Introduction

This document provides a guideline for the execution of the FCC radio certification tests of Zigbee / Matter™/ Bluetooth Low Energy modules using QPG6105 chips. This document focusses on Bluetooth Low Energy mode certification for the FCC regulatory domain.

At start of the radio certification test the applicable PHY (BLE) can be selected in the Radio Control Console software [1].

This document is based on, and aligned with, the technical requirements given in CFR 47 PART 15, Section 15.247 “Operation within the bands 902 - 928 MHz, 2400 - 2483.5 MHz, and 5725 - 5850 MHz”.

Table of Contents

1 Device under Test (DUT)

This certification guide has been customized for the following product:

Type: QPE6105A
Model: 19644_QPE6105a_Module
H/W Revision: 0.60 onwards
S/W Revision: PTC_QPG6105_10DBM_CFG_B_v1.9.0.0.dll

2 Block Diagrams and Functional Description

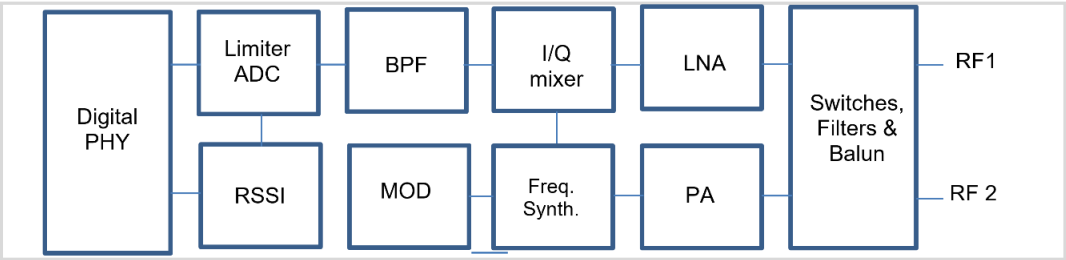

Figure 1: RF Block Diagram of the QPG6105 Chip

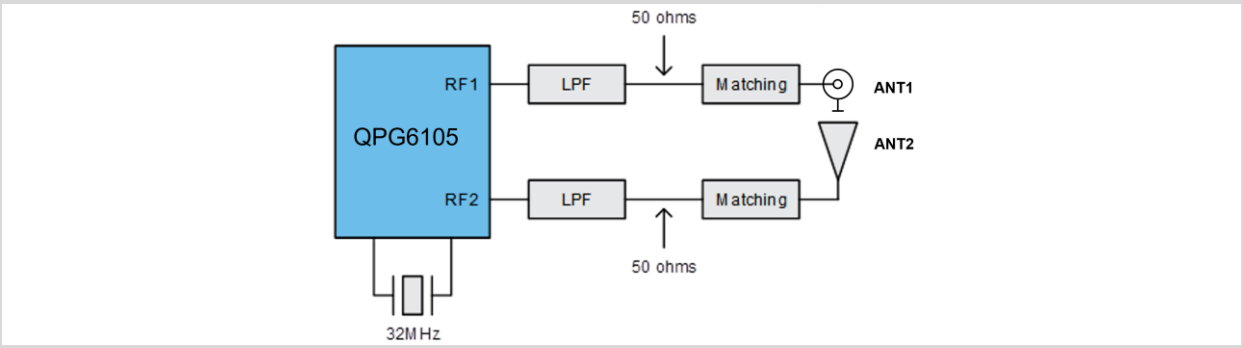

Figure 2: RF Block Diagram of the QPE6105A Module with one Embedded Antenna and one Antenna Pin

2.1 General Description

The QPG6105 chip is an **IEEE 802.15.4 / Bluetooth Low Energy** Multi-Protocol Multi-Channel Communications Controller for ultra-low power wireless. It is compliant with the IEEE Standard 802.15.4 for Zigbee, and the Bluetooth Core Specification version 5.3 for Bluetooth Low Energy.

