DL-LN3X Series 2.4G Ad-hoc Network Wireless Communication Module

DL-LN3X series module is the wireless communication module independently developed. The module is designed specifically for the applications requiring multi-hop transmission of ad-hoc network. Compared to other common ad-hoc network wireless communication solutions, this scheme is more flexible and robust. Users can cast aside the complicated protocol stack and datasheet and get control of the wireless multi-hop transmission as long as they master the simple serial port communication.

Product features

- **Ad-hoc network protocol of directed diffusion type**
  - After powered on, the module will automatically build a multi-hop mesh network completely without the user's intervention.
  - Each module can send data to any other node in the network.
  - With the function to confirm transmission, the module carries out wireless transmission to be verified with CRC. Re-transmission can be done for 15 times at most.
  - The fault in any node of the network will not affect the running of the whole network. The network has very powerful invulnerability.
  - 190 modules (maximum) are supported to form the network. The module address can be modified through Uart.
  - Single package length can be up to 63bytes, with data package buffering mechanism.
- **User interface is simple and easy to follow.**
  - uart is used as interactive interface
  - Baud rate is adjustable
  - Length-variable package should be used to transmit data and the safe data should be used to sub-package protocol.
  - Port splitter is supported
- **The program runs stably**
  - Based on thread slice, the operating system runs stably.

- Memory pool is used to replace heap and complete distribution of dynamic memory. With it, no memory fragment will be generated during the long-term work.

- **With indicating light**
  - The module has indicating lights for receiving/sending.
  - The module has indicating light for positioning that can be remotely lit up. Through the indicating light, you can find the module easily.

Model Selection of products

DL-LN33 Using printing-plate antenna Single hop of communication withinvisual range is 70m.

DL-LN32 Using IPEX interface Single hop of communication within visual range is 100m.

DL-LN32P Using IPEX interface with on-board wireless amplifier Single hop of communication within visual range is 500m.

1 Networking

1.1 Overview of networking communication

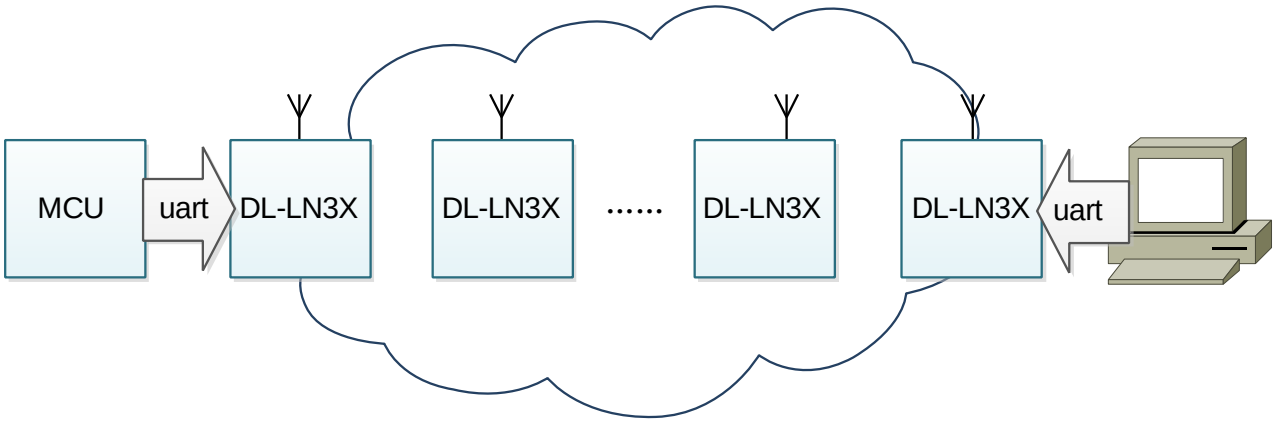
DL-LN3X module is a multi-hop wireless communication module of ad-hoc network. The radio frequency of module is 2.4GHz-2.45GHz, which is free global radio frequency. When the module is working, it will automatically build a wireless multi-hop network with the surrounding modules. Such network is a peer-to-peer network (PPN), requiring no central nodes. The network includes the following configurable parameters:

Table 1-1Module network parameters

Parameters	**Description**	**Requirements of values**
Address	Used to differentiate the identities of different modules in the network.	The value range is 0x0001-0xfffe. The module addresses in the same network must be different.
Channel	Consistent with IEEE802.15.4. The frequency between 2.4GHz-2.45GHz is divided into 16 channels by the module. Each module can work on one of the channels. Modules withdifferent channels will not interfere with each other.	The value range is 0x0B-0x1A. The module channels in the same network must be the same.
Network ID	Used to differentiate multiple different networks which might exist in the same channel. The modules with the same channel and different network IDs will not communicate with each other. However, the communication rate will become slow when many modules are working at the same time.	The value range is 0x0001-0xfffe. The module network IDs in the same network must be the same.

