ANR014 PROTEUS QUICKSTART

CONNECT A SMART PHONE TO A PROTEUS BLUETOOTH LE RADIO MODULE

Version 1.2

March 11, 2021
## Revision history

<table>
<thead>
<tr>
<th>Manual version</th>
<th>Notes</th>
<th>Date</th>
</tr>
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<tr>
<td>1.0</td>
<td>• Initial version</td>
<td>July 2019</td>
</tr>
<tr>
<td>1.1</td>
<td>• Added description for Proteus-III</td>
<td>January 2020</td>
</tr>
<tr>
<td></td>
<td>• Updated address of Division Wireless Connectivity &amp; Sensors location</td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>• Added example for connection setup using the Proteus Connect App</td>
<td>March 2021</td>
</tr>
<tr>
<td></td>
<td>• Added information on Proteus-III-SPI and the mini evaluation board</td>
<td></td>
</tr>
</tbody>
</table>
# Abbreviations and abstract

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTMAC</td>
<td>Bluetooth® conform MAC address of the module used on the RF-interface.</td>
<td></td>
</tr>
<tr>
<td>CS</td>
<td>Checksum</td>
<td>Byte wise XOR combination of the preceding fields.</td>
</tr>
<tr>
<td>Central</td>
<td>Bluetooth® LE device role that scans for advertising packets &amp; initiates connections, e.g. smart phone.</td>
<td></td>
</tr>
<tr>
<td>DTM</td>
<td>Direct test mode</td>
<td>Mode to test Bluetooth® specific RF settings.</td>
</tr>
<tr>
<td>GAP</td>
<td>Generic Access Profile</td>
<td>The GAP provides a basic level of functionality that all Bluetooth® devices must implement.</td>
</tr>
<tr>
<td>I/O</td>
<td>Input/output</td>
<td>Pinout description.</td>
</tr>
<tr>
<td>LPM</td>
<td>Low power mode</td>
<td>Mode for efficient power consumption.</td>
</tr>
<tr>
<td>MAC</td>
<td>MAC address of the module.</td>
<td></td>
</tr>
<tr>
<td>MTU</td>
<td>Maximum transmission unit</td>
<td>Maximum packet size of the Bluetooth® connection.</td>
</tr>
<tr>
<td>Payload</td>
<td></td>
<td>The intended message in a frame / package.</td>
</tr>
<tr>
<td>Peripheral</td>
<td>Bluetooth® Low Energy device role that provides services &amp; advertises, e.g. sensor or our Proteus module.</td>
<td></td>
</tr>
<tr>
<td>RF</td>
<td>Radio frequency</td>
<td>Describes wireless transmission.</td>
</tr>
<tr>
<td>RSSI</td>
<td>Receive Signal Strength Indicator</td>
<td>The RSSI indicates the strength of the RF signal. Its value is always printed in two’s complement notation.</td>
</tr>
<tr>
<td>SoC</td>
<td>System on Chip.</td>
<td></td>
</tr>
<tr>
<td>Soft device</td>
<td>Operating system used by the nRF52 chip.</td>
<td></td>
</tr>
<tr>
<td>SPI</td>
<td>Serial Peripheral Interface</td>
<td>Allows the serial communication with the module.</td>
</tr>
<tr>
<td>UART</td>
<td>Universal Asynchronous Receiver Transmitter</td>
<td>Allows the serial communication with the module.</td>
</tr>
<tr>
<td>[HEX] 0xhh</td>
<td>Hexadecimal</td>
<td>All numbers beginning with 0x are hexadecimal numbers. All other numbers are decimal, unless stated otherwise.</td>
</tr>
</tbody>
</table>
1 Introduction

The Proteus series is a radio module series that is based on Nordic Semiconductors SoC which presents various Bluetooth® LE and low power features. By default, a radio module of the Proteus series can be controlled and configured by the host using predefined commands, in the so called command mode.

This application note describes how to setup a connection between a Bluetooth® LE enabled smart device, e.g. smart phone or tablet, to a Proteus module and how to interchange data in command mode. These steps are described with help of the nRF Connect App which is an open source App providing standard Bluetooth® LE functions for iOS as well as for Android devices.

