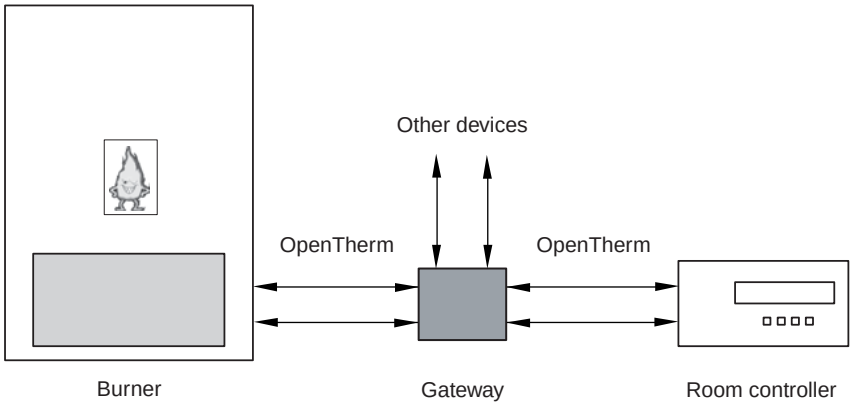
OpenTherm is a point to point communication system, which connects a boiler with a room controller. The room-unit calculates a heating demand signal and transmits it to the boiler, the boiler will answer with status messages and system information for diagnostic.

Figure 1-1: Block Diagram 1



There are two different protocols for OpenTherm, an analog one, which is called OT/- and the digital one called OT/+. Some devices supports both and have to detect automatically the protocol used by the partner-device. This is done after reset/restart of the room-controller by communication time-out regarding the OT+ protocol.
The design allows future expansion by the use of reserved ID's and spare bits in the frame, but it is no bus system, therefore an intermediate gateway will be required.

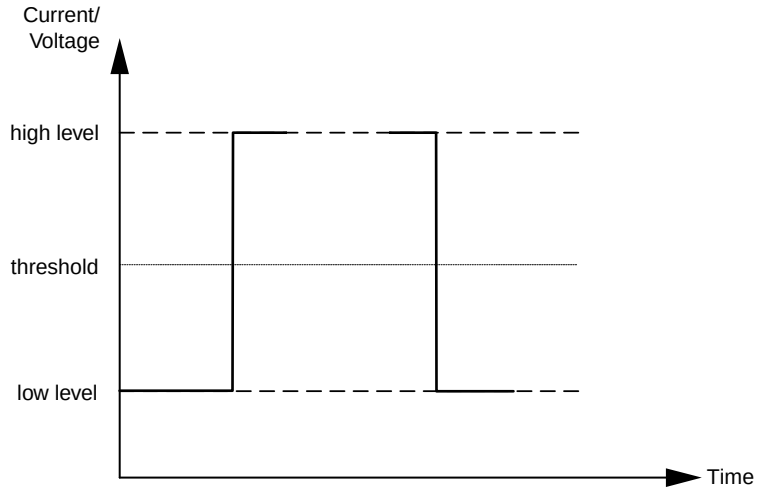
Figure 1-2: Block Diagram 2



1.1 Electrical Specification

The OpenTherm bus is a two wire interface (non-polarity), where the data transmission and the power for the room controller is provided on the same lines, so that there is no need for an external power supply for the room unit.
The room controller will send voltage signals and the boiler will answer with current signals.

Figure 1-3: Current / Voltage



Current:	high signal	17….23 mA
	Low signal	5….9 mA
	Threshold	11.5….14.5 mA
Voltage:	high signal	15….18 V
	Low signal	……7 V max.
	Threshold	9.5….12.5 V

Rise and fall times: 50 µs max.

So the max. available current for the room controller is 5 mA (idle state), the minimum voltage for the room unit is a function of the implementation of the interface.