The configuration of these parameters will be illustrated in section 3.3.

Multiple DL-LN3X modules are be configured to the state with different addresses but identical channel and network ID. Such modules will form a network. The micro-controller (MCU) or computer can tell the module the destination address and the data to be sent through Uart. The module will select the optimal route through network to transmit the information to the destination module and the destination module will output the source address and the above-mentioned data through Uart.



DL-LN3X module searches for routing with directed diffusion protocol. This routing algorithm will record the network status. Each node can record the routing of 190 destination nodes on the average. After the network is established, the transmission rate and transmission delay can be optimal. However, the operation to establish this algorithm through network takes quite some time. When the node is newly started, the network needs to regenerate the routing in 1-5 minutes. During this time, the network carries out data communication with flooding routing. At the moment, the transmission rate of the network is quite slow.

1.2 Network performances

Table1-2Network performances

Parameters	Significance	Value
Maximum number of nodes	The number of modules accommodated by a network that can work normally.	The typical value is 190.
The maximum package length	The maximum length of each package (including the address information of port).	63 Byte.
Transmission capacity	The maximum sending rate when only one node sends data.	As the routing information of sending package will occupy some bandwidth, the longer each package, the higher the sending efficiency. When each package includes 3B data, the sending rate is 2,400 Bit/s. When each package includes 30B data, the sending rate is 10 KBit/s.
Maximum hop count	The maximum hop count transmitted by the package.	15 hops.
Retransmission times in the event of package loss	The times allow for retransmission after the transmission fails.	15 times at most. When the network is at heavy load, it is 5 times at maximum.

Retransmission interval	The next transmission time after the transmission fails	0.3s
Radio rate	The rate to transmit signals in a wireless way.	250KBit/s.
Air delay	The time when one package begins to be input into the module till it is outputted from another module after the transmission.	When the single hop incurs between nodes, it is less than 20mS.
Radio frequency		2.4GHz-2.45GHz.

2. Uart Communication Protocol

2.1 Uart parameters

Uart interface is used as data interactive interface by DL-LN3X module. The interface parameters are as follows:

Data bit 8 bits

Start bit 1 bit

Stop bit 1 bit

Check bit No verification

The Baud rate of Uart interface can be configured as the following values by the user:

2400 48009600 14400 19200 28800 38400 57600 115200 230400 125000 250000 500000

Uart output of almost any of the single-chip microcomputers can communicate with Uart of DL-LN3X module, while computer serial port can be converted to Uart with MAX3232 chip to communicate with DL-LN3X.

2.2 Package splitting

In the communication process, the most common situation is that the single-chip microcomputer tells the module the following information through Uart:

"Send data 00 AE 13 33 to the module with the address of 0003, destination port of 90 and source port of 91."

As for MCU, such information should be consolidated into a package and sent to the module through Uart:

FE 08 91 90 03 00 00 AE 13 33 FF

See the following table for the description of the package:

Table2-1Definition of Uart package structure

Information name	Length	Description	Examples
Package head	2byte	The package head is composed of FE and package length. The length is the package data length plus 4.	FE 08

Source port number	1byte	Source port number of package.	91
Destination port number	1byte	Destination port number of package.	90
Remote address	2byte	The address of remote address. When the data is sent to the module, the remote address is the address of destination module. When the destination address is 0x0000, it indicates that the package is sent to the remote module. When the destination address is 0xFFFF, it indicates that the package will be sent to all nodes in the network. When the data is received from the module, the remote address is the source address of data.	03 00
Data	Variable	Data intended to be sent.	00 AE 13 33
Package end	1byte	Terminator. When fixed as FF, it indicates that one package has been transmitted.	FF

When the remote address length is 2byte, small endian model is used for transmission, i.e., lower 8 bits should be transmitted first and then the higher 8 bits.

In the process of transmitting, when FF occurs in data section, address or port number, FE FD should be used to replace; in the event of FE, FE FC should be used to replace. Such replacement aims to avoid the package head and end occurring in the transmission process, thus causing misjudgment made by the receiver. During transmission, such replacement refers to "escaping".