2.2 Power Regulation

The QPG6105 chip has an integrated power management system using a Global Low Dropout Regulator (GLDO). This generates an internal 1.8 V power supply. The internal 1.8 V power rail is used to supply separate local LDO regulators feeding RF/analog and digital blocks. The local LDOs used to supply RF/analog blocks are specially designed to have high power supply rejection ratio (PSRR) to suppress the supply ripples.

In case the external supply voltage is too low to deliver the 1.8V internal supply voltage, the QPG6105 chip will reset and consequently stop all RF communication. This means that RF frequency and RF modulation will be independent from the supply voltage.

2.3 Frequency Synthesis and Modulation

The QPG6105 chip uses a FLL circuit with a VCO operating at 2 times of the transmit frequency. The VCO is directly modulated by a Digital Signal Processor (DSP). The modulation is fully compatible with Offset Quadrature Phase-Shift Keying (O-QPSK) and MSK modulation as used by Bluetooth Low Energy.

The receiver uses a low Intermediate Frequency (IF) scheme, where the IF frequency is 2 MHz. The formula to calculate the VCO frequency in RX mode can be found in section 3.6.2.

2.4 RF Interface

The QPE6105A module has two RF outputs: RF1 and RF2. Both RF ports are bidirectional and will be used for both transmit (TX) and receive (RX) mode. The antenna ports outputs are 50 Ω single ended. Only one antenna is used for RX or TX at the time (i.e., not supporting MIMO). Antenna Diversity is supported in

RX mode.

3 Radio Information

3.1 Applicable Standard

CFR 47 PART 15, § 15.247 - Operation within the bands 902 – 928 MHz, 2400 - 2483.5 MHz, and 5725 - 5850 MHz. See reference [11].

For spurious emissions § 15.247 is calling § 15.205 “Restricted bands of operation” and § 15.209 “Radiated emission limits; general requirements”.

Please mind that § 15.209 (d) states: *“… the frequency bands 9-90 kHz, 110-490 kHz and above 1000 MHz. Radiated emission limits in these three bands are based on measurements employing an average detector.*”

Averaging can be done by choosing a narrow video bandwidth setting on the spectrum analyzer or by averaging multiple traces.

3.2 Duty Cycle Correction Spurious Emission According Section 15.35(c)

Section 15.35 (c) states: *“Unless otherwise specified,* [...]*, when the radiated emission limits are expressed in terms of the average value of the emission, and pulsed operation is employed, the measurement field strength shall be determined by averaging over one complete pulse train, including blanking intervals, as long as the pulse train does not exceed 0.1 seconds. As an alternative (provided the transmitter operates for longer than 0.1 seconds) or in cases where the pulse train exceeds 0.1 seconds, the measured field strength shall be determined from the average absolute voltage during a 0.1 second interval during which the field strength is at its maximum value. The exact method of calculating the average field strength shall be submitted with any application for certification or shall be retained in the measurement data file for equipment subject to Supplier's Declaration of Conformity*.”

Details on applying duty cycle correction can be found in reference [12], in the “Frequently Asked Questions” section at “Question 3”, “Answer 3 (c)”;

“Taking a RMS average measurement while EUT is transmitting continuously, i.e., greater than 98%, and correcting for operational duty cycle – When greater than 98% duty cycle is achieved for testing purposes, applying average measurement techniques (e.g., average detector / reduced VBW) ***then adjusting for the protocol limited duty factor to determine the average emission is acceptable.*** *If the EUT supports more than operational duty cycle the worst-case value should be used, i.e., the highest operational duty cycle. This measurement refers to spectrum analyzer settings 11.12.2.5.1 (Trace averaging with continuous EUT transmissions at full power) in ANSI C63.10*.”

See also reference [13].

This answer explains that duty cycle correction of average spurious emissions for protocol limited devices is allowed under the condition that the average spurious emissions are measured with a continuous wave signal.

3.3 Bluetooth Low Energy Duty Cycle Correction Factor

3.3.1 Application limited

The maximum BLE TX duty cycle is application dependent. The maximum duty cycle is measured over a 100 ms observation interval.

