TPT1021&TPT1029 Application Note

By Interface AE Team

ABSTRACT

This application note provide application hints / recommendations for the design of LIN electronic control units (ECUs) using the LIN transceiver TPT1021 and TPT1029 from 3PEAK.

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1 Introduction

1.1 LIN

The Local Interconnect Network (LIN) is a low speed serial bus protocol. The most recent LIN standard was defined in 2010 (LIN 2.2A, LIN Consortium), then incorporated by the International Organization for Standardization (ISO) as ISO 17897 and officially published in 2016.The LIN protocol specification specifies the physical layer and the data link layer, while the LIN configuration language makes it possible to describe groups of LIN instruments in a file that is easy for all developers to understand.
A LIN network consists of one master node and one or more slave nodes; SCI is the main interface used by the LIN transceiver to communicate with the micro-controller.

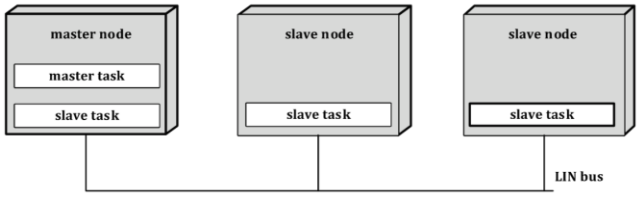

Figure. 1 Master & Slave Task

The LIN physical layer is based on the ISO 9141 standard with some tweaks for automotive applications, especially EMC, ESD, transient impulse response, and more. It is a bidirectional bus communication interface that is biased to the car's battery voltage (master node only) via resistors and diodes, and connects to transceivers at each node in the LIN network. The LIN bus is a single-wire, wired AND bus with a 12 V/24V-battery related recessive level. The voltage levels on the LIN bus line are shown in Figure 2.

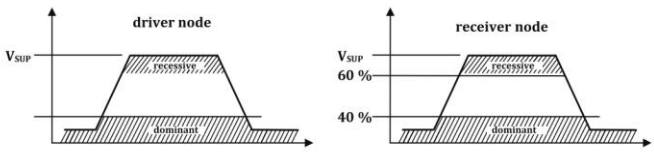

Figure. 2 Voltage Levels on the BUS

This note describes the technical implementation of the TPT1021 as Physical Medium Attaichment within LIN. Its focus is to provide application hints /recommendations for the design of LIN electronic control units (ECUs) using the LIN transceiver TPT1021 from 3PEAK.

2 General Description

2.1 Features

2.1.1 TPT1021

The TPT1021 is a local interconnect network (LIN) physical layer transceiver that compliant to the ISO 17987-4, SAE J2602 and LIN 2.0, LIN 2.1, LIN 2.2,and LIN 2.2-A physical layer standard. The device supports LIN networks up to 20 Kbps with enhanced timing margin the WAKE pin wake and INH control enablement. The device converts the transmitted data received at the TXD with optimized slew rate to minimize the Electro magnetec emission(EME) andreports the state of LIN bus at the RXD. The TPT1021 is available in SOP-8 and DFN3X3-8L packages and is characterized from −40°C to +125°C.

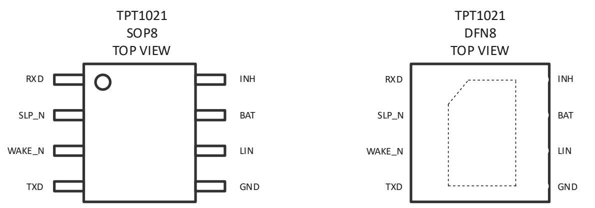

Figure. 3 TPT1021 Pin Configuration

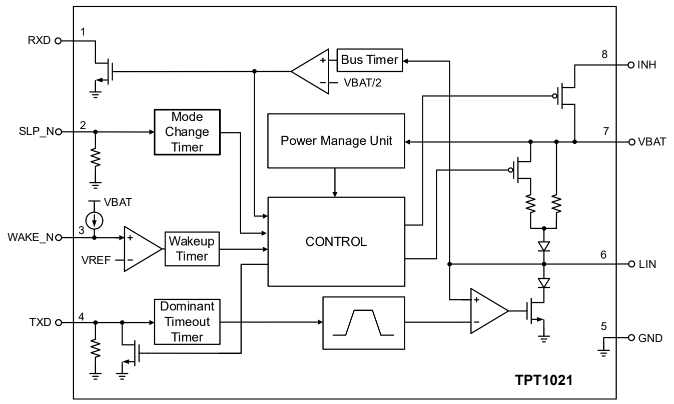

Figure. 4 TPT1021 Functional Block Diagram

2.1.2 TPT1029

The LIN transceivers TPT1029 are system efficient transceivers for LIN applications, where neither switch event detection via WAKE pin nor voltage regulator control via INH pin is required. The TPT1029 is available in SOP-8 and DFN3X3-8Lpackages and is characterized from −40°C to +125°C.