The package length will not be affected by escaping. For instance, when the sent data is 09 FF, after it is replaced with 09 FE FD, the data length in the package head will still be calculated as per 2+4. In such case, the packagesent is as follows:

FE 06 91 90 03 00 09 FE FD FF

Although a total of 7 bytes are transmitted, the package length is 6. In the event of FF and FE occurring in the address or port number, escaping is also required.

2.3 Port

DL-LN3X module is designed with ports. After receiving one package, the receiver will select the corresponding program processing package according to the port number of the package. The value range of the port number is 0x00-0xFF, in which ports from 0x00-0x7F are occupied by the internal module program, and ports from 0x80-0xFF are open to MCU or computer connected to Uart.

When MCU sends data to one module, if the source port number is filled in with a value less than 0x80, the package cannot be sent out. If the destination port number is filled in with a value, the internal module program of the receiver will process this package and perform relevant actions. This package is not sent out from Uart.

For instance, to send this package:

FE 05 91 20 03 00 0A FF

The red light of the module with the address of 0300 will be lit up for 1s, and its Uart will not output data.

Most of the ports inside the module are used to debug and some of them are open to the users. These ports will be illustrated in Chapter 0.

2.4 Examples of communication

2.4.1 One node sends data to another node

For example, multiple nodes are used to build the following network. In this document, the node particularly refers to PC or the hardware equipment comprised by MCU and DL-LN3X module.

When the temperature and humidity of MCU collected are respectively 23℃ and 60%, the data subject to wireless transmission are 0x17, 0x3C. Both the node and computer transmit the temperature and humidity respectively with port A0 and port A1. If the known module address of MCU connected to the computer is 0x000F, the data sent to the module by MCU are:

FE 05 A0 A0 0F 00 17 FF FE 05 A1 A1 0F 00 3C FF

The data received by the computer serial port are:

FE 05 A0 A0 01 00 17 FF FE 05 A1 A1 01 00 3C FF

Among the data received by the computer serial port, the remote address is replaced as the address of source node.

2.4.2 One node sends data to the internal port of another node

Here, the network in section *2.4.1* will still be used.

When the node with the address of 0x0002 is required to be found, PC will order the red light of this module to be lit up for 5s by sending the following:

FE 05 A3 20 02 00 32 FF

You can see that the modules with the address of 0x0002 light up the red light for 5s.

2.4.3 One node sends data to its own internal ports

The module can send data to its own ports. More details of this part will be illustrated in section *0*.

2.2.1 Data transmissions not recommended

Here, the network in section *2.4.1* will still be used. The transmissions not recommended are classified into the following two kinds.

1. The module uses the port number less than 80 as the source port number. For instance, when the module sends FE 05 20 20 02 00 32 FF, the module will receive a *report package of wrong port number*: FE 06 22 20 02 00 E0 20 FF;actually, the module will not send any data. Therefore, such transmission is not recommended.
2. The module transmits data to some of its own ports. For instance, as for the node with the address of 0x000F transmitting data to its own port 80, after the module sends FE 05 81 80 0F 00 32 FF, it will receive FE 05 81 80 0F

00 32 FF and the single-chip microcomputer of the node will transmit a piece of data to itself. Obviously, it is unnecessary. Therefore, such transmission is not recommended.

3 Internal ports of module

3.1 Overview

This section will introduce the defined ports inside some modules, including the packages accepted by these ports and the packages to be sent by these ports. To illustrate the package, the document will describe the data part. The part related to the package structure will not be specified.

For instance:

Table0-1 Examples of package structure

Data	Length	Significance
Command	1Byte	Must be 0x12,
New network ID	2Byte	The new network ID value intended to be set. The new network ID must be legal.

This package is a package accepted by port 21. The data actually sent out through Uart are: FE 07 91 21 00 00 12 98 88 FF, in which 91 can be any port number, 00 00 is destination address, 12 is the command and 98 99 is the new network ID. See Chapter **2** for the composition of this package.

3.2 Port to control the flashing red light

Port 0x20 is used to control the lighting up of the red LED of the module. By sending this package, the red LED of the module can be lit up for certain time.

The port can receive the following packages:

Table 0-2 Lighting up LED package

Data	Length	Significance
Time delay	1Byte	Red LED lighting-up time = this parameter x 100ms

By sending the data to this module, the red LED can be lit up. The user can send this package both to the local module, and to the remote module.

Such function is used to test whether the module with a specified address is included in the network. If you want to rapidly locate the node with certain specified address from many nodes, you can also use this function.

