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April 1st, 2010
Renesas Electronics Corporation

Issued by: Renesas Electronics Corporation (http://www.renesas.com)

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R8C Family

Renesas LIN Overview

Introduction

LIN is a communication and distributed processing bus system. It is characterized by low cost hardware and a relatively low data transmission speed and number of bus nodes. Only a microcontroller with a common UART interface hardware is necessary. LIN is limited to 64 data frame identifiers and a bus speed of 20 kbaud. The size of a network is typically under 12 nodes.

A primary topic for looking at a communication bus is that of centralized vs. distributed processing. Does it make sense to wire all sensors and actuators to one central MCU, or does it make more (economical!) sense to have ‘smart’ sensors and actuators that communicate with each other via some sort of bus? There are two primary reasons why one might want to choose a distributed processing configuration:

1) Reduction of wiring complexity

2) Reuse of hardware modules in multiple products.

Distributed processing with LIN supports the reuse of hardware modules in multiple products. LIN makes the ‘scale tip’ in favor of distributed processing due to its low per device hardware cost. CAN requires a more complex peripheral, as more transaction mechanisms are solved by the hardware. In LIN, almost all functionality is done by the firmware. The LIN specification also introduces a mechanism for module discovery and configuration.

In short: LIN as a solution that provides a very simple and inexpensive method of module interconnection.

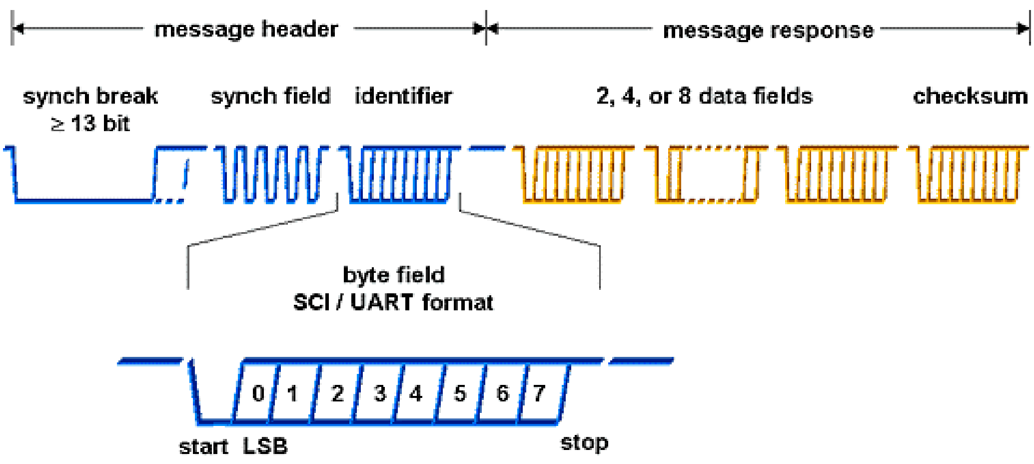

Figure: LIN Data Link Layer

Contents

1. Physical Layer

LIN uses a single wire transmission line that is passively pulled up to the battery supply voltage. A logic '1' equals a recessive state e.g. 5V or any voltage the LIN transceiver circuit can operate with. All voltages are measured with respect to system ground, which is used for both signal and power return currents. The LIN bus transceiver rise and fall times are limited (ramped transceiver function) to reduce EMI.

A LIN cluster consists of one master node and up to 15 slave nodes, connected in a wired AND configuration that allows any single node to drive the bus to logic 0 (the dominant state), overriding the passive (recessive) logic 1 being 'sent' by every other node in the cluster. The limit of 15 slave nodes is determined by the line driver and receiver specifications for a standard LIN transceiver. This number may be increased to as many 254 slave nodes if a non-standard transceiver circuit is used.

Data is sent as 8-bit bytes (with no parity) preceded by a start bit (logic 0) and followed by a stop bit (logic 1). The LSBit of each byte is sent first and the LSByte of multiple byte fields is sent first (little endian).

2. LIN Data Link Layer

LIN communication is conducted via message frames. Message frame headers are transmitted by the master according to a pre-defined sequence. The LIN device that 'fills in' the data bytes in a message frame is called the 'publisher' node. A LIN device that accepts and processes message frame data is known as a 'subscriber' node. The publisher node also transmits the final checksum byte of the message frame. The primary function of the master node is to send out the message headers. However, the master node may also be configured to subscribe to data published by any or all of the slave nodes.

Message frames fall into two basic categories: Command frames in which the master node publishes message frame data to one or more slave nodes and request frames where one (or more) slaves respond by publishing the message frame data. LIN does not define a formal subscription process, so, a 'publisher' node has no idea which nodes may be using the data it publishes, or transmits. Thus, slave-to-slave communication is possible by having the master node transmit the header for a request frame; one slave publishes the data that another slave subscribes to. But, this is only at a time determined by the master.

3. Frame fields

A message frame consists of the following sections, or fields. As said above, data is preceded by a start bit and followed by a stop bit for all fields.