There is a second operation mode, that offers a transparent UART interface to transmit data without any overhead on the UART. For more information concerning this mode, please refer to the application node AN-R004_Proteus_Peripheral_Only_Mode.
2 Prerequisites

To follow the description in this application note, the following prerequisites may be helpful:

- A Bluetooth® LE enabled smart phone including a suitable App, for example
  - the Proteus Connect App for Android [3][5] or iOS [4][6]
  - the Nordic Semiconductor nRF Connect App for Android [1] or iOS [2]

- A Proteus evaluation board in factory state, for example
  - the Proteus-I evaluation board with jumpers set as specified in figure 1. Other jumpers not set.
  - the Proteus-II evaluation board with jumpers set as specified in figure 1. Other jumpers not set.
  - the Proteus-III evaluation board with jumpers set as specified in figure 2. Other jumpers not set.
  - the Proteus-III-SPI mini evaluation board with jumpers set as specified in figure 3. Other jumpers not set.

![Figure 1: Default jumper placement of the Proteus-I and Proteus-II evaluation board. Red means "jumper must be set".](image-url)
Figure 2: Default jumper placement of the Proteus-III evaluation board. Red means “jumper must be set”.

Figure 3: Default jumper placement of the Proteus-III-SPI mini evaluation board.

The complete description of Proteus modules can be found in the respective radio module manual and application notes. This may be helpful to understand the background of the following quick start:

- Proteus-I
  - Proteus-I reference manual
  - Proteus-I advanced user guide ANR002_Proteus-I_Advanced_Developer_Guide

- Proteus-II
  - Proteus-II reference manual
  - Proteus-II advanced user guide ANR005_Proteus-II_Advanced_Developer_Guide

- Proteus-III
- Proteus-III reference manual
- Proteus-III advanced user guide ANR009_Proteus-III_Advanced_Developer_Guide

- Proteus-III-SPI
  - Proteus-III-SPI reference manual
  - Proteus-III advanced user guide ANR009_Proteus-III_Advanced_Developer_Guide
3 Basics

The setup of a Bluetooth® LE connection to a Proteus radio module contains several steps:

1. Physical connection establishment
   First of all, a physical connection has to be established. Therefore, a central device (usually smart phone) has to connect to the Proteus module which runs as peripheral.

2. Optional: Pairing process
   Second, the pairing process is run that consists of the authentication and exchange of encryption information. The central device must request at least the same security level to access the characteristics of the peripheral (Proteus module).
   - In factory state, the Proteus module has no security enabled and this step can be neglected.
   - Security can be enabled by modifying the user setting RF_SecFlags.

   If the security level of the central device is lower than the security mode of the peripheral, the central cannot access the peripheral's characteristics. In this case, the central sends the notification enable message, which is ignored by the peripheral. Thus, the central signalizes an open connection, although it does not have access to the peripheral and thus data cannot be transmitted! In some cases, the peripheral may also disconnect to avoid to be blocked by attackers.

3. Optional: Exchange of the maximum transmission unit (MTU)
   Next, the maximum transmission unit can be increased to allow the transmission of larger data packets. The Proteus module allows an MTU of up to 247 bytes, which results in a payload of up to 243 bytes. This step is optional. Not selecting a higher MTU will use the Bluetooth® 4.0 default MTU which results in 19 bytes payload for the user but will be compatible to pre Bluetooth® 4.2 devices.

4. Discover the characteristics of the Proteus module SPP-like profile
   Afterwards, the characteristics offered by the Proteus module have to be discovered by the central. This is needed to share the information how data can be transmitted.

5. Notification enable
   To finalize the connection setup, the notification enabled message has to be send. With this feature, the peripheral device lets the central know, when there is new data, which is important for bidirectional data transmission. After this step, the channel is open and data transmission can start.