3.3 Basic information management port

Port 0x21 is used to configure the basic parameters of the module, including address, network ID, channel and Baud rate.

This port only accepts the packages with the remote address filled in with 0x0000; therefore, the information can only be read and modified through Uart of this module. Such operation cannot be done remotely.

3.3.1 Reading information

Table0-3 Information-reading package

Data	Length	Significance
Command	1Byte	Must be one of the following values: 0X01 reading address; 0x02 reading network ID; 0X03 reading channel number; 0x04 reading the Baud rate of Uart.

After sending the data, the module will return an *address returning package*, , *channel returning package or Baud rate returning package* according to the modified contents. These packages will carry the corresponding configuration information.

3.3.2 Setting up information

Table 0-4 Address setting package

Data	Length	Significance
Command	1Byte	Must be 0x11,
New address	2Byte	The new address intended to be set up. The new address must be legal.

After sending the data, the module address will be modified as the value given by the new address, unless such value is illegal. After the operation, this port will return one *response package*.

Table 0-5Network ID setting package

Data	Length	Significance
Command	1Byte	Must be 0x12,
New network ID	2Byte	The new network ID value intended to be set. The new network ID must be legal.

After sending the data, the network ID of the module will be modified as the value given by the new network ID, unless such value is illegal. After the operation, this port will return one *response package*.

Table 0-6 Channel setting package

Data	Length	Significance
Command	1Byte	Must be 0x13,
New channel	1Byte	The new channel value intended to be set. The new network channel must be legal.

After sending the data, the network ID of the module will be modified as the value given by the new network ID, unless such value is illegal. After the operation, this port will return one *response package*.

Table0-7 Baud rate setting package

Data	Length	Significance
Command	1Byte	Must be 0x14,
New Baud rate	1Byte	The new Baud rate readings intended to be set up. The relationship between such readings and the actual Baud rate can refer to *Table 3-14 Comparison of Baud Rate Readings*.

After sending the data, the Baud rate of the module will be modified as the new value, unless such value is illegal. After the operation, this port will return one *response package*.

Information setting package includes setting address, network ID, Baud rate and channel. After the setting information is updated, it will not be executed immediately. The module will continue to operate with the original parameters. At this time, if you want the written parameters to take effect, you need to send *command-restart package* to the module. When you set up the address information and have not sent the restart command, if the module is restarted after powered off, the information set will also be lost. Once the information is set and *command-restart package*is sent, the information will not be lost due to power failure or reset in any form.

Table 0-8 Command restart package

Data	Length	Significance
Command	1Byte	After updating information and restarting, it must be 0x10;

3.3.3 The package replied by this port

Table 0-9 Response package

Data	Length	Significance
Response type	1Byte	The response type might be one of the following bytes: 0x00 Operation is completed 0xF0 This port forbids remote access. If remotely accessed, such response will be returned. 0xF8 Wrong command 0xF9 Package length is inconsistent with that required by the command The value of package 0xFA is not available. For instance, the channel in the channel setting package is greater than 1A, Baud rate uses the undefined number, the address is 0x0000 or 0xFFFF, or the network ID is 0x0000 or 0xFFFF.

Table 0-10 Address returning package

Data	Length	Significance
Command	1Byte	Must be 0x21,
Address	2Byte	Current address. If the node once received the information setting package and failed to update it, the latest set value will be returned here.

Table 0-11 Network ID returning package

Data	Length	Significance
Command	1Byte	Must be 0x22,
Network ID	2Byte	Current network ID. If the node once received the information setting package and failed to update it, the latest set value will be returned here.

Table 0-12 Channel returning package

Data	Length	Significance
Command	1Byte	Must be 0x23,
Channel	1Byte	Current channel. If the node once received the information setting package and failed to update it, the latest set value will be returned here.

Table 0-13 Baud rate returning package

Data	Length	Significance
Command	1Byte	Must be 0x24,
Baud rate	1Byte	Current Baud rate. If the node once received the information setting package and failed to update it, the latest Baud rate readings set up will be returned here. The relationship between these readings and the actual Baud rate can refer to *Table 3-14 Comparison of Baud Rate Readings*.

Table 0-14 Comparison table of Baud rate readings

Baud rate	Readings	Baud rate	Readings
2400	0x00	57600	0x07
4800	0x01	115200	0x08
9600	0x02	230400	0x09
14400	0x03	125000	0x0A
19200	0x04	250000	0x0B
28800	0x05	500000	0x0C
38400	0x06		

3.3.4 Setup instructions

This section will illustrate how to set up DL- LN series modules with examples.