3.1 break field

This stop bit is called the 'break delimiter' and is defined as 'at least one bit period'. The LIN specification requires that a slave detect a break after '11 nominal bit times'. The Baud rate for a LIN cluster is defined as part of the global configuration data, so the nominal bit time is known even before the sync field is received. A slave must have an initial oscillator accuracy of 14% in order to detect the initial break field properly.

3.2 Sync field

The sync field consists of the byte 0x55 which together with the start and stop bits forms a square wave synchronization segment. The purpose of the sync field is to allow the slave nodes to adjust their Baud rate generators to agree with the Baud rate being used by the master node. The intent is to make fine adjustments to the Baud rate defined for the cluster, and not to allow automatic Baud rate detection or the use of different Baud rates for various nodes in a LIN cluster. The slave must generate the defined Baud rate with an accuracy of 0.5%. A slave must be capable of syncing to the baud rate with an accuracy of 1.5% for master/slave communications and 1% for slave/slave communications. Any two nodes communicating via LIN may have Baud rates that differ by 2% at most.

3.3 Protected ID field

The Protected ID field identifies the content of the frame. The ID field may not be considered to be a physical node address on the LIN bus. The ID field identifies the specific data content of the message frame, but has nothing to say about which node (or nodes) may publish the data or subscribe to it. This is a matter of node configuration. A node will typically be configured to publish data for a specific ID while another node configured to subscribe to this ID. The ID is

6 bits long, allowing up to 64 different IDs to be defined for a cluster. Bits 6 & 7 of the ID field make up the parity value of the first 6 bits.

ID	Used for
0-59	General purpose signal carrying message frames.
60, 61	Diagnostic message frames. See separate section
62	User defined frames.
63	Future expansion of the LIN specification.

The ID field does not indicate the length of the following data field (1-8 bytes), nor does it make any indication of whether the data is to be treated as a ‘command’ or ‘request’. All of that is left up to the configuration of the nodes. The length of the data field is fixed for each specific message frame ID during system configuration.

3.4 Data field

The Data field may be 1-8 bytes in length, as determined during system configuration of the message frame IDs. The data field may consist of one or more ‘signals’ appended together. The individual signals can be 1-bit Booleans, bytes, words, uneven bit widths (1-15 bits) or multiple byte arrays. There are few restrictions on the data field, but if Booleans or uneven width signals are packed into bytes, a maximum of 16 bits may be packed into 2 successive bytes, which are treated as an unsigned integer. The interpretation of the data bytes is all a matter of node configuration.

3.5 Checksum field

The checksum field consists of a single byte. The checksum is defined as the 1’s complement sum of all data bytes. An 8-bit 1’s complement checksum is the bit-wise inverted 8-bit sum of all bytes (with any carry bits added in).

LIN 1.3 and Diagnostic message frames: Classic checksum.

LIN 2.0: Extended checksum: All data bytes plus the Protected ID byte.

4. Signals

Several signals may be associated with one frame. Commonly, each action that may be commanded or each sensor that may be read is defined as a signal, and each signal is assigned to a message frame. Each defined message frame is assigned a cluster specific message frame ID. The master node is configured to issue message headers for each ID in some particular sequence at some particular frequency. These IDs are most often treated as ‘Unconditional’ message frame IDs, meaning that a slave configured to respond to the ID will always respond to that ID, unconditionally.

Master command message frames are always Unconditional.

5. Unconditional frames

Unconditional frames are the most common and straightforward of frame types. Each slave node will typically be configured to respond to an unconditional frame of some ID with some signal data.

6. Master Schedule Table(s)

The master node is configured to send out a specific sequence of message headers by means of a ‘schedule table’, which is a list of message headers specifying type of frame and a total slot time, and the time the master waits until the next message header is sent.

Once initialized and started, the master processes this list repeatedly, without pause. The message headers can be listed in any order in the schedule table and any given message header may appear multiple times in the same schedule table, so if some particular message data requires a low latency time, the message header for that message can be listed in the schedule table as often as needed to meet the latency requirements. The slot times can be configured to be equal, regardless of the actual message length, or the slot times can each be ‘tailored’ to fit the length of the message to be sent in the slot.

The master node may even have multiple schedule tables and switch between these schedule tables, as required by special circumstances, using the LIN API 'l_sch_set()' function call. The '0th' schedule table is called the L_NULL_SCHEDULE table and has no entries, so the master can be shut down by switching to this schedule table. After initialization, the master is running from the null schedule table and does nothing until the master application switches to some non-null schedule table.

Note: This shutdown could allow the master node function to be passed from one device to another in the LIN cluster. This is not really foreseen in the LIN specification, but technically, it is possible.