If the application limits the duty cycle in a 100 ms interval to e.g., 10%, the correction factor for the average spurious emission field strength becomes:

Correction factor is 20 * LOG (0.10) = **-20 dB**.

3.3.2 TX Frequency Domain Duty Cycle / Spreading

According to the Bluetooth Core specification, the minimum number of RF channels to maintain a BLE connection is **2**. Consequently, if the connection interval is ≤ 50 ms, the RF energy in a 100 ms observation period will be spread over at least 2 physical RF channels. The channel separation is N * 2 MHz (N = 1, 2, 3…) which is larger than the 1 MHz RBW filter that should be used according to the FCC.

Correction factor is 20 * LOG (0.5) = **-6 dB.**

3.3.3 Summary FCC Duty Cycle Correction

IF connection interval is ≤ 50 ms the **frequency spreading** provides **-6 dB** duty cycle correction.

The maximum duty cycle in Application Mode, combined with the frequency domain spreading, results in a **total correction factor, in this example:**

Total correction factor is **-**20 dB + -6 dB = **-26 dB.**

FCC rules limits the correction factor to **-20 dB.**

3.4 Measurement of Radiated Emissions at the Band Edge

To measure the band edge spurious emissions, please refer to the guidelines in FCC Publication 558074 [12].

NOTE: according to Bluetooth Core Specification, 2 Mbit/s is not used on the advertisement channels. This implies that the data rate on 2402 MHz, 2426 MHz and 2480 MHz is **1 Mbit/s**.

3.5 Bluetooth Low Energy Frequency Range

The BLE PHY supports 40 channels, these channels follow the BLE standard channel numbering.

These RF channels have center frequencies 2402 + k * 2 MHz, where k = 0 … 39.
“k” is the channel number.

The lowest RF frequency with k= 0 is 2402 MHz, the highest RF frequency with k= 39 is 2480 MHz.

3.6 Frequency Generation Scheme

3.6.1 TX mode

The local oscillator operates on 2 times the TX frequency. The local oscillator is directly modulated.

3.6.2 RX mode

The local oscillator operates on (Fo + 2) * 2, where Fo is the frequency of the RF channel [MHz].

3.7 Radio Frequency Radiation Exposure Evaluation

The applicable FCC sections are:

- CFR 47 Part 2 - § 2.1091 - Radiofrequency radiation exposure evaluation: mobile devices.
- CFR 47 Part 1 - § 1.1310 - Radiofrequency radiation exposure limits.

The DUT is classified as a **mobile device**, so the applicable distance for the radiation exposure evaluation is 20 cm (0.2 m) and the limit is 1 mW/cm^2. Please find below an example on calculating the power density.

The default Tx power level is 10 dBm, the peak antenna gain is -3 dBi.

Antenna pattern, see ref [4]

$P_{Tx} = Tx\ power\ at\ Antenna = 10$ dBm

$G_a = Antenna\ gain = -3$ dBi (equal for both antennas)

$d = Distance = 0.2$ m

$EIRP_{[dBm]} = Effective\ Isotropic\ Radiated\ Power = P_{tx} + G_a = 7$ dBm

$EIRP_{[W]} = Effective\ Isotropic\ Radiated\ Power = 10^{\frac{EIRP_{[dBm]}-30}{10}} = 0.005$ W

$PD_{[W/m^2]} = Power\ Density = \frac{EIRP_{[W]}}{4.\pi.d^2} = 0.01\ \mathrm{W/m^2}$

$PD_{[mW/cm^2]} = Power\ Density = PD_{[W/m^2]} \times \frac{1000}{10000}$

$= \mathbf{0.001\ mW/cm^2}$ @ 0.2 m distance

Note: limit of Power Density: 1 mW/cm^2.

4 Operating Manual

4.1 System Setup

Test software allowing control of the radio is distributed via Radio Control Software packages [1] [2]. These packages consist of a Radio Control Console (RCC) PC application and Product Test Component (PTC) firmware binaries. Below figure shows the high-level overview of the system.