If you do not know the Baud rate configured for the module, the BaudReset pin can be connected to GND. In such case, Baud rate 115200 can be used to configure the module.

Firstly, the current setting information of the module should be read. Certainly, if you are not concerned about the information on the current modules, you will not be required to read it.

See the following table for the information that can be sent:

Table 0-1 Information reading package

Sending information	Receiving information	Significance
FE 05 90 21 00 00 01 FF	FE 07 21 90 00 00 21 **0F 00**FF	For the address read by this command, the module will return one *address returning package*. The underlined data is the address of the module: 0x000F.
FE 05 90 21 00 00 02 FF	FE 07 21 90 00 00 22 **88 19** FF	For the network ID read by this command, the module will return one *network ID returning package*. The underlined data is the address of the module: 0x1988.
FE 05 90 21 00 00 03 FF	FE 06 21 90 00 00 23 **0F** FF	For the channel read by this command, the module will return one *channel returning package*. The underlined data is the channel of the module. The channel is 0x0F.
FE 05 90 21 00 00 04 FF	FE 06 21 90 00 00 24 **08** FF	For the Baud rate read by this command, the module will return one *Baud rate returning package*. The underlined data are the Baud rate readings of module, 0x08 refers to *Table 3-14 Comparison of Baud Rate Readings*. The Baud rate of the module is 115200.

Please pay attention, only when 0x0000 is used as destination address can it communicate with port 21. 0x0000 is the local address of the module.

Then fill in the information to be configured.

Table 0-2 Information setting package

Sending information	Significance
FE 07 90 21 00 00 11 **1F 00** FF	The address should be configured as 0x001F. The underlined part is the configured destination address. The address cannot be configured as 0x0000 and 0xFFFF
FE 07 90 21 00 00 12 **91 19** FF	The network ID should be configured as 0x1991. The underlined part is the configured destination network ID. The network ID cannot be configured as 0xFFFF
FE 06 90 21 00 00 13 **12** FF	The channel should be configured as channel 0x12. The underlined part is the configured destination channel. The channel range is between 0x0B and 0x1A.
FE 06 90 21 00 00 14 **02** FF	The Baud rate should be configured as 9600. Refer to *Table 3-14 Comparison of Baud Rate Readings* 9600 corresponding to the Baud rate readings is 02, namely, the underlined data.

After the configured command is sent to the module, the module will return FE 05 21 90 00 00 00 FF, indicating that the configuration is completed. The returned information will indicate the error of the sent package. See *response package* for the details of error messages.

Finally, if the configured information well is confirmed and FE 05 90 21 00 00 10 FF is sent to the module, the module will be restarted and then operate with new parameters.

3.4 Wrong report port

Port 0x22 is used to report communication error. The user should not send data to this port. When the user sends data with illegal address, this port will send error report package:

Table 0-3Report package of wrong port number

Data	Length	Significance
Error type	1Byte	Must be 0xe0,
Abnormal port	1Byte	The user adopts the illegal port number.

When sending the package with source address less than 0x80, the user will receive the error report from this port.

3.5 Connection quality test port

Port 0x23 is used to detect the bi-directional link quality between two modules. When the link quality is the average signal strength of the data received when two modules send packages to each other, the signal strength depends on the distance between two modules and on whether there are obstructions. If it is known that there are no obstructions between two modules, this value can be used to evaluate the distance between the modules.

The port can receive the following packages:

Table 0-4Command to collect connection quality

Data	Length	Significance
Collecting destination address	2Byte	The address of another module that collect RSSI cannot be 0x0000 and 0xFFFF

The following is an example of the data package:

FE 06 80 23 01 00 02 00 FF

This command will collect RSSI between two modules. One of modules is the modules receiving this package, i.e. the address is 0x0001. The address of another module is 0x0002 and it is the destination address collected. In such case, module 0x0001 will send to module 0x0002 one command to collect RSSI. After receiving this command, module 0x0002 will return a RSSI value. After receiving this package, module 0x0001 will integrate two pieces of data and then return this package:

FE 0723 80 XX XX 02 00 12 FF

Table0-5 Connection quality collecting and returning

Data	Length	Significance
Collecting destination address	2Byte	The address of another module that collect RSSI cannot be 0x0000 and 0xFFFF
Connection quality parameters	1byte	With symbolic number. It indicates the connection quality between two nodes. The higher the value, the better the connection quality between two nodes. If this value is -128 (0x80), it indicates that the node receives no package returned by the other party, namely, the data

This package can be sent remotely, namely, node A can command B to collect the link quality between B and C and return it to A;

The link quality collected has nothing to do with the link established between two modules. Without establishing the link, collection can still be done;

If the return value of the link quality collected is 128, it indicates that the information collected fails to be sent. This might be caused by the far distance between two nodes, or the excessively frequent network communication. Therefore, the information collected cannot be sent.

