PHAT-NBIOT TECHNICAL DESCRIPTION

pHAT Module Series

Document: pHAT-NBIOT Technical Description

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About the Document

History

Revision	Description	Date	Author
Draft A	Create	14/7/19	DIO
Issue 1	First release	25/8/19	-
Issue 2	Added QLEDMODE to application and updated LED indication	24/9/19	-
Issue 3	Added Raspberry-Pi Kernal workaround and Python 3 setup	12/7/23	-

Contents

Page No.

Tables

Figures

1 Introduction

This document defines the pHAT-NBIOT NB IoT module and describes the hardware interface that is connected to the customer's to the customers Raspberry-Pi application.
This document can help customers quickly understand module interface specifications, electrical and mechanical details, as well as other related information of the module. Associated with the quick start guide and demo software, customers can use this document to easily set up the module.

2 Product Concept

2.1 General Description

The Designer Systems pHAT-NBIOT is a multi-band LTE Cat NB1 module that works on bands B1-5, B8, B12, B13, B17-20, B25, B28 & B66 supporting single/multitoned data and Small-Message-System (SMS) functionality.

Specifically designed for the Raspberry-Pi Zero user (can also be used on all the other Raspberry-Pi variants) the pHAT-NBIOT features I^2C communication to leave the Raspberry-Pi UART for other functions eg. Sensors, debug etc.

pHAT-NBIOT features full AT command control over the embedded I^2C to UART bridge allowing the Raspberry-Pi to create UDP/TCP/MQTT data links with downlink transfers at up to 25.5kbps.

The compact form factor, low power consumption and extended temperature range make pHAT-NBIOT a best choice for M2M applications when using Raspberry-Pi modules.

The module fully complies with the RoHS/RED directive of the European Union.

2.2 Key Features

The following table describes the key features of the pHAT-NBIOT.

Table 1: Key Features

Features	Details
Power Supply	• Supply Voltage: 4.5 ~ 5.5VDC • Typical Supply Voltage: 5.0VDC
Power Consumption	• 1mA @ 5VDC Idle • 80mA @ 5VDC Peak
Frequency Bands	Multiband B1-5, B8, B12, B13, B17-20, B25, B28 & B66
Output Power	23dBm ± 2dB
Sensitivity	-129dBm Typ.
Data Rate	• Single-Tone: 25.5kbps(DL)/16.7kbps(UL) • Multi-Tone: 25.5kbps(DL)/62.5kbps(UL)
Protocols	UDP/TCP LwM2M/MQTT/DTLS/SNTP
SMS Support	Text and PDU modes
SIM Card	Micro SIM(3.0/1.8V)
Indication	Blue STATUS LED
Controls	Power ON/OFF button (also GPIO controllable)
I^2C Speed	400kHz max.
Environmental	• Operating Temperature -20℃ to 85℃ • Storage Temperature -30℃ to 125℃
Dimensions	65 x 30 x 4mm
Weight	12g approx.

3 Application

3.1 Installation

The module should be attached to the Raspberry-Pi board using a 20+20 2.54mmP pin header/socket (not supplied).

3.1.1 SIM Card and Antenna

Insert a NB IoT capable micro SIM card into the card connector identified as 'SIM CARD' and attach the supplied Flexi antenna to the U.FL connector identified as 'WIDEBAND ANTENNA', ensuring that the antenna is located away from any metal objects.

3.2 Operation

When power is applied to the pHAT-NBIOT, from the connected Raspberry-Pi board, it is possible to either manually power-up the module, by depressing the button identified as 'POWER' for > 1 second, or by setting the GPIO23 (pin 16) high for > 1 second. The module will power-up, indicated by the STATUS indicator flashing, and will register on to the network provider defined by the inserted SIM card.
Once registered the pHAT-NBIOT will await incoming AT commands allowing configuration, SMS send/receive and data communication.