1.2 The Protocol

OpenTherm uses a Manchester encoded unidirectional serial protocol with a transmission rate of 1.0 kHz. So the bit time is 1000 µs -10%/+15%.
The advantage of such kind of protocol is that a transition is done in every bit, so also the synchronization can be done every bit to avoid the accumulation of timing errors. The absence of an expected transition has to be recognized by the receiver and the frame has to be rejected.

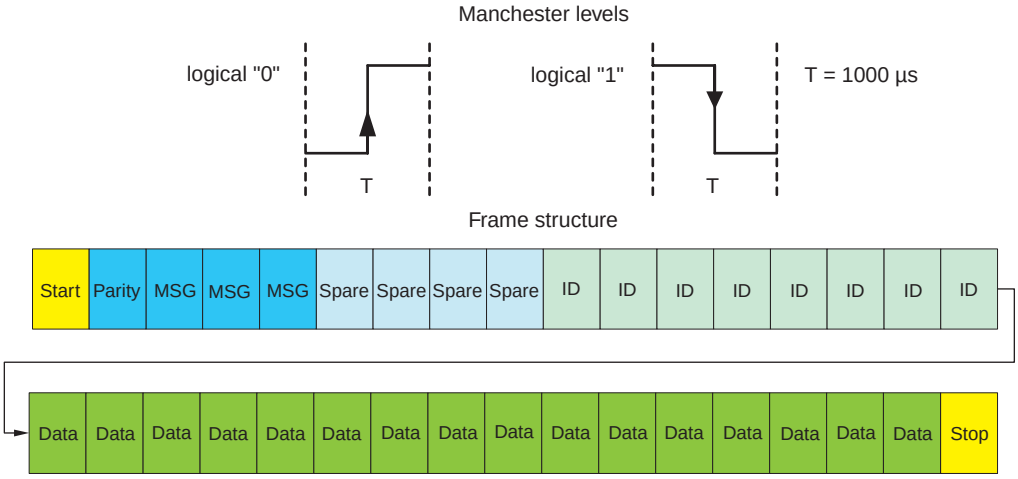
The frame consists of 34 bits:

- 1 start-bit (logical 1)
- 32 data bits
- 1 stop bit (logical 1)

The 32 data bits are divided into:

- 1 parity-bit (even)
- 3 message type bits
- 4 spare bits (logical 0 for future use)
- 8 data-ID bits
- 16 data-Value bits

Figure 1-4: OpenTherm Protocol Frame Timing



The **parity bit (P)** should be manipulated so that the total number of “1” bits in the 32bit frame is even. The **message type (MSG)** will identify the contents and the meaning of the frame:

Message type	Value	Direction
Read-data	000	Room-controller → Boiler
The room-controller is requesting a data value, typically 0x0000 is send as data, but in some cases also verification data can be send		
Write-data	001	Room-controller → Boiler
The room-controller sends data to the boiler as specified by the identifier		
Invalid-data	010	Room-controller → Boiler
In some cases it might be necessary to send data which are invalid in the particular application. Then the room unit will use this message type.		
-reserved-	011	
Read-acknowledge	100	Boiler→ Room-controller
The ID is recognized by the boiler and the requested data are available and valid. Data is returned.		
Write-acknowledge	101	Boiler→ Room-controller
The ID is recognized by the boiler and the data sent are valid.		
Data-invalid	110	Boiler→ Room-controller
The ID is recognized by the boiler but the data sent are invalid or the requested data are not available or invalid.		
Unknown-Data-ID	111	Boiler→ Room-controller
The ID is not known by the boiler.		