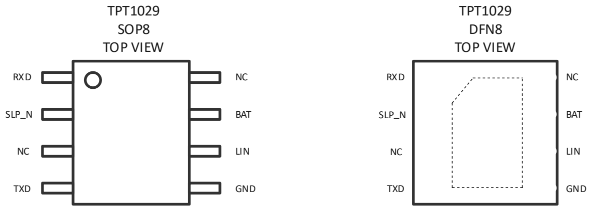

Figure. 5 TPT1029 Pin Configuration

2.2 Operating Modes

2.2.1 TPT1021

The TPT1021 provides four operating modes: Normal mode, Power-on mode,Standby mode and Sleep mode. The operating modes are shown in Table 1 and Figure 5.

Mode	SLP_N	TXD	RXD	Transmitter	Comments	INH
Normal	High	High:recessive state Low:dominant state	High:recessive state LOW:dominant state	Normal		High
Sleep	Low	Weak pull-down	Floating	Off	NO wake-up event detected	floating
Standby	Low	Weak pull-down: remote wake-up; Strong pull-down: local wake-up	Low	Off	Wake-up event detected	High
Power on	Low	Weak pull-down	Floating	Off		High

Table. 1 TPT1021 Function

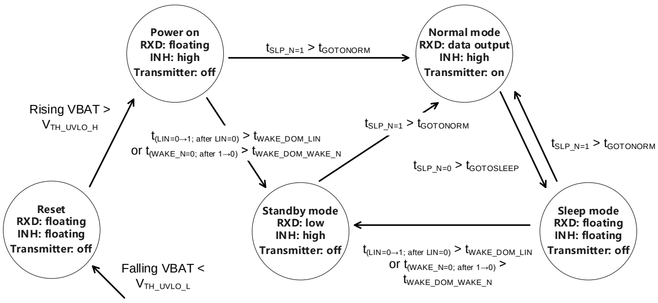

Figure. 6 TPT1021 States Diagram

2.2.2 TPT1029

The WAKE and INH function are not available at the TPT1029. PIN 3、PIN 8 of the TPT1029 are ‘ not connected ’ pin.

The TPT1021 provides four operating modes: Normal mode, Power-on mode,Standby mode and Sleep mode. The operating modes are shown in Table 2 and Figure 6.

Mode	SLP_N	TXD	RXD	Transmitter	Comments
Normal	High	High:recessive state Low:dominant state	High:recessive state LOW:dominant state	Normal	
Sleep	LOW	Weak pull-down	Floating	off	NO wake-up event detected
Standby	LOW	Weak pull-down	Low	off	Wake-up event detected

Table. 2 TPT1029 Function

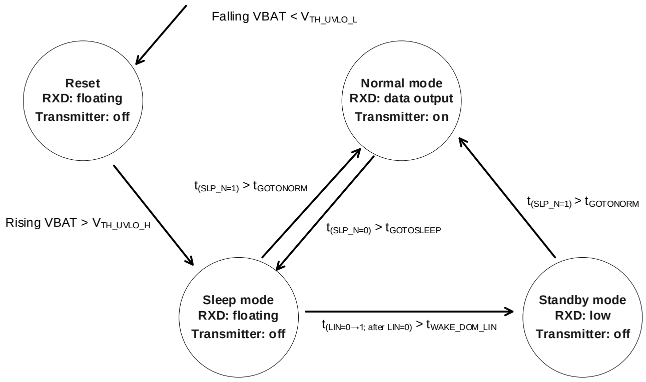

Figure. 7 TPT1029 States Diagram

2.3 Normal Mode

In Normal mode, the TPT1021/TPT1029 can transmit and receive data through the LIN bus line. The receiver detects the data stream at the LIN bus input pin and

transfers it to the micro-controller via the RXD pin. On the bus, a HIGH level corresponds to a recessive state, while a LOW level represents a dominant state. The receiver incorporates a voltage-dependent threshold with hysteresis and an integrated filter to suppress noise on the bus.
The transmit data stream from the protocol controller at the TXD input is converted by the transmitter into a bus signal with optimized slew rate and wave shaping, aiming to minimize electromagnetic emissions (EME). The LIN bus output pin is pulled HIGH through an internal slave termination resistor. For master applications, an external resistor in series with a diode should be connected between pin INH or VBAT and pin LIN.