3.3 Indication

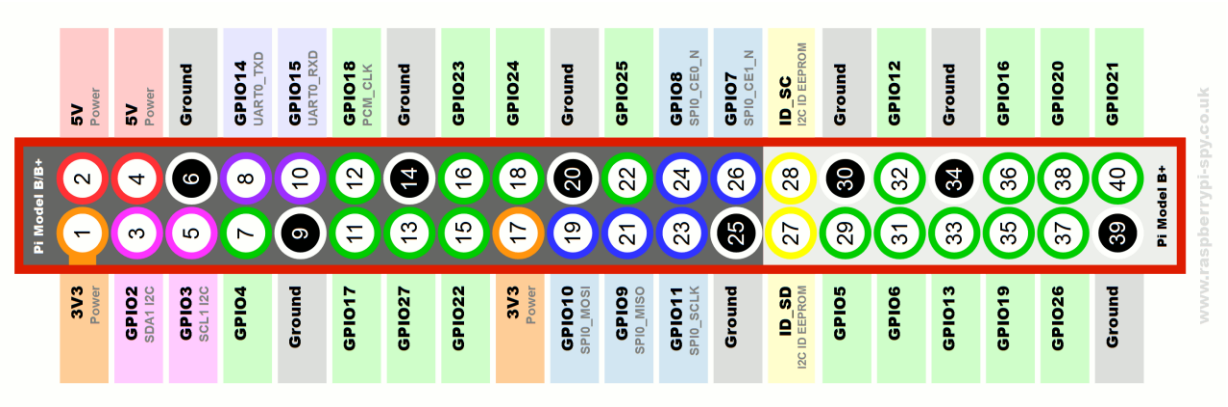
The STATUS indicator is used to provide visual feedback of the current network condition. There are three (3) conditions as follows.

Table 2: Status Indication

Indication	Description
OFF	Powered down or registered
Flash every 800mS	Searching for registration
Flash every 2 seconds	Connected

These conditions will change as network status and modes change.

3.4 Pin Assignment



3.5 Power Supply

3.5.1 Power Supply Pins

The pHAT-NBIOT provides a supply input and multiple ground connections on the 20+20 header that connect to the 5.0V supply on the Raspberry-Pi board. The table below describes the module supply and ground pins.

Table 3: Power Supply Pins

Pin Name	Pin No	Description	Min	Typ.	Max	Unit
V+	2, 4	Power Supply	4.5	5.0	6.0	V
Ground	6,9,14,20, 25,30,34, 39	Power Ground				

3.6 Antenna Interface

3.6.1 Antenna Connector

The pHAT-NBIOT provides a 50Ω (ohm) impedance U.FL antenna connector that should be connected to an external Wideband antenna. A suitable antenna is supplied.

Table 4: Antenna Connector

Pin Name	Pin No	I/O	Description	Comment
NB_ANT	Inner	RF	Wideband Antenna RF feed	
GND	Outer	RF	Wideband Antenna RF ground	

3.7 GPIO Interface

3.7.1 GPIO Interface Pins

The pHAT-NBIOT provides power control (PWR_ONOFF) and modem wake-up from sleep (PSM_EINT) connections on the 20+20 header that connects to GPIO23 and GPIO17 on the Raspberry-Pi board. The table below describes the module GPIO pins.

Table 5: GPIO Interface Pins

Pin Name	Pin No	I/O	Description	Comment
GPIO17	11	DIO	Modem PSM_EINT	3.3V level
GPIO23	16	DIO	Modem PWR_ONOFF	3.3V level

The PWR_ONOFF GPIO line can be used to control the modem power in applications where manual power on/off is not possible. Activating GPIO23 as a set output for > 1 second holds the modem power on/off line low allowing modem power-on or > 1.5 seconds for power-off.

The PSM_EINT GPIO line can be used to control the modem wake-up in applications where the modem is configured for Power Saving Mode (PSM). Activating GPIO17 as a set output for > 50 milliseconds wakes the modem ready for UART communication.

3.8 I²C Interface

3.8.1 I²C Interface Pins

The pHAT-NBIOT provides I²C data (SDA), clock (SCL) and interrupt (INT) connections on the 20+20 header that connect to the SDA, SCL and GPIO25 on the Raspberry-Pi board. The table below describes the module I²C pins.

Table 6: I²C Interface Pins

Pin Name	Pin No	I/O	Description	Comment
SDA	3	DIO	I2C Data	3.3V level
SCL	5	CO	I2C Clock	3.3V level
INT	22	DIO	Interrupt (GPIO25)	3.3V level

The pHAT-NBIOT does NOT have I²C pullups but relies on the pullups present on the Raspberry-Pi board. When not connecting to a Raspberry-Pi board external pullups of 4.7Kohms should be connected on SDA and SCL to a 3.3V supply.

3.8.2 I²C Communication

The pHAT-NBIOT uses an I²C to UART bridge (NXP SC16IS750) to communicate between the Raspberry-Pi and the modem UART interface. This frees the Raspberry-Pi UART interface to be used with other serial devices. The default UART baud rate is 115200 bps which maximises data throughput between the Raspberry-Pi and modem.

3.9 Configuration

The Raspberry-Pi system configuration is undertaken by downloading and installing device tree overlay files and modifying system files to install the pHAT-NBIOT as a serial device.