For the description, we assume that a smart phone is the initiator of the connection. Thus, it acts as central and the Proteus module acts as peripheral in figure 4.
Figure 4: Steps for the connection setup
4 Quick start

The following description demonstrates how to setup a connection with a smart phone to a Proteus radio module. The smart phone acts as central device. First of all the Proteus Connect App is used. Then the same is done using the Nordic Semiconductor nRF Connect App.
4.1 Proteus Connect App

This chapter describes how to setup a connection to the Proteus module in command mode, when a smart phone and the Proteus Connect App are used.

The Proteus Connect App for iOS and Android is provided by Würth Elektronik eiSos as executable [3][4] as well as source code [5][6].

Please perform the following steps:

<table>
<thead>
<tr>
<th>Android</th>
<th>iOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Connect the Proteus evaluation board to a host. In this application note, we assume that a Windows PC and the terminal program <code>hterm</code> is used. For Proteus-I, -II and -III evaluation board this can be simply achieved by using a simple USB cable to connect it to a PC. To make life easy, also the SmartCommander PC tool provided by Würth Elektronik eiSos can be used. This tool implements all commands of the Proteus radio module.</td>
<td></td>
</tr>
<tr>
<td>• Open the terminal program using the Proteus default UART settings (115200 Baud, 8n1).</td>
<td></td>
</tr>
<tr>
<td>• Press the reset button on the Proteus evaluation board. The Proteus module outputs a <code>CMD_GETSTATE_CNF (0x02410200010141)</code> message to indicate that it is ready for operation.</td>
<td></td>
</tr>
</tbody>
</table>
- Initially, the module is advertising. Thus, one LED of the Proteus evaluation board is blinking.

- Start your smart phone, enable the Bluetooth® LE feature and start the **Proteus Connect** App.

- Press "Scan" to find the module on the radio.

- When the module appears, select it to start the connection process.

- As soon as the module has received the connection request the module **LED_1** (**LED_3** on the Proteus-EV) will constantly light up.
• Optional pairing: In case a security mode has been configured before, the smart phone requests the user for pairing actions. In case of the static passkey authentication, the Proteus requests to enter the static passkey. The default passkey is "123123". The Bluetooth® coupling requirement pop-up is shown on your smart phone. When the bonding feature is enabled in the authentication settings and the bonding information already exists, a re-entering of the passkey is not required when reconnecting.
In few cases the Android may show an "authentication timeout" pop-up message, when entering the key. In this case, please proceed entering the key and simply do a reconnect. On this reconnect, the entered key information is reused and the connection is opened.

<table>
<thead>
<tr>
<th>Android</th>
<th>iOS</th>
</tr>
</thead>
</table>

- Now you are authenticated and the LED_2 (LED_2 on the Proteus-EV) is turned on. Now data can be transmitted in both directions.
- On the Proteus side, the radio module sent the corresponding `CMD_CONNECT_IND (0x02860700...)` and `CMD_CHANNELOPEN_RSP (0x02C60800...)` in between. These messages indicate that a connection has been setup and a link has been opened. The `CMD_CHANNELOPEN_RSP` message contains the MTU (maximum transmission unit) of the current link, which defines the maximum supported packet payload length. In this example it's 0xF3 (243 dec) bytes payload per packet.
<table>
<thead>
<tr>
<th>Android</th>
<th>iOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• First of all, we want to send data from the smart phone to the radio module. To do so, enter your payload (for example 0x11 0x22 0x33 0x44) in the respective field and press “SEND”. The allowed payload size is dependent on the MTU that was negotiated in the connection process. The smallest supported MTU for all Bluetooth® 4.0 (or newer) devices results in a max payload of 19 bytes.</td>
<td>• iOS usually allows up to 181 bytes.</td>
</tr>
<tr>
<td>• Android usually allows up to 243 bytes.</td>
<td></td>
</tr>
</tbody>
</table>
The payload that has been sent is output by the Proteus module via UART. In the terminal program a **CMD_DATA_IND** message has been received that contains the **BTMAC** of the sending device and the transmitted payload 0x11 0x22 0x33 0x44. The format of the **CMD_DATA_IND** message is as follows:

<table>
<thead>
<tr>
<th>Start signal</th>
<th>Command</th>
<th>Length</th>
<th>BTMAC</th>
<th>RSSI</th>
<th>Payload</th>
<th>CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x84</td>
<td>2 Bytes</td>
<td>6 Bytes</td>
<td>1 Byte</td>
<td>(Length - 7) Bytes</td>
<td>1 Byte</td>
</tr>
<tr>
<td>0x02</td>
<td>0x84</td>
<td>0x0B 0x00</td>
<td>0x82 0x5C 0xA7 0xE2 0x87 0xD0</td>
<td>0xCB</td>
<td>0x11 0x22 0x33 0x44</td>
<td>0xCE</td>
</tr>
</tbody>
</table>
• To send back data to the smart phone simply insert your payload (here we choose 0xDE 0xAD 0xBE 0xEF) in a \texttt{CMD\_DATA\_REQ} message. The format of the \texttt{CMD\_DATA\_REQ} message is as follows, where the check sum (CS) is calculated as XOR of the preceding bytes:

<table>
<thead>
<tr>
<th>Start signal</th>
<th>Command</th>
<th>Length</th>
<th>Payload</th>
<th>CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x04</td>
<td>2 Bytes</td>
<td>Length Bytes</td>
<td>1 Byte</td>
</tr>
<tr>
<td>0x02</td>
<td>0x04</td>
<td>0x04 0x00</td>
<td>0xDE 0xAD 0xBE 0xEF</td>
<td>0x20</td>
</tr>
</tbody>
</table>

• The header 0x01 of the radio frame header will be automatically applied by the module and is not part of the payload of the \texttt{CMD\_DATA\_REQ} message.
• The received data is shown in the status window. It contains the header byte 0x01 and the payload 0xDE 0xAD 0xBE 0xEF, that has been entered in the terminal program.

• The received data is shown in the status window.
4.1.1 Background service on iOS

By default, iOS disconnects the Bluetooth® LE connection, in case the Proteus Connect App is put to background. To avoid this behavior, the background service of the Proteus Connect App must be enabled by going to the info tab and selecting the "Bluetooth Background Mode” slider.

Figure 5: Enable the background service on iOS
4.2 nRF Connect App

This chapter describes how to setup a connection to the Proteus module in command mode, when a smart phone and the nRF Connect App [1][2] are used. Please perform the following steps:

<table>
<thead>
<tr>
<th>Android</th>
<th>iOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Connect the Proteus evaluation board to a host. In this application note, we assume that a Windows PC and the terminal program <em>term</em> is used. For Proteus-I, -II and -III evaluation board this can be simply achieved by using a simple USB cable to connect it to a PC. To make life easy, also the SmartCommander PC tool provided by Würth Elektronik eiSos can be used. This tool implements all commands of the Proteus radio module.</td>
<td>• Open the terminal program using the Proteus default UART settings (115200 Baud, 8n1).</td>
</tr>
<tr>
<td>• Press the reset button on the Proteus evaluation board. The Proteus module outputs a CMD_GETSTATE_CNF (0x02410200010141) message to indicate that it is ready for operation.</td>
<td>• Press the reset button on the Proteus evaluation board. The Proteus module outputs a CMD_GETSTATE_CNF (0x02410200010141) message to indicate that it is ready for operation.</td>
</tr>
<tr>
<td>Android</td>
<td>iOS</td>
</tr>
<tr>
<td>---------</td>
<td>-----</td>
</tr>
<tr>
<td>• Initially, the module is advertising. Thus, one LED of the Proteus evaluation board is blinking.</td>
<td></td>
</tr>
<tr>
<td>• Start your smart phone, enable the Bluetooth® LE feature and start the <strong>nRF Connect</strong> App.</td>
<td></td>
</tr>
<tr>
<td>• Press &quot;SCAN&quot; to find the module on the radio. In case several Proteus modules are found, the Bluetooth® MAC 0x0018DAxxxxxx can be used to detect the right one. The Bluetooth® MAC consists of the module’s serial number, that can be also found on the module label.</td>
<td></td>
</tr>
<tr>
<td><img src="android-scan.png" alt="Android Scan" /></td>
<td><img src="ios-scan.png" alt="iOS Scan" /></td>
</tr>
<tr>
<td>• When the module appears, press &quot;CONNECT&quot;.</td>
<td></td>
</tr>
</tbody>
</table>
• As soon as the module has received the connection request from the smart phone the blinking LED will switch to constant on.