2.4 Sleep Mode

The TPT1021/1029 offers an energy-efficient mode known as the power-saving mode. Despite its extremely low current
consumption, transceivers retains the capability to be remotely awakened via the LIN pin, locally awakened via the WAKE_N pin(only for TPT1021), or directly activated through the SLP_N pin. Input filters are incorporated at the receiver (LIN), WAKE_N pin, and SLP_N pin to prevent undesired wake-up events caused by automotive transients or electromagnetic interference (EMI).

2.5 Standby Mode

2.5.1 TPT1021

Whenever a local or remote wake-up occurs while the TPT1021 is in Sleep mode, Standby mode is automatically activated. These wake-up events trigger the activation of pin INH and enable the slave termination resistor at the LIN pin.Consequently, the voltage regulator and micro controller can be powered on due to the HIGH condition on pin INH.Standby mode is indicated by a low level on the RXD pin, which can serve as an interrupt for the micro controller.During Standby mode (with pin SLP_N still low), the state of the TXD pin (weak pull-down or strong pull-down) indicates the source of the wake-up: a weak pull-down for a remote wake-up request and a strong pull-down for a local wake-up request.

2.5.2 TPT1029

A remote wake-up occurs while the TPT1029 is in Sleep mode, Standby mode is automatically activated. Standby mode is indicated by a low level on the RXD pin, which can serve as an interrupt for the micro controller. During Standby mode (with pin SLP_N still low), the state of the TXD pin (weak pull-down or strong pull-down) indicates the source of the wake-up: a weak pull-down for a remote wake-up request and a strong pull-down for a local wake-up request.

2.6 Power-on Mode

After the supply voltage on VBAT is switched on，the TPT1021 enables the INH switch.The Power-on Mode and Standby Mode can be distinguished by the state of RXD. In the Power-on mode the RXD output remains floating, while in the Standby mode the RXD output goes LOW signaling a wake-up event.

3 Application Information

Application of the LIN transceiver TPT1021 is shown in Figure 8. The protocol controller (e.g. micro controller) is connected to the LIN transceiver via a UART/SCI based interface or standard I/O port pins. According to the ISO17987-4-2016, the pull up resistor and diode in the dotted box are only for the master node.

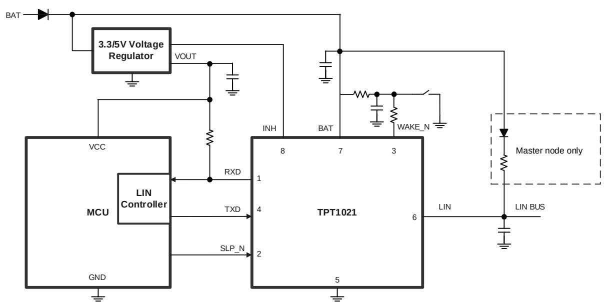

Figure. 8 TPT1021 Application Example

3.1 Detailed Pin Description

3.1.1 SLP

SLP recommends connecting to VDD through a 10KΩ pull-up resistor.If low power mode is required, SLP needs to be connected to the controller, and the controller IO port controls the LIN chip to enter sleep mode.

3.1.2 INH

INH is used for system power management. If not use this function，It is recommended to connect a 100kΩ resistor to the ground ,ensure that the INH pin can be quickly driven to a low state。

3.1.3 TXD

TPT 1021:In Normal mode ,The TXD pin is used as transmit data input whereas in Standby mode the wake-up source is signaled. If a local wake-up source at the WAKE_N pin is used, a pull-up behavior to VDD at pin TXD is required. a HIGH level indicates a remote wake-up request (weak pull-down at pin TXD) and a LOW level indicates a local wake-up request (strong pull-down at pin TXD; much stronger than the external pull-up resistor). The required pull-up current of the micro controller port pin as well as the external resistor RTX should be in the range from 100 µA to 2 mA.
In case no local wake-up source is present (WAKE_N is unused), no external pull-up resistor is required. Then TXD will never be pulled to a strong LOW-level by the TPT1021.

TPT1029: the TXD pin of TPT1029 is an input pin only. The input threshold of the TXD pin supports 3.0 V, 3.3 V and 5.0V supplied devices.The required pull-up current of the micro-controller port pin should be stronger than 200µA.

3.1.4 RXD

The receive data output RXD provides an open drain behavior in order to get an output level, which can be adapted to the micro-controller supply voltage. Thus 3.0 V/3.3V micro-controller derivatives without 5 V tolerant ports can be used. In case the micro-controller port pin does not provide an integrated pull-up, an external pull-up resistor connected to the micro-controller supply voltage VCC is required. A recommended value for the external pull-up resistor RRX is 2.4 kΩ.