3.9.1 File Installation

Download the product file: https://www.designersystems.co.uk/download/pHAT-NBIOT.zip and extract. The following files are included:

phat-nbiot_test.py	-	Python modem test application
phat-nbiot.dtbo	-	DTBO overlay file

Copy the phat-nbiot.dtbo file to the /boot/overlays folder using the following command:

```
sudo cp phat-nbiot.dtbo /boot/overlays/
```

3.9.2 System File Modification

Install the I^2C tools using the following command:

```
sudo apt-get install i2c-tools
```

Modify the /boot/config.txt file using the following command:

```
sudo nano /boot/config.txt
```

Check that the following command lines are present and add those that are missing:

```
dtparam=i2c_arm=on,i2c_arm_baudrate=400000
dtoverlay=phat-nbiot
```

Press CTRL+O then return to save the file and CTRL+X to exit and then modify the /etc/modules file using the following command:

```
sudo nano /etc/modules
```

Check that the following line is present and add if missing:

```
sc16is7xx
```

Press CTRL+O then return to save the file and CTRL+X to exit and then enter the following command to reboot:

```
sudo reboot
```

3.9.3 Hardware Testing

To check that the pHAT-NBIOT hardware is working the I²C port communication can be checked by entering the following command:

```
i2cdetect -y 1
```

This will list all the connected I²C devices. The pHAT-NBIOT should show 'UU' at address 40: c (0x4C) as follows:

```
     0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:          -- -- -- -- -- -- -- -- -- -- -- -- --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: -- -- -- -- -- -- -- -- -- -- -- -- UU -- -- --
50: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
70: -- -- -- -- -- -- -- --
```

Additionally, you should be able to list the new serial device using the following command:

```
ls -l /dev/ttyS*
```

This should return a list of serial devices, one of which should be ttySC0.

If no serial devices are listed it could be that the Raspberry-Pi Kernel you are running has a problem with the SC16IS750 I2C DTBO overlay file.

In this case re-edit the /boot/config.txt file again using the following command:

```
sudo nano /boot/config.txt
```

Change the following line:

```
dtoverlay=phat-nbiot
```

to the following:

```
dtoverlay=sc16is750-i2c,addr=0x4c,int_pin=25,fixed-
clock=14745600
```

Press CTRL+O then return to save the file and CTRL+X to exit and then enter the following command to reboot:

```
sudo reboot
```

3.9.4 Modem Testing

To check that the pHAT-NBIOT modem is working we have produced a small Python program that sends a couple of configuration commands and a software version request command to the modem and displays the reply. To use this test program PySerial needs to be installed, which allows access to serial ports in Python.

Firstly install the Python dependencies by entering the following command:

```
sudo apt-get install python-smbus, python-dev, python-rpi.gpio
```

Or for Python 3 only systems by entering the following command:

```
sudo apt-get install python3-smbus, python3-dev, python3-
rpi.gpio
```

Additionally 'pip' installer is required to install some additional python modules so enter the following command to download get-pip.py:

```
curl https://bootstrap.pypa.io/get-pip.py -o get-pip.py
```

Then run get-pip.py to download and install pip by entering the following command:

```
sudo python get-pip.py
```

Or for Python 3 only systems by entering the following command:

```
sudo python3 get-pip.py
```

Install 'PySerial' using pip by entering the following command:

```
sudo pip install pyserial
```

Then install 'termcolor' by entering the following command:

```
sudo pip install termcolor
```

The test program can now be started by entering the following command:

```
python phat-nbiot_test.py
```

The following output should be seen:

```
GPIO Initialised...

Starting modem...
```

```
Configuring modem...

Modem send: AT
Modem receive: OK

Modem send: ATE0
Modem receive: OK

Modem send: AT+IPR=115200
Modem receive: OK

Modem send: AT+QSCLK=0
Modem receive: OK

Modem send: AT+QLEDMODE=1
Modem receive: OK

Tests running...

Modem send: ATI
Modem receive: Quectel_Ltd
Modem receive: Quectel_BC66
Modem receive: Revision: BC66NBR01A07

Modem receive: OK

Modem send: AT+CSQ
Modem receive: +CSQ: 20,0

Modem receive: OK
```

If the above, or something similar, is not shown go back to Hardware Testing and check that ttySC0 is listed as a serial device.

This Python program can be used as a starting point to create your own NB IoT connected application

3.10 Basic AT Commands

The pHAT-NBIOT uses the standard 3GPP TS 27.00x AT command set for communication. Below is a description of some of the most useful basic commands.

3.10.1 AT+CREG Request Network Registration Status

On command receipt replies with current network registration status.

AT+CREG?