• Optional pairing: In case a security mode has been configured before, the smart phone requests the user for pairing actions. In case of the static passkey authentication, the Proteus requests to enter the static passkey. The default passkey is “123123”. The Bluetooth® coupling requirement pop-up is shown on your smartphone. When the bonding feature is enabled in the authentication settings and the bonding information already exists, a re-entering of the passkey is not required when reconnecting.
<table>
<thead>
<tr>
<th>Android</th>
<th>iOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Please click on the menu bullets on the right and press &quot;Request MTU&quot; to request for a larger MTU.</td>
<td>• Please click on the &quot;Unknown Service&quot; to start the service discovery and the MTU request.</td>
</tr>
</tbody>
</table>

![Android screenshot](image1)

![iOS screenshot](image2)
<table>
<thead>
<tr>
<th>Android</th>
<th>iOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The Proteus module allows a MTU of up to 247 bytes, which results in a payload size of 243 bytes.</td>
<td>• The iOS App runs this step simultaneously in the background, a user-defined MTU is not possible.</td>
</tr>
<tr>
<td>Android</td>
<td>iOS</td>
</tr>
<tr>
<td>---------</td>
<td>-----</td>
</tr>
<tr>
<td>• Again click on the menu bullets on the right and press &quot;Enable services&quot; to enable the notifications.</td>
<td>• Press the arrow on the RX-characteristic 6E400003-C352-11E5-953D-0002A5D5C51B to enable the notifications. Press it until a cross appears (see below, it has to be pressed at least once). If a cross is already shown press it twice so the cross disappears and then reappears.</td>
</tr>
</tbody>
</table>

![Android screenshot](image)

![iOS screenshot](image)

• As soon as the module has received the notification enable request the second LED on the Proteus evaluation board is turned on. Now you are fully connected and you can access the characteristics to transmit and receive data.
On the Proteus side, the radio module sent the corresponding `CMD_CONNECT_IND (0x02860700...)` and `CMD_CHANNELOPEN_RSP (0x02C60800...)` in between. These messages indicate that a connection has been setup and a link has been opened. The `CMD_CHANNELOPEN_RSP` message contains the MTU (maximum transmission unit) of the current link, which defines the maximum supported packet payload length. In this example it’s 0xF3 (243\_\text{dec}) bytes payload per packet.
• To send data to the Proteus module, press the arrow next to the TX-characteristic 6E400002-C352-11E5-953D-0002A5D5C51B in the nRF Connect App.

• First enter 01 right behind the 0x as header byte, followed by your payload (for example 0x11 0x22 0x33 0x44) and press "SEND" to start the transmission. The maximum allowed payload size is dependent on the MTU that was selected in the connection process (see CMD_CHANNELOPEN_RSP message on the previous page).
The payload that has been sent is output by the Proteus module via UART. In the terminal program a CMD_DATA_IND message has been received that contains the BTMAC of the sending device and the transmitted payload 0x11 0x22 0x33 0x44.

The format of the CMD_DATA_IND message is as follows:

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<td>0xCB</td>
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<td>0xCE</td>
</tr>
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</table>

![Diagram of CMD_DATA_IND message](image.png)
• To send back data to the smart phone simply insert your payload (here we choose 0xDE 0xAD 0xBE 0xEF) in a CMD_DATA_REQ message. The format of the CMD_DATA_REQ message is as follows, where the check sum (CS) is calculated as XOR of the preceding bytes:

<table>
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<th>Payload</th>
<th>CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x04</td>
<td>2 Bytes</td>
<td>Length Bytes</td>
<td>0xDE 0xAD 0xBE 0xEF</td>
</tr>
</tbody>
</table>

• The header 0x01 of the radio frame header will be automatically applied by the module and is not part of the payload of the CMD_DATA_REQ message.