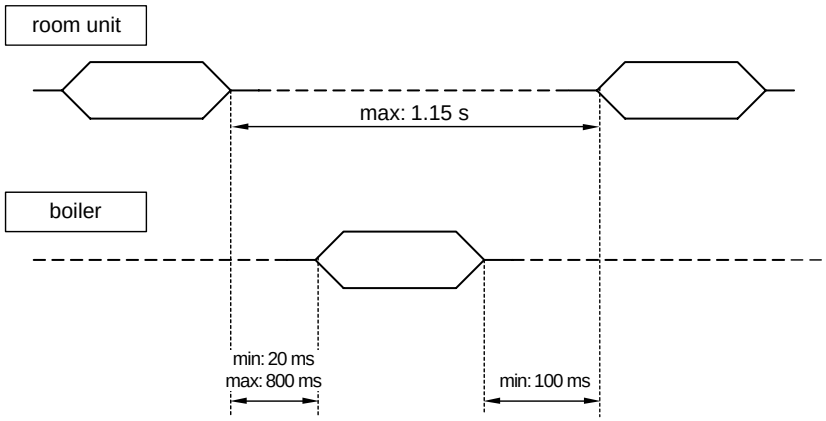
The **data-ID (ID)** identifies uniquely the transmitted values. A full description can be found in the Application layer section of the OpenTherm specification.

The **data-value (data)** transmitted contain either a 16-bit value or two 8-bit values corresponding to the data-ID send before.

The partial frame has to be rejected, if an error was detected. The communication should be terminated. The room controller has to recognize this termination and should reattempt the same message at the next time schedule.

1.2.1 Conversation timing

Figure 1-5: Conversation timing



So in normal operation mode the room unit has to send a frame at least every second (+15%), it expects an answer from the boiler earliest after 20 ms and latest after 800 ms.After this answer there has to be a pause for 100 ms.

But there are also some special cases:

<1> At the initialization the protocol-type is automatically detected, the room unit tries to communicate with the boiler using the OT+ protocol, if there is no response within 20 seconds, the room unit switches to OT- protocol and no further OT+ communication is possible, unless the room unit is reset.

<2> Short circuit feature: The boiler must recognize a short circuit for longer than 5 seconds, as a heating demand and must act within 15 seconds. After release of the short-circuit the standard communication continues.

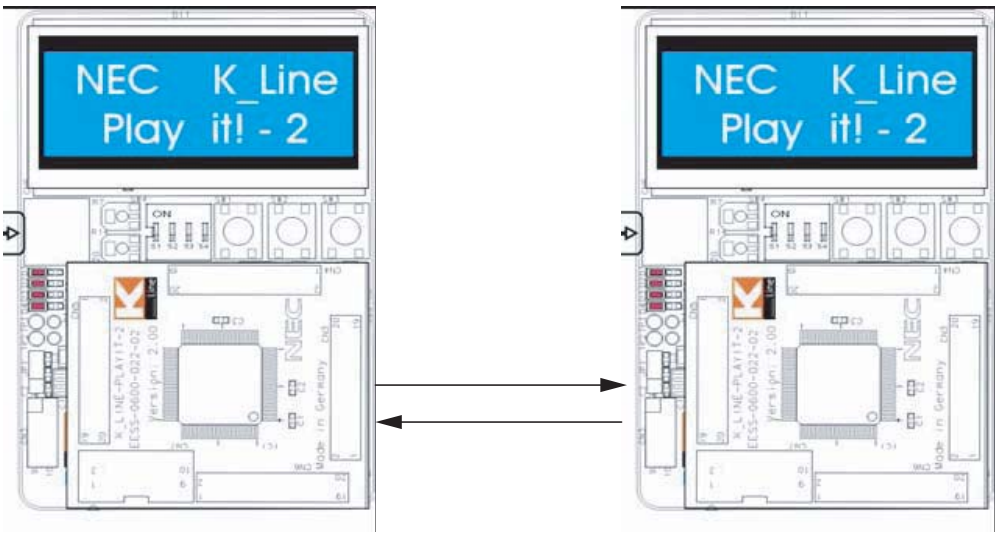
[MEMO]

Chapter 2 Demo-System

2.1 Used Hardware

To demonstrate the communication between two units, a system consisting of two playit2 kits representing a room-thermostat and a boiler was set up.