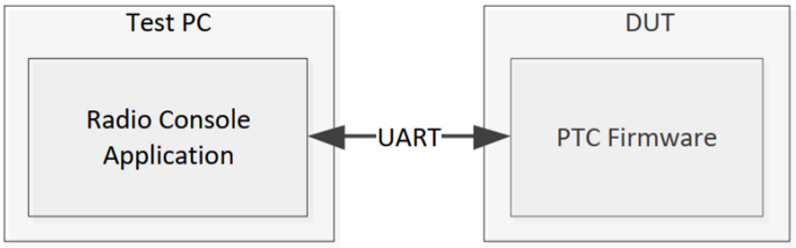

Figure 3: System Setup

The physical interface in-between the RCC application and the PTC firmware is a UART link. The UART pin mapping options are described in the PTC release notes.

The PTC firmware [2] should be flashed into the processor of the DUT. The RCC application can be started by means of the RadioConsoleControl.exe executable.

Figure 4: QPE6105A Module on Radio Adaptor Board

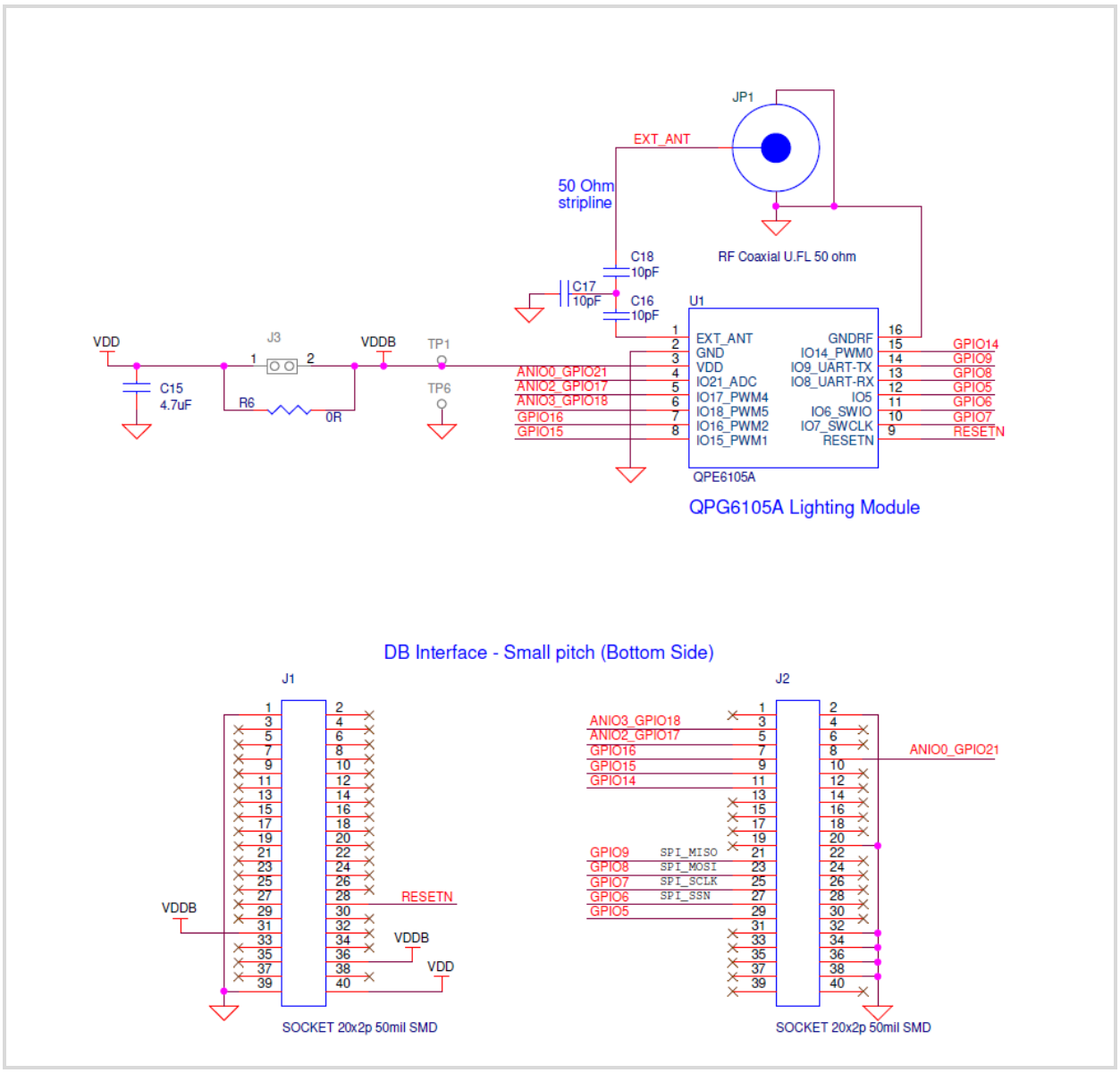

Figure 5: Pinning of the QPE6105a Radio Adaptor Board

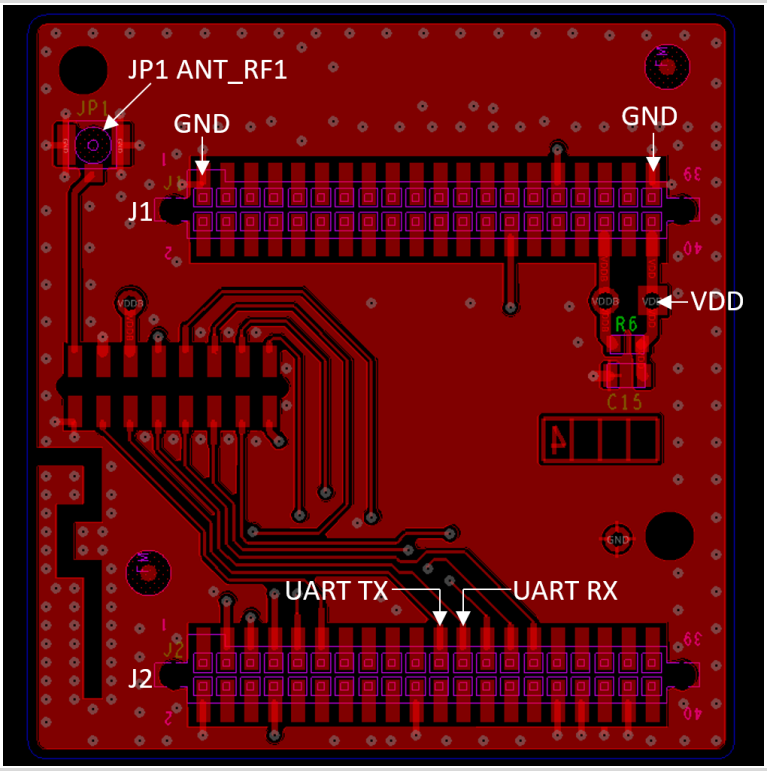

Figure 6: Connecting Power Supply and UART Interface on Radio Adaptor Board

Connecting power supply and UART interface on adaptor board:

Commands	Descriptions
JP1	UFL connector for ANT_RF1
J1 pin 1, 39	GND
J2 pin 2, 20, 32, 34, 36, 38	GND
J2 pin 21	J2 GPIO9 UART TX, Data from target to the tester
J2 pin 23	J2 GPIO8 UART RX, Data from tester to the target
J1 pin 40	VDD 1.8 ~ 3.6 V; nominal voltage is 3.0V

4.2 Quick Start Guide for Terminal Emulator

The commands required to perform the Certification Test are listed in Table 1 below. For information on the full command set of this application, see [1]

At the start of the test the intended PHY needs to be selected. Please use the "PHY" command to do this.

NOTE: In case of issues (e.g., non-responsive device) please repeat the power up cycle.