3.1.5 WAKE(TPT1021Q only)

The local wake-up input WAKE is used to detect local wake-up events using a falling edge。This falling edge has to be followed by a continuous low level of at least t_{WAKE} in order to successfully pass the integrated EMI filter.The NWAKE pin provides an internal weak pull-up current source towards battery. It is recommended to connect an external pull-up resistor RWAKE1 to provide sufficient current for an external wake-up switch or transistor。The pin series resistance RWAKE2 limits the current entering the WAKE pin to prevent over-current situations. The pull-up resistor requires sufficient current to be provided within the local WAKE event time. The recommended setting for current limiting resistance is 3k Ω; It is recommended to connect the NWAKE pin directly to the BAT pin,if no local wake-up is required.

3.1.6 INH(TPT1021 only)

INH is used for system power management. It is recommended to connect a 100KΩ resistor to the ground ,ensure that the INH pin can be quickly driven to a low state when entering the sleep mode.

3.1.7 LIN

The pin LIN is used to transmit and receive data on the LIN bus line. A low side switch with controlled wave shaping is used for bit transmission while an integrated receive comparator (receiver) converts the LIN bus voltage back to a binary signal.

The LIN pin has a slave termination resistor of RSLAVE in parallel to BAT. The slave termination resistor and the low side switch are implemented with a reverse current diode. Thus no external components are required for salve application. Nevertheless, improvement of EME and EMI can be achieved by applying a capacitive load at the LIN bus line as shown in Figure 8.

A master application differs from a slave application mainly with respect to the external master termination resistor RMASTER.

R_{MASTER} :According to the ISO17987-4-2016, for the master node, the recommended resistance value for R_{MASTER} is 1K Ω. For slave nodes, R_{MASTER} does not need to be connected.

For a 12V battery system: The maximum voltage of the system is 14V. During normal operation, the peak power is 0.098W.it is recommended to use the 0805 package for R3. If an abnormal state needs to be considered, the Lin bus is short circuited to ground, and the power consumption on R3 is 0.196W. It is recommended to choose 1206 packaging for R_{MASTER}。

For a 24V battery system:The maximum voltage of the system is 27V. During normal operation, the peak power is 0.3645W, so it is recommended to use 1812 packaging for R3. If abnormal conditions need to be considered, the Lin bus is short circuited to ground, and the power consumption on R3 is 0.729 W. It is recommended to choose a 2512 packaging for R_{MASTER}.

D_{MASTER}:For a LIN master application a reverse current diode in series with the LIN master resistor is connected between LIN and VBAT。Recommended diode selection CD4148 (VRRM=75V, IF=150mA, trr=4ns). The recommendation principles are as follows

1.Considering the need to protect against reverse voltage while ensuring switching frequency, switch diodes are selected.

2.The LIN bus operates at a speed of 10Kbps or 20Kbps, so the diode switching time must be much less than 5us.

3.In the case of a LIN bus short circuit to ground, the maximum working voltage of the chip is 40V, and a resistance of 1K Ω is pulled up, corresponding to a current of 40mA. Therefore, the forward continuous current of the diode must be greater than 40mA.

4 EMC Aspects

4.1 Network Design

The Electromagnetic Emission (EME) depends mainly on the falling and rising slope of the LIN bus waveform. The smoother these slopes are the more EME reduction can be achieved. The slope decreases with increasing capacitive load. Therefore increasing the total network capacitance (CBUS = CMASTER +n × CSLAVE + CLINE) can reduce the EME.

According to the LIN standard (ISO17987-4-2016), the capacitance on the slave node must be less than 250pF, and the capacitance of ESD protection devices is also included. Therefore, the recommended capacitance value on the slave node is 220pF, and the recommended withstand voltage value is 50V.

The ground capacitance on the main node can be used to adjust the slope of the LIN bus waveform to achieve better EMC characteristics. According to the requirements of ISO17987-4-2016, the bus time parameters τ Less than 5us.

Assuming a 6-node network is connected. According to the following formula:

$$Cmaster = \frac{\tau}{Rbus} - N * Cslave - Cline$$

C_{Master}：master node capacitance

τ: Bus time constant

R_{bus}：Bus resistance

N：number of slave nodes

C_{slave}：slave node capacitance

C_{line}：Line capacitance

Assuming 6 slave nodes are connected and the line capacitance is 600pF

$$C_{Master.Max}=\frac{5*10^{-6}}{Rbus} - 6 * 220 * 10^{-12} - 600 * 10^{-12}$$

$C_{Master.Max}$=3.28nF。

In this example a master capacitor of CMASTER = 3.3 nF is recommended.