3.6 Controllable TTL output

Pin 4 and Pin 5 of the module are outputted from the testing serial port. During the normal use by the user, these two ports can be used as TTL output. By sending commands to 0x44 and 0x45, the output from Pin 4 and Pin 5 can be respectively controlled.

Table 0-6 TTL control return

Data	Length	Significance
Command	1byte	Only the following three values are allowed: 0x11 commands the port to output high level 0x10 commands the port to output low level 0x12 means to read the level outputted by the current port

After the control command is sent, the port level will change.

After 0x12 is sent, the module will return the current port level state. The returned data are as follows

Table 0-21 TTL control return

Data	Length	Significance
Command	1byte	Only the following three values are allowed: 0x01 indicates that the port outputs high level 0x00 indicates that the port outputs low level

The controllable TTL output can be used to control some simplest controller. For instance, the lighting, fan, solenoid valve and other equipment can be controlled, or the indicating light can be directly connected through relay or field effect.

In general, the frequency used to control the equipment should not be excessively high. Otherwise, it will consume a large amount of network resources.

The control commands of Pin4 and Pin5 are the same. Port 0x44 controls Pin4, while port 0x45 controls Pin5.

4 Electrical characteristics

Table 0-1 DL-LN33 electrical parameters

Parameters	Significance	Value
Operating voltage	Service voltage when the module is operating	2.5V-3.6V; the typical value is 3.3V
Operating current	Current consumed when the module is operating	Less than 30mA
Wireless transmission of power	Sending power of the radio	4.5dBm

Table 0-2 DL-LN32 electrical parameters

Parameters	Significance	Value
Operating voltage	Service voltage when the module is operating	2.5V-3.6V; the typical value is 3.3V
Operating current	Current consumed when the module is operating	Less than 30mA
Wireless transmission of power	Sending power of the radio	4.5dBm

Table0-3DL-LN32P electrical parameters

Parameters	Significance	Value
Operating voltage	Service voltage when the module is operating	2.5V-3.6V; the typical value is 3.3V
Operating current	Current consumed when the module is operating	Less than 55mA
Wireless transmission of power	Sending power of the radio	20dBm

5 Pin configuration

DL-LN33/ DL-LN32/ DL-LN32P modules use the same pin configuration. These modules are designed as the shape of stamp-hole PCB. The pin configuration is as shown in the figure below:

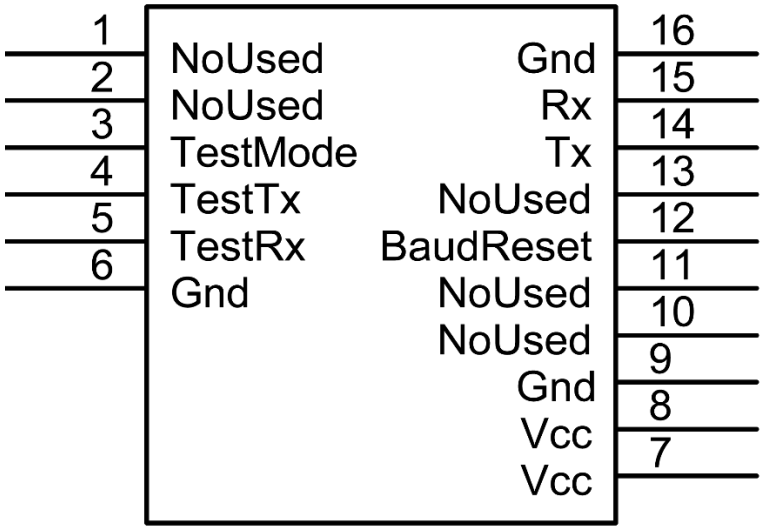
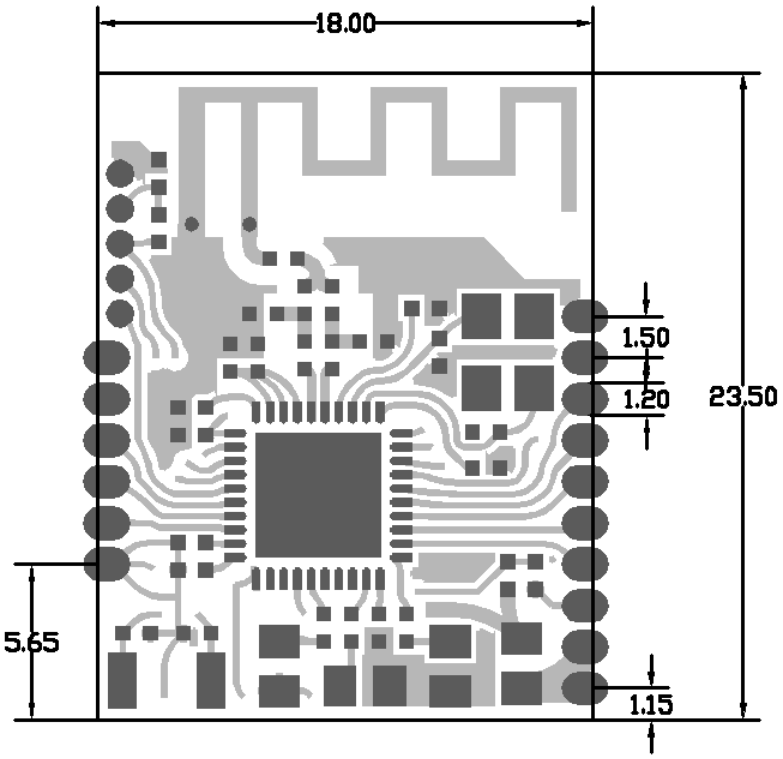