Table 1: Radio Control Console Command Set

Commands	Descriptions
H	Show Help on all possible commands.
PHY BLE/RF4CE	Select the BLE or RF4CE (Zigbee) PHY.
I	Print (display) the current settings/state of the chip.
AN 0	Select antenna port 0.
CH 20	Set channel to channel 20, channel 0 to 39 can be selected.
W 10	Set TX power to 10 dBm. Supported values of parameters: 10 to -24 in steps of 1 dB.
CW U	Configure DUT to send Continuous **Un**modulated Wave.
CW M	Configure DUT to send Continuous Modulated Wave.
SETCW ON/OFF	Start/stop Continuous Wave (CW) transmission.
RX ON/OFF	Switch receiver ON or OFF.
P	Show packet statistics.
R	Reset packet statistics.
TX <number> <interval> <length> ON/OFF	Transmit packets with payload.
PACKETLENGTH *<number>*	Set packet length in bytes. In BLE Mode the maximum packet payload is 241 bytes.
BLETESTPACKET <number>	Defines the BLE test packet type to be used in Direct Test Mode Transmit.
BLEDATARATE <number>	Select the PHY BLE datarate (1 Mbit/s / 2 Mbit/s).

5 RF Testing

Devices for certification tests are loaded with PTC software. With this software, it is possible to perform all radio tests. Detailed instructions on how to use all the features of this software can be found in [1].

5.1 Select the PHY Mode

Make sure that BLE mode is selected:

`PHY BLE` (select BLE)

5.2 Select RF Port/Antenna

`AN 0` (select RF1 port)

`AN 1` (select RF2 port)

In the case of differential mode PTC version, as used with a symmetrical dipole antenna, the AN command is ignored.

5.3 Set-Up Procedure for TX Modes

5.3.1 Configure Board Support Package

`WR 0x008e 0x007`

It is recommended to copy & paste the command in the Console window.

To verify if the correct data is written, the following command can be used:

`RR 0x008e` will display content of register 0x008e.

5.3.2 Select Output Power Level

`W 10` (set power to 10 dBm)

NOTE: The default setting for output power is +10 dBm which is also the default setting for FCC certification.

5.3.3 Select RF Channel

`CH 0` (low channel, 1 Mbit/s only)

`CH 20` (mid channel)

`CH 39` (high channel, 1 Mbit/s only)

Enter "**`I`**" at the console to verify if the DUT has changed the RF channel.

5.3.4 Select BLE Data Rate

`BLEDATARATE 1M` (select 1 Mbit/s)

`BLEDATARATE 2M` (select 2 Mbit/s)

NOTE: on the primary BLE advertisement channels the Bluetooth Core Specification limits PHY data rate to 1 Mbit/s.

The advertisement channels are: 2402 MHz, 2426 MHz and 2480 MHz. Please take this in consideration when performing FCC band-edge testing (do **not** select a 2 Mbit/s data rate on any advertisement channel).

5.3.5 Turn TX on, (Un-)modulated CW

`CW U` (select unmodulated CW)
`CW M` (select modulated CW)
`SETCW ON` (set continuous wave to “ON”)
`SETCW OFF` (set continuous wave to “OFF)

5.4 Transmit Packets

For selecting the BLE data rate, see section 5.3.4.

5.4.1 BLE Test Packet

`BLETESTPACKET 0` (select packet type 0, other packet types are stated in the table below)

Type	Description
0	**PRBS9** sequence ‘**11111111100000111101…**’ (in transmission order)
1	repeated ‘**11110000**’ (in transmission order)
2	repeated ‘**10101010**’ (in transmission order)
3	**PRBS15** sequence
4	repeated ‘**11111111**’ (in transmission order) sequence
5	repeated ‘**00000000**’ (in transmission order) sequence
6	repeated ‘**00001111**’ (in transmission order) sequence
7	repeated ‘**01010101**’ (in transmission order) sequence

5.4.2 BLE Packet Length

`PACKETLENGTH 10` (select packet length in bytes, maximum: 241)

5.4.3 Transmit Packets

`TX 100 0 ON` (transmit 100 packets)

It is not possible to select the interval time between packets in BLE Mode, so it is defaulted to **0**. Therefore, it is not obvious how to control the TX duty cycle for average spurious emission measurements. Typical duty cycles can be found in the table below. The duty cycle can depend on Host MCU.