6.1 Message Frame Timing

A nominal message frame requires 34 bit-times for the header, 10 to 80 bit times for the data and 10 bit times for the checksum. The nominal transmission times at 20kbaud are as follows:

Message Length	Header	Data	Checksum	Total	Min. slot time
1 byte	1.7 ms	0.5 ms	0.5 ms	2.7 ms	3.78 ms
2 bytes	"	1.0 ms	"	3.2 ms	4.48 ms
3 bytes	"	1.5 ms	"	3.7 ms	5.18 ms
4 bytes	"	2.0 ms	"	4.2 ms	5.88 ms
5 bytes	"	2.5 ms	"	4.7 ms	6.58 ms
6 bytes	"	3.0 ms	"	5.2 ms	7.28 ms
7 bytes	"	3.5 ms	"	5.7 ms	7.98 ms
8 bytes	"	4.0 ms	"	6.2 ms	8.68 ms

The LIN specification allows 'gaps' between bytes that may total up to 40% of the nominal transmission time. Each LIN slot in the master frame schedule table must therefore be 'long' enough to accommodate this maximum message time. The timing diagrams show a 'Response space' between the end of the Protected ID byte (end of the header) and the start of the first data byte. Presumably, this delay may be as much as 40% of the total response time (data plus checksum) if the publishing node device has no 'gaps' between its published data (and checksum) bytes. However, the LIN specification requires that slave devices be able to receive message frames that are sent with the nominal timing, that is, no response space and no inter-byte space.

7. Event Triggered frames

Event triggered frames and unconditional and are always associated with each other in that they carry the same signal data content. Typically, several slave nodes will be configured to respond with the same signals as for the associated unconditional frame ID, but only if they have some signal state change to report. The only difference between an event triggered frame and its associated unconditional frame is the Frame ID value and that the event frame will have as its first data byte that node's unconditional frame ID to distinguish it. The following data bytes will be the same as the data returned for the Unconditional ID. This limits the data length for any unconditional frame associated with an Event Triggered ID to effectively 7 bytes.

8. Sporadic Message Frames

You can skip Sporadic Messages for now if you are a beginner to LIN.

There really is no such thing as a "Sporadic Message Frame", but rather a Sporadic message frame slot configured in a schedule table that allows the Master node to send one of any number of Unconditional master command message frames in that time period. Note that any message frame sent in a Sporadic message frame slot must be a master command message frame for which the Master node publishes the data, not a slave response message frame. By definition, master command message frames are always Unconditional. The function of Sporadic message frame slots is therefore similar to Event Triggered message frames (which are always Slave response message frames), but in reverse. A Sporadic message frame slot will be empty (no header, no data) if the Master node has no updated signal data to send in that slot. The Master node is configured with a list of Unconditional master command message frames that could be sent in each Sporadic message frame slot configured in a schedule table.

This mechanism allows the Master node to process master command message frames whose signal data changes infrequently, without having to assign a fixed slot for each message frame within the schedule table.

It is possible for a schedule table to be configured with multiple Sporadic message frames slots, each with a different list of Unconditional master command message frames. When a Sporadic message frame slot comes up in the schedule table, the Master node checks the list of message frames associated with that slot and checks the signal status of each of these message frames. If none of the associated message frames has updated signal data, the Sporadic frame slot will be empty. If one of the associated message frames is found to have updated signal data, then that message frame will be sent in the Sporadic message frame slot – header plus data. If more than one associated message frame has updated signal data, the second message frame must wait until the Sporadic message frame slot comes up again before the second message frame can be sent.

9. Diagnostic Message Frames

You can skip Diagnostic message frames for now if you are a beginner. In short; assign a certain Frame ID to a certain Message ID per slave.

The LIN standard defines how a node shall be configured to set up nodes in a cluster. It is a tool to configure slaves within a cluster of off-the-shelf nodes depending on their initial unique node address 'NAD' and Product Id. (Product Id is specified uniquely in the slave as Supplier ID and Function ID.) Using these it is possible to uniquely configure a slave to subsequently respond to frames in a custom manner using Frame ID and Message ID.

Frame IDs 60 and 61 (0x3C and 3D) are reserved for Diagnostic message frames:

- ID 60 = Master diagnostic request frame. If the NAD matches, the slave node publishes its data or is configured depending on a secondary id. See the Lin 2.0 spec.
- ID 61 = slave response frame. (Slave diagnostic response frame).

The procedure to customize a node to respond uniquely to frame IDs is called 'Assign Frame ID Node Configuration request'. Using this request frame a Frame ID in the node's signal table is changed so it is now associated with a new message ID.

10. More information

Documents and training

- Doc. REU05B0069. Renesas LIN Basics and Overview.
- Doc. REU05B0070. Customer frequently asked questions.
- Doc. REU05B0078. Renesas LIN R8C Demo and Quick Start. 'QSG' for setting up our RSK boards and the LIN demo. Explains how the demo is built regarding frames & signals.
- Doc. REU05B0079. Renesas LIN configuration and API. How to set up a project and use the LIN API.

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Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	July 6 2007	—	First edition published to RTA LIN download page.
1.01	Aug 24 2007	—	Second edition after formal review at RTA AE.
1.02	Aug, 2008		Minor changes to layout.
1.03	Dec 1, 2008		Update chapter 10.

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