Replies with:

+CREG: 0,<stat>
OK

Parameter

<stat>	Decimal digit, 0 ~ 5	0 Not registered not searching 1 Registered to home network 2 Not registered but searching 3 Registration denied 4 Unknown 5 Registered, roaming

3.10.2 AT+CSQ Request Network Signal Quality

On command receipt replies with current network signal.

AT+CSQ

Replies with:

+CSQ: <rssi>,<ber>
OK

Parameter

<rssi>	Decimal digits, 0 ~ 99	0 -113 dBm or less 1 -111 dBm 2..30 -109…-53 dBm 31 -51 dBm or greater 99 Not known or not detectable
<ber>	Decimal digits, 0 ~ 7	0…7 Quality value 99 Not known

3.10.3 AT+QCCID Request ICCID (SIM number)

On command receipt replies with SIM number (ICCID).

AT+QCCID

Replies with:

+QCCID: <iccid>
OK

Parameter

<iccid>	Decimal digits, eg. 89314404000225088625	SIM number

3.10.4 AT+QCGDEFCONT Set Default PSD Connection

On command receipt configures the default (power-on) data connection setup.

AT+QCGDEFCONT=<PDP_type>,<APN>,<username>,<password>

Replies with:

OK

Parameter

<PDP_type>	String type, either “IP”, “IPV6”, “IPV4V4” or “Non-IP”	Specifies the packet data protocol, normally set to “IP”
<APN>	String type	Specifies the packet data network ie. for Vodaphone “ep.inetd.sdsp”
<username>	String type	Specifies the username for the preceding APN, normally blank
<password>	String type	Specifies the password for the preceding APN, normally blank

3.10.5 AT+QRST Automatically Reset

On command receipt modem resets immediately.

AT+QRST=1

Replies with start-up response:

F1: 0000 0000
V0: 0000 0000 [0001]
00: 0006 000C
01: 0000 0000
U0: 0000 0001 [0000]
T0: 0000 00B4
Leaving the BROM

RDY

+CFUN: 1

+CPIN: READY

3.11 Full AT Command Descriptions

All other AT commands may be found within the modem AT Command Manuals which can be downloaded here:
www.designersystems.co.uk/download/Quectel_BC66_AT_Commands_Manual_V1.0.pdf
www.designersystems.co.uk/download/Quectel_BC66_TCP(IP)_AT_Commands_Manual_V1.0.pdf

4 Electrical Characteristics

4.1 Absolute Maximum Ratings

Absolute maximum ratings for power supply and voltage on digital pins of the module are listed in the following table.

Table 7: Absolute Maximum Ratings

Parameter	Min.	Max.	Unit
Power Supply Voltage (V+)	-0.3	6.0	V
Input Voltage on GPIO pins	-0.3	3.6	V
Storage temperature	-45	100	^{o}C

4.2 Operating Conditions

Normal operational conditions are listed in the following table.

Table 8: Normal Operating Conditions

Parameter	Min.	Typ.	Max.	Unit
Power Supply Voltage (V+)	4.5	5.0	5.5	V
Input voltage on GPIO pins		3.3		V
Peak Supply Current			100	mA
Operating Temperature	-20	25	85	^{o}C

4.3 Current Consumption

Normal values for current consumption are listed in the following table.

Table 9: Current Consumption

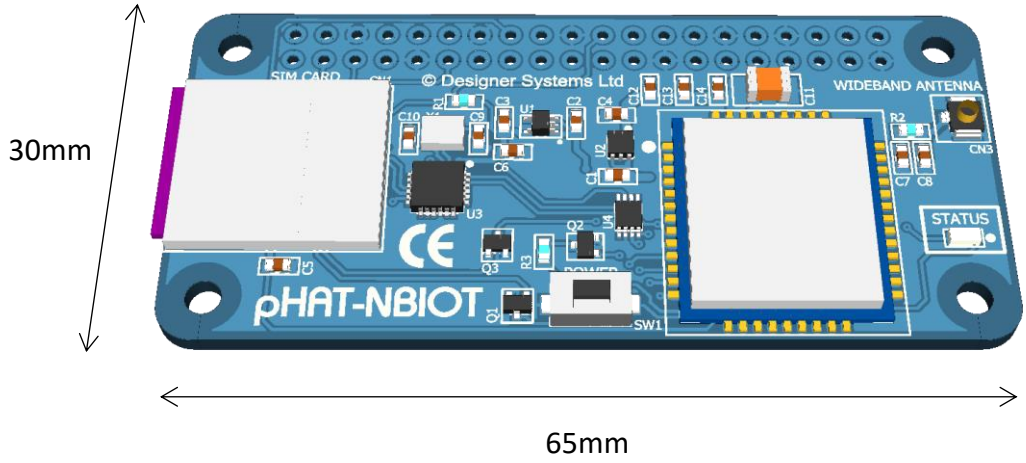
Parameter	Min.	Typ.	Max.	Unit
Supply Current – Modem OFF		2		mA
Supply Current – Network registration			80	mA
Supply Current – Idle (no sleep mode)		12		mA
Supply Current – GPRS session (EGSM900)		400		mA

5 Mechanical

5.1 Dimensions

Mechanical drawing – all dimensions in millimetres.