Ferrite magnetic beads are beneficial for improving the EMC characteristics of the system, and are recommended for applications with high reliability requirements. Selection: Single 0603 magnetic bead impedance 120 Ω @ 100MHz. The layout of the magnetic bead is placed close to the chip.

4.2 ESD Protect

IEC 61000-4-2 level: - IEC 61000-4-2 test standard defines actual ESD impacts. This standard is more stringent than the Human Body Model (HBM). LIN transceivers should have at least HBM ESD protection, which provides component-level protection for assembly and manufacturing environments. However, these protections are insufficient to address system-level ESD encountered in uncontrolled end-user environments. It is recommended to adopt the IEC 61000-4-2 15kV level, with an option for even stricter protection of up to 30kV.

Operating Voltage: The LIN bus voltage must not exceed the reverse working voltage (VRWM) of the ESD diode. The operating voltage range of the LIN bus is 9V to 18V. In order to reduce the risk of improper rapid start-up of the battery, 24 VRWM is required when two 12V batteries are connected in series.

Capacitance: In most applications, to achieve correct transmission and minimize noise as much as possible, the capacitance of the LIN slave node should not exceed 220pF. For design flexibility, it is recommended to select a diode with the smallest capacitance (with a suggested maximum value of 50pF).

Clamping Voltage: The clamping voltage must be less than the absolute maximum rated voltage of the LIN transceiver, typically a maximum of ±42V. The clamping voltage is the voltage drop that the protected IC withstands during ESD impact, so the clamping voltage must be lower than the transceiver's maximum rated voltage.

Polarity: To prevent damage caused by negative DC voltage on the LIN bus due to battery wiring faults, a bidirectional diode should be used.

Leakage Current: When the LIN transceiver is in low-power mode (if applicable), it must conserve power. It is recommended to use a lower maximum leakage current rating for the diode to conserve power when operating below the working voltage.

Parameter	Reference Value	Note
ESD	15-30kV	
VRWM	24-27V	
VCL	30V	＜40V
Cd	15-30pF	≤50pF
Ippm	1.5A-4.0A	
Pppm	150W	150W

Table. 3 ESD Protect Reference Value

5 Layout

5.1 Layout Guide

Pin 1 (RXD): The RXD pin is an open drain output, and the recommended typical value for pull-up resistance is 2.4 k Ω;

Pin 2 (SLP): SLP is an input pin used to place the device in low-power sleep mode. If this function is not used, please use a pull-up resistor between 10 k Ω to connect the pin to the power supply voltage of the controller (3.3V/5V);

Pin 3 (WAKE): The local wake-up input WAKE_N is used to detect local wake-up events using a falling edge. The pin series resistance R2 limits the current entering the WAKE pin to prevent over-current situations. The pull-up resistor requires sufficient current to be provided within the local WAKE event time. The recommended setting for pull-up resistance is 3k Ω, and the recommended setting for current limiting resistance is 33k Ω;

Pin 4 (TXD): The TXD pin is the input signal sent by the controller to the transceiver. Series resistors can be placed to limit the input current of the transceiver. The grounding capacitor can be close to the input pins of the device to help filter noise;

Pin 5 (GND): Ground connection of the device. This pin should be connected to the ground plane using a short wire to limit the total return inductance;

Pin 6 (LIN): For slave node applications, a 220pF capacitor to ground should be used. For master node applications, an additional series resistor and diode should be placed between the LIN pin and VBAT pin; Please refer to the selection instructions for details. Place the TVS diode near the external connector;

Pin 7 (VBAT): The power pin of the device. Place C1-100nF decoupling capacitors near the pins;

Pin 8 (INH): INH is the output pin used for system power management. Please refer to the selection instructions for the pull-down resistance value;

5.2 Layout Example

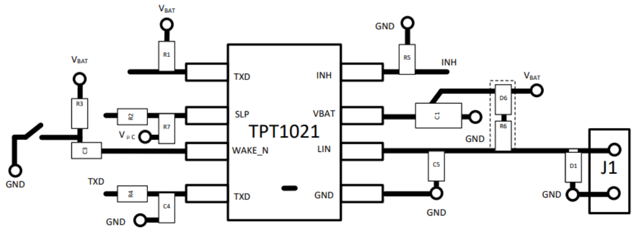

Figure. 9 Layout Example

6 References

1. TPT1021Q Datasheet——3PEAK
2. TPT1029Q Datasheet——3PEAK
3. ISO 17987-4-2016-Road vehicles_Local Interconnect Network (LIN)
4. ISO 17987-7-2016-Road vehicles_Local Interconnect Network (LIN)