Figure 2-1: Hardware Block Diagram



The communication between the two units is displayed on the LCD.
Always the received message is displayed with the following shortcuts:

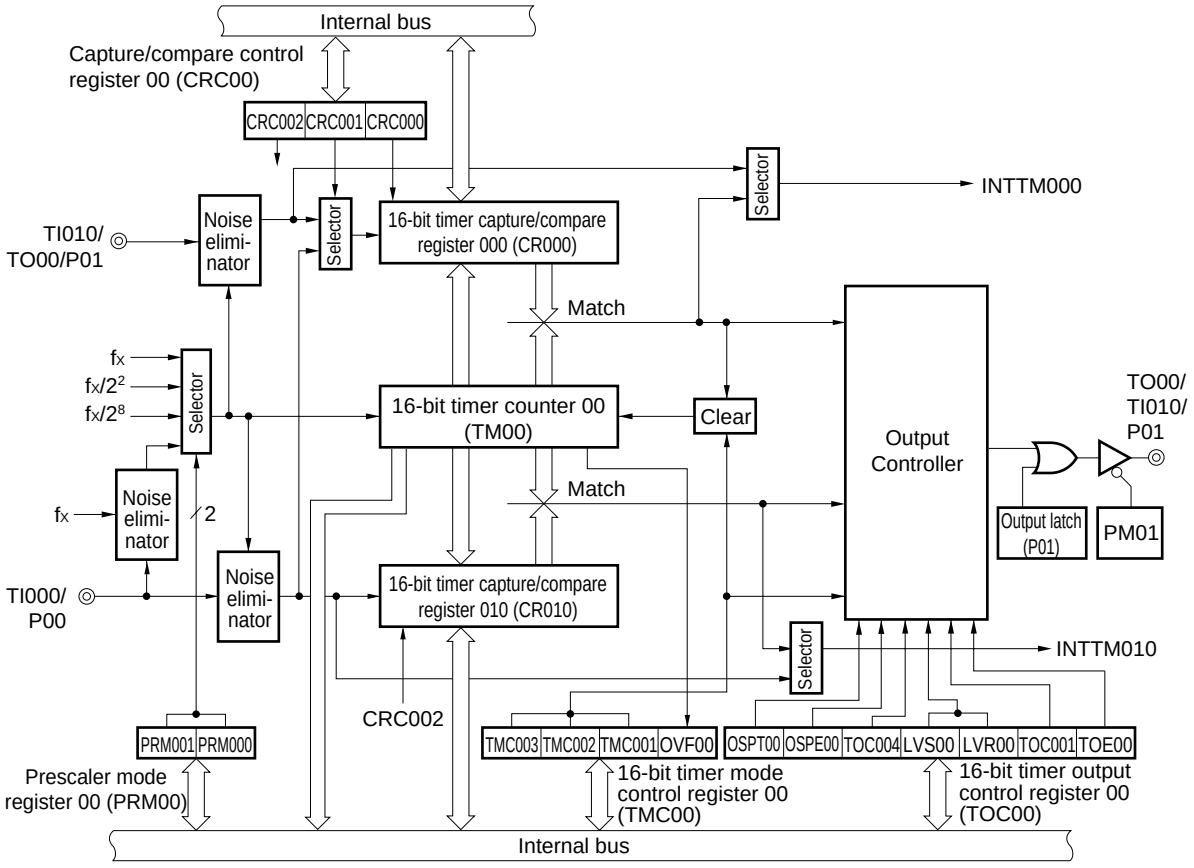
Message-type	→ MT:	x (x value 0 - 7)
Data-ID	→ ID:	xxx (xxx value 0 - 255)
Data-1	→ D1:	xxx (xxx value 0 - 255)
Data-2	→ D2:	xxx (xxx value 0 - 255)

The transmitted message will change every 5 seconds.

2.2 Used Peripherals

The 16-bit timer (TM00) of the µPD78F0148HD is used to generate the needed timings for the Manchester encoder / decoder. One channel operates with a cycle time of 500 µs, this one will handle all the timeouts and the send-routine. The second channel operates as capture timer and handles the timing for the receive-signal, so it can be easily decided, if the detected edge of the receive signal is in- or outside the valid time window.