Packet length (bytes)	TX duty cycle @ 1 Mbit/s	TX duty cycle @ 2 Mbit/s
10	32%	16%
20	42%	30%
30	54%	29%
40	32%	35%

5.5 Set-up Procedure for RX Mode

Before starting the RX test, please RESET the DUT by removing batteries and restarting the Radio Control Console application.

5.5.1 Select RF Channel

See section 5.3.3 an RF channel.

5.5.2 Turn RX On

Make sure TX is OFF.

RX ON	(switch receiver ON)

5.5.3 Print Packets Sent/Received in BLE Mode

RX OFF	(switch receiver OFF)
P	(show number of received packets)
R	(reset the number of the sent/received counter)

! In BLE Mode, the values returned by the Show Packet Statistics are only valid after the RX/TX/TXR Mode has been stopped explicitly by issuing the RX OFF or TX OFF command, depending on which mode was activated.

References

[1] User Manual for Radio Control Console; GP_P864_UM_16380_PTC_Overview

[2] Radio Control SW Package; Qorvo document GP_P864_SW_16383

[3] Product Test Component Release note; Qorvo document GP_P864_RN_12462_ProductTestComponentReleaseNotes

[4] Antenna Pattern report GP_P1246_TR_20019_RD_Lighting_QPG6105_Antenna_Pattern_Measurements.xlsx

[5] Bill of Material QPE6105a GP_P1246_BOM_19644_RD_Lighting_QPG6105

[6] Schematic QPE6105a GP_P1246_HW_19642_RD_Lighting_QPG6105_SCH

[7] PCB design files QPE6105a GP_P1246_HW_19643_RD_Lighting_QPG6105_PCB

[8] Bill of Material QPE6105a Radio Adaptor Board GP_P345_BOM_19687_QPE6105A_Radio_Board

[9] Schematic QPE6105a Radio Adaptor Board GP_P345_HW_19685_QPE6105A_Radio_Board_SCH

[10] PCB design files QPE6105a Radio Adaptor Board GP_P345_HW_19686_QPE6105A_Radio_Board_PC

[11] Electronic Code of Federal Regulations (e-CFR), Title 47, Part 15 – Radio Frequency Devices

[12] FCC Publication number 558074 - D01 15.247 Meas Guidance v05r02.pdf

[13] ANSI C63.10-2013 - Procedures for Compliance Testing of Unlicensed Wireless Devices

[14] FCC Certification guide Zigbee / Matter™ mode GP_P335_UM_20020_FCC_Certification_Guide_QPE6105a__IoT_Controller_Zigbee_Mode.pdf

[15] ETSI Certification guide Zigbee / Matter™ mode GP_P335_UM_20255_ETSI_Certification_Guide_QPE6105a__IoT_Controller_Zigbee_Mode.pdf

[16] ETSI Certification guide Bluetooth Low Energy mode GP_P335_UM_20256_ETSI_Certification_Guide_QPE6105a__IoT_Controller_BLE_Mode.pdf

Abbreviations

ADC	Analog-to-Digital Converter	LPF	Low-Pass Filter
BPF	Band-Pass Filter	MIMO	Multiple-Input Multiple-Output
BLE	Bluetooth Low Energy	MSK	Minimum Shift Keying
CW	Continuous Wave	O-QPSK	Offset Quadrature Phase-Shift Keying
DSP	Digital Signal Processor		
DUT	Device Under Test	PSRR	Power Supply Rejection Ratio
FLL	Frequency Locked Loop	PTC	Product Test Component
GLDO	Global Low Dropout Regulator	RCC	Radio Control Console
LDO	Low Dropout Regulator	RCU	Remote Control Unit
LNA	Low-Noise Amplifier	VCO	Voltage Controlled Oscillator

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Document History

Version	Date	Section	Changes
1.00	Aug 9, 2023		Released version.