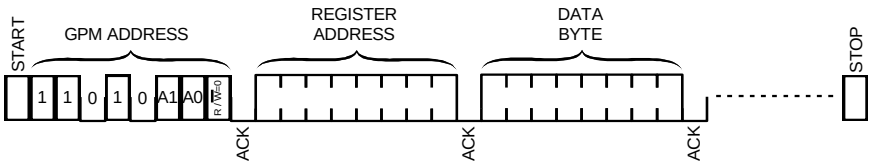
Figure 1: Dimensions



6 References

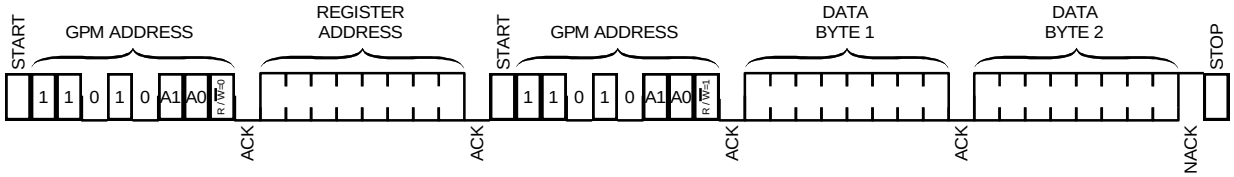
6.1 I²C protocols

Figure 2: I²C Write protocol



Multiple bytes may be written before the 'STOP' condition. Data is written into registers starting at 'REGISTER ADDRESS', then 'REGISTER ADDRESS' +1, then 'REGISTER ADDRESS' +2 etc.
Each byte transfer is acknowledged 'ACK' by the pHAT-NBIOT until the 'STOP' condition.

Figure 3: I²C Read protocol



'DATA BYTE 1 & 2' are register values returned from the GPM. Each byte written is acknowledged 'ACK' by the GPM , every byte read is acknowledged 'ACK' by the I2C Master. A Not-acknowledge 'NACK' condition is generated by the I2C Master when it has finished reading.

7 Appendix

Table 10: Related Documents

Document Name	Remark
Quectel_BC66_Hardware_Design_V1.1.pdf	More information about the BC66 modem used in this product
Quectel_BC66_AT_Commands_Manual_V1.0.pdf	More information about the BC66 AT command set

Table 11: Terms and Abbreviations

Abbreviation	Description
NB IoT	Narrowband Internet of Things
SMS	Small Message System
LTE	Long-Term Evolution
ESD	Electrostatic Discharge

8 Compliance

WEEE Consumer Notice

This product is subject to Directive 2012/19/EC of the European Parliament and the Council of the European Union on Waste of Electrical and Electronic Equipment (WEEE) and, in jurisdictions adopting that Directive, is marked as being put on the market after August 13, 2005, and should not be disposed of as unsorted municipal/public waste. Please utilise your local WEEE collection facilities in the disposition and otherwise observe all applicable requirements. For further information on the requirements regarding the disposition of this product in other languages please visit www.designersystems.co.uk

RoHS Compliance

This product complies with Directive 2011/65/EC (RoHS 2) and 2015/863/WU (RoHS 3) of the European Parliament and the Council of the European Union on the Restriction of Hazardous Substances (RoHS) which prohibits the use of various heavy metals (lead, mercury, cadmium, and hexavalent chromium), polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE), Bis(2-Ethylhexyl) phthalate (DEHP), Benzyl butyl phthalate (BBP), Dibutyl phthalate (DBP) and Diisobutyl phthalate (DIBP).

REACH Compliance

This product complies with Regulation 1907/2006 covering the Registration, Evaluation, Authorisation and restriction of Chemicals (REACH). Designer Systems Ltd confirms that none of its products or packaging contain any of the 174 Substances of Very High Concern (SVHC) on the REACH Candidate List in a concentration above the 0.1% by weight allowable limit.

RED Compliance

This product complies with the Radio Equipment Directive 2014/53/EU (RED) for health and safety, electromagnetic compatibility (EMC) and efficient use of the radio spectrum.