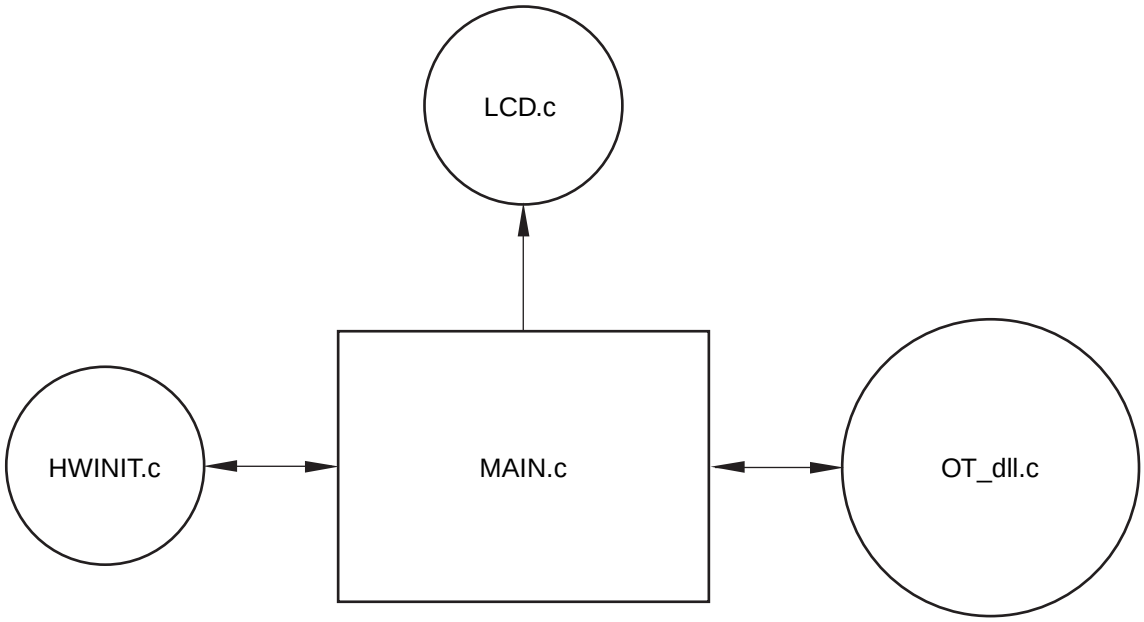
Figure 2-2: 16-bit Timer Block Diagram



2.3 Software

The software for the sub-unit is divided into functional modules.
The structure is shown in the picture below.
The source code will be attached in the next version of this document.

Figure 2-3: Software Block Diagram



2.3.1 Modules

MAIN:
This module initializes the microcontroller via the HWINIT.c module, handles the data received by the OT_dll module and will start the transmission of data, if requested.
The module will slightly differ whether the device will emulate the room-unit or the boiler. The received data is processed and displayed via the LCD-module.

HWINIT:
This module initializes the microcontroller. The clock generator is set, the ports are set to the desired direction, the interrupts are masked and the watchdog is disabled.

LCD:
This module contains the routines to generate the necessary signals for the 2x12 LCD-module. Also the functions for printing a string or a number are located in this module.

OT_DLL:
All functions which are needed to do an OpenTherm-communication are placed in this module:
Both timer interrupt service routines, one to handle all timings and the transmission, the other one to decode the received Manchester signal and check the validity of the bit timing.
The functions to initialize the used peripherals for OpenTherm and to generate the parity-bit.
The functions send_OT_frame and decode_OT_frame, which will handle the data for reception and transmission.

Chapter 3 References

3.1 Used Documentation

OpenTherm™ Protocol Specification V2.2 7.February 2002

3.2 Revision History

No.	Date	Description
1	17.03.2005	The first release

[MEMO]

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