![Image of HTerm interface displaying CMD_DATA_REQ message with payload and check sum calculation]
The received data can be found in the RX-characteristic 6E400003-C352-11E5-953D-0002A5D5C51B. It contains the header byte 0x01 and the payload 0xDE 0xAD 0xBE 0xEF.
• When sending the CMD_DATA_REQ to the Proteus module, it responds with two different messages. First a CMD_DATA_CNF (0x024401000047) message is returned, as soon as the request was interpreted. Then a CMD_TXCOMPLETE_RSP (0x02C4010000C7) message is returned as soon as the data has been transmitted.
• To disconnect the smart phone from the Proteus module, press the "DISCONNECT" button in the nRF Connect App. The Proteus module will output a CMD_DISCONNECT_IND (0x028701001397) message to indicate that the connection has been closed.

• After disconnecting the Proteus module starts advertising again, such that a re-connection can be performed.
5 References


6 Important notes

The following conditions apply to all goods within the wireless connectivity product range of Würth Elektronik eiSos GmbH & Co. KG:

6.1 General customer responsibility

Some goods within the product range of Würth Elektronik eiSos GmbH & Co. KG contain statements regarding general suitability for certain application areas. These statements about suitability are based on our knowledge and experience of typical requirements concerning the areas, serve as general guidance and cannot be estimated as binding statements about the suitability for a customer application. The responsibility for the applicability and use in a particular customer design is always solely within the authority of the customer. Due to this fact, it is up to the customer to evaluate, where appropriate to investigate and to decide whether the device with the specific product characteristics described in the product specification is valid and suitable for the respective customer application or not. Accordingly, the customer is cautioned to verify that the documentation is current before placing orders.

6.2 Customer responsibility related to specific, in particular safety-relevant applications

It has to be clearly pointed out that the possibility of a malfunction of electronic components or failure before the end of the usual lifetime cannot be completely eliminated in the current state of the art, even if the products are operated within the range of the specifications. The same statement is valid for all software sourcecode and firmware parts contained in or used with or for products in the wireless connectivity and sensor product range of Würth Elektronik eiSos GmbH & Co. KG. In certain customer applications requiring a high level of safety and especially in customer applications in which the malfunction or failure of an electronic component could endanger human life or health, it must be ensured by most advanced technological aid of suitable design of the customer application that no injury or damage is caused to third parties in the event of malfunction or failure of an electronic component.

6.3 Best care and attention

Any product-specific data sheets, manuals, application notes, PCN’s, warnings and cautions must be strictly observed in the most recent versions and matching to the products firmware revisions. This documents can be downloaded from the product specific sections on the wireless connectivity homepage.

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Some products within the product range may contain substances, which are subject to restrictions in certain jurisdictions in order to serve specific technical requirements. Necessary information is available on request. In this case, the field sales engineer or the internal sales person in charge should be contacted who will be happy to support in this matter.
6.5 Product improvements

Due to constant product improvement, product specifications may change from time to time. As a standard reporting procedure of the Product Change Notification (PCN) according to the JEDEC-Standard, we inform about major changes. In case of further queries regarding the PCN, the field sales engineer, the internal sales person or the technical support team in charge should be contacted. The basic responsibility of the customer as per section 6.1 and 6.2 remains unaffected. All wireless connectivity module driver software "wireless connectivity SDK" and it's source codes as well as all PC software tools are not subject to the Product Change Notification information process.

6.6 Product life cycle

Due to technical progress and economical evaluation we also reserve the right to discontinue production and delivery of products. As a standard reporting procedure of the Product Termination Notification (PTN) according to the JEDEC-Standard we will inform at an early stage about inevitable product discontinuance. According to this, we cannot ensure that all products within our product range will always be available. Therefore, it needs to be verified with the field sales engineer or the internal sales person in charge about the current product availability expectancy before or when the product for application design-in disposal is considered. The approach named above does not apply in the case of individual agreements deviating from the foregoing for customer-specific products.

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6.8 General terms and conditions

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7 Legal notice

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