Table 0-1 Pin definition

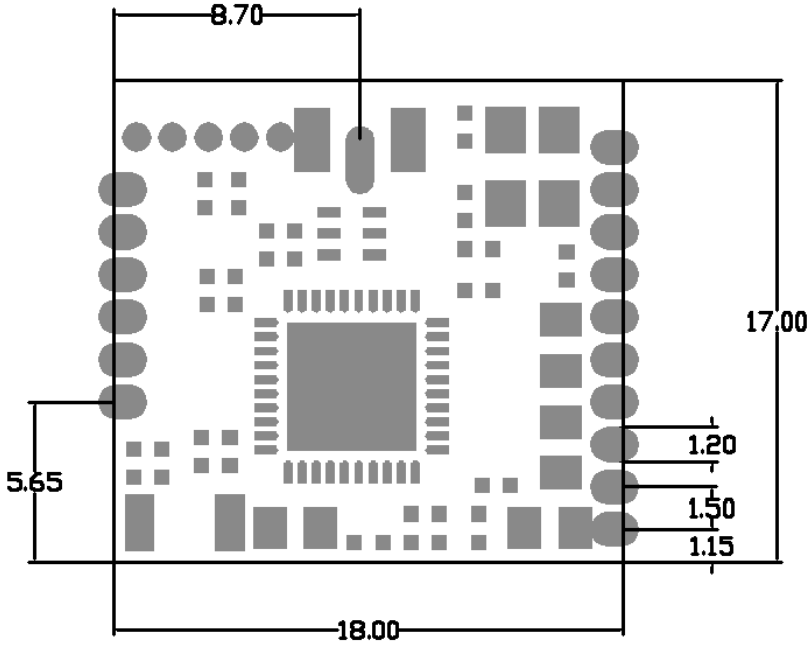
Pin name	Pin location	Significance
NoUsed	1,2,10,11,13	Unused. Please remains in suspense (in suspense means not to be connected to any electric circuit)
TestMode	3	In test mode, when suspended in air, the pin is operating in the normal mode, while earthing is carried in the test mode. Please remain it in suspense when it is used by the user.
TestTx	4	The test information outputted in the testing mode will be used as controllable IO port output when used by the user.
TestRx	5	The test information outputted in the test mode will be used as controllable IO port output when used by the user
Gnd	6,9,16	Connect to ground
Vcc	7,8	Powering on
BaudReset	12	If this pin is connected to Gnd when powered on , the module will be forced to operate with the default Baud rate 115200. In this mode, the Baud rate of the module can be read or set. The Baud rate read is the Baud rate previously set by the module, not 115200. If the module is restarted without setting up the Baud rate, the module will operate with the Baud rate previously set.
Tx	14	Uart output of the module
Rx	15	Uart input of the module

6. Packaging information

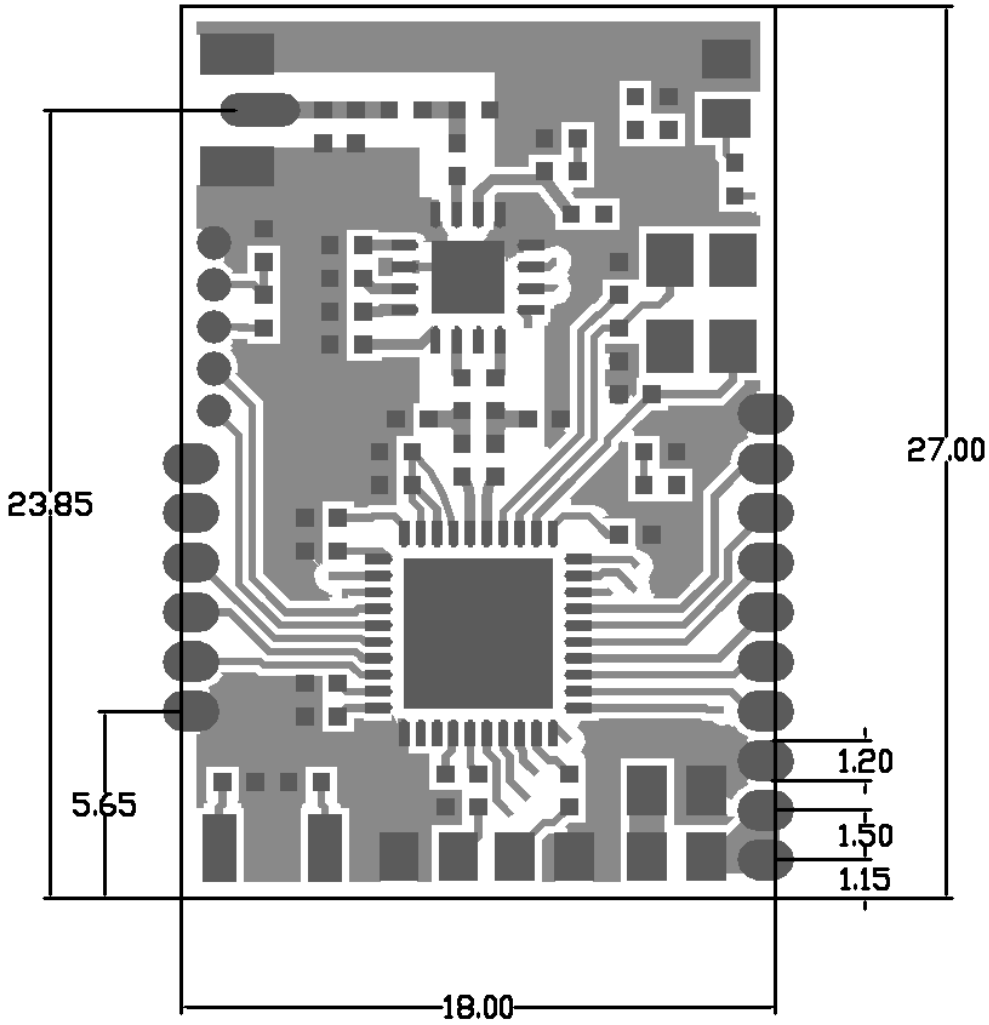
6.1 DL-LN33 packaging



6.2 DL-LN32 packaging



6.3 DL-LN32P packaging



7. Reference for hardware design

7.1 Precautions for PCB design

Pay attention to the following points with respect to PCB design:

1．The power supply pin of the module must be connected to the power and all the GNDs should be connected accordingly.

2．It is better to connect a100nF filter capacitor near the outside part of the supply pin of the module.

3．All the unused pins of the module must be floated.

4．Please paint the silk-screen printing on the whole circuit board on the back of the module to prevent short circuit.

5．There should not be any cable run under or copper laid under the module antenna, whether the front side or the reverse side.

6. The reverse side of the module's download cable interface is exposed to bare copper. There should not be any cables run or copper laid on the front side of PCB of the bare copper. Otherwise, it might cause short circuit.

7．The printing-plate antennas of DL-LN33 and Dl-LN32 should be close to the edge of the PCB. In such case, the wiring will be simpler and the antenna signal will be better.

7.2 Precautions for structural design

Pay attention to the following points with respect to structural design:

1. The antenna should not be included in the metal housing or metal mesh, in case that the signals are shielded.

2. Metal screws and other objects around the antenna should try to be avoided, in case that the communication distance is affected.

3. The antenna should be arranged outside the product. For example, when the product is placed on the floor, the antenna should try to face upwards; when the product is installed on the wall, the antenna should try to stay away from the wall.