

1 Introduction

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

At start of the radio certification test the applicable PHY (rf4ce) 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”.

! Obtaining regulatory certifications is the responsibility of the end customer.

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2 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

3 Block Diagrams and Functional Description

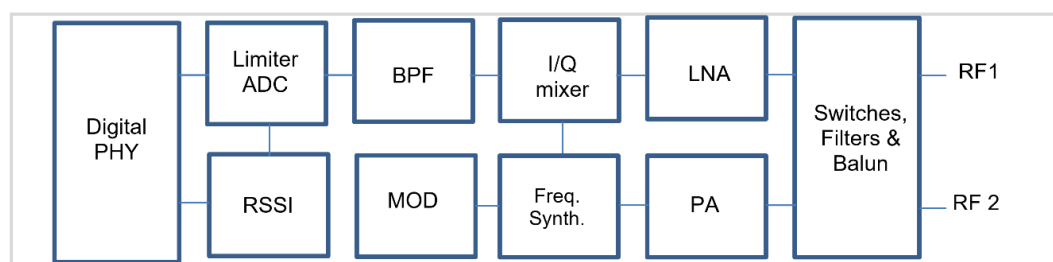


Figure 1: RF Block Diagram of the QPG6105 Chip

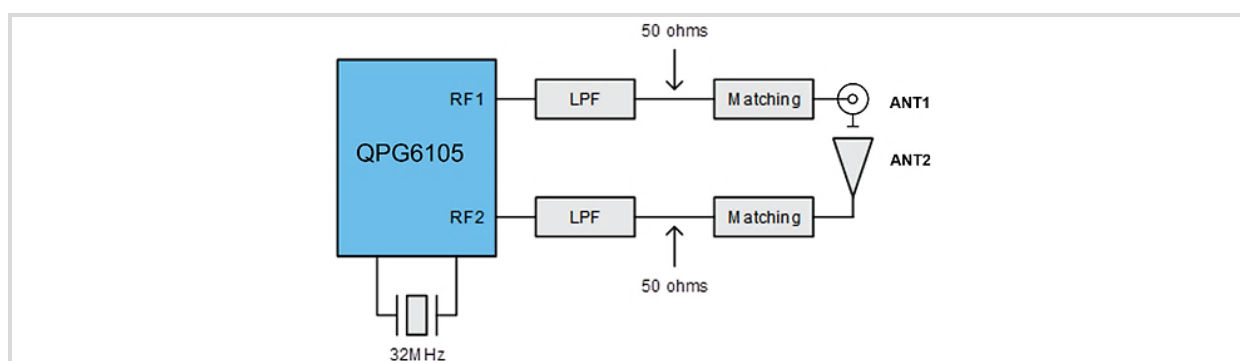


Figure 2: RF Block Diagram of the QPE6105A Module with one Embedded Antenna and one Antenna Pin

3.1 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 communications. It is compliant with the IEEE Standard 802.15.4 for Zigbee / Matter, and the Bluetooth Core Specification version 5.0 for Bluetooth Low Energy. In IEEE 802.15.4 communications, antenna diversity offers additional robustness in a crowded wireless 2.4 GHz environment.

3.2 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.

3.3 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 the Offset Quadrature Phase-Shift Keying (O-QPSK) as required by the IEEE 802.15.4 standard. With different settings it also supports 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 4.6.2.

3.4 RF Interface

The QPG6105 chip 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 (1) antenna is used for RX or TX at the time (i.e., not supporting MIMO). Antenna Diversity is supported in RX mode.

4 Radio Information

4.1 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 [3].

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.

4.2 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.

4.3 Zigbee / Matter Duty Cycle Correction Factor

End Node application

The maximum medium occupancy in a 100 ms observation period occurs when 4 maximum length packets are transmitted. The maximum packet length is 133 bytes
(127 bytes payload + 4 bytes preamble + 1 bytes SFD + 1 byte length indication).

The length of 1 byte is 32 µs, so the max packet length is $133 * 32 = 4256 \mu\text{s}$.

The maximum duty cycle in Zigbee / Matter End Node mode is $(4 * 4256) \div 100 = 17 \%$.

This means that the correction factor for the average spurious emission field strength is:

$$20 * \log_{10} (0.17) = -15.4 \text{ dB} \text{ (the max correction factor FCC allows is 20 dB).}$$

Extreme use case with maximum duty cycle

The maximum theoretical TX duty cycle using the IEEE 802.15.4 protocol is 80%.

The correction factor for the average spurious emission filed strength becomes in this extreme use case:

$$20 * \log_{10} (0.80) = - 1.94 \text{ dB.}$$

4.4 Measurement of Radiated Emissions at the Band Edge

The device is capable of transmitting at 100% duty cycle.

Normally the device can meet the 54 dBμV/m at 3 m distance average spurious emission limit on 2483.5 MHz with 100% duty cycle.

If special circumstances require that the average spurious emission spur should be reduced on CH 26 with e.g., 4 dB, this 4 dB reduction can be achieved in the following way:

- back-off of TX power with 2 dB on CH 26
- 2 dB duty cycle correction as explained in section 4.3.

Alternatively, this 4 dB reduction can also be achieved in the following way:

- back-off of TX power with 0 dB on CH 26 (allows to use the max 10 dBm power setting)
- add 4 dB duty cycle correction as explained in section 4.3. In this case the application SW should limit the duty cycle to 63%.

$$20 * \log_{10} (0.63) = - 4.0 \text{ dB.}$$

4.5 Zigbee / Matter Frequency Range

The Zigbee / Matter PHY supports 16 RF-channels; these channels use the following IEEE 802.15.4 channel numbering. These RF channels have center frequencies of $2400 + (k-10) * 5 \text{ MHz}$, where $k = 11, \dots, 26$. “k” is the channel number.

The frequencies are:

- CH 11 2405 MHz
- CH 12 2410 MHz
-
- CH 26 2480 MHz

4.6 Frequency Generation Scheme**4.6.1 TX mode**

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

4.6.2 RX mode

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

4.7 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/cm². Please find below an example on calculating the power density.

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

For antenna pattern, see [4].

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

$$G_a = \text{Antenna gain} = -3 \text{ dBi (embedded antenna)}$$

$$d = \text{Distance} = 0.2 \text{ m}$$

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

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

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

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

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

Note: limit of Power Density: 1 mW/cm².

5 Operating Manual

5.1 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.

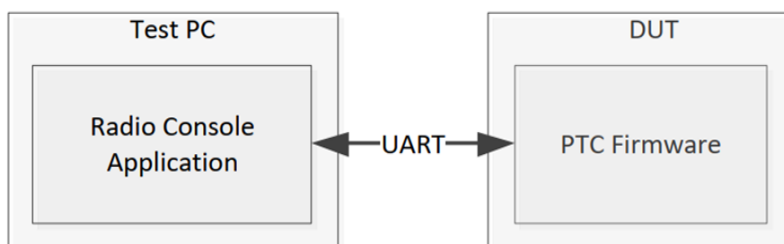


Figure 3: System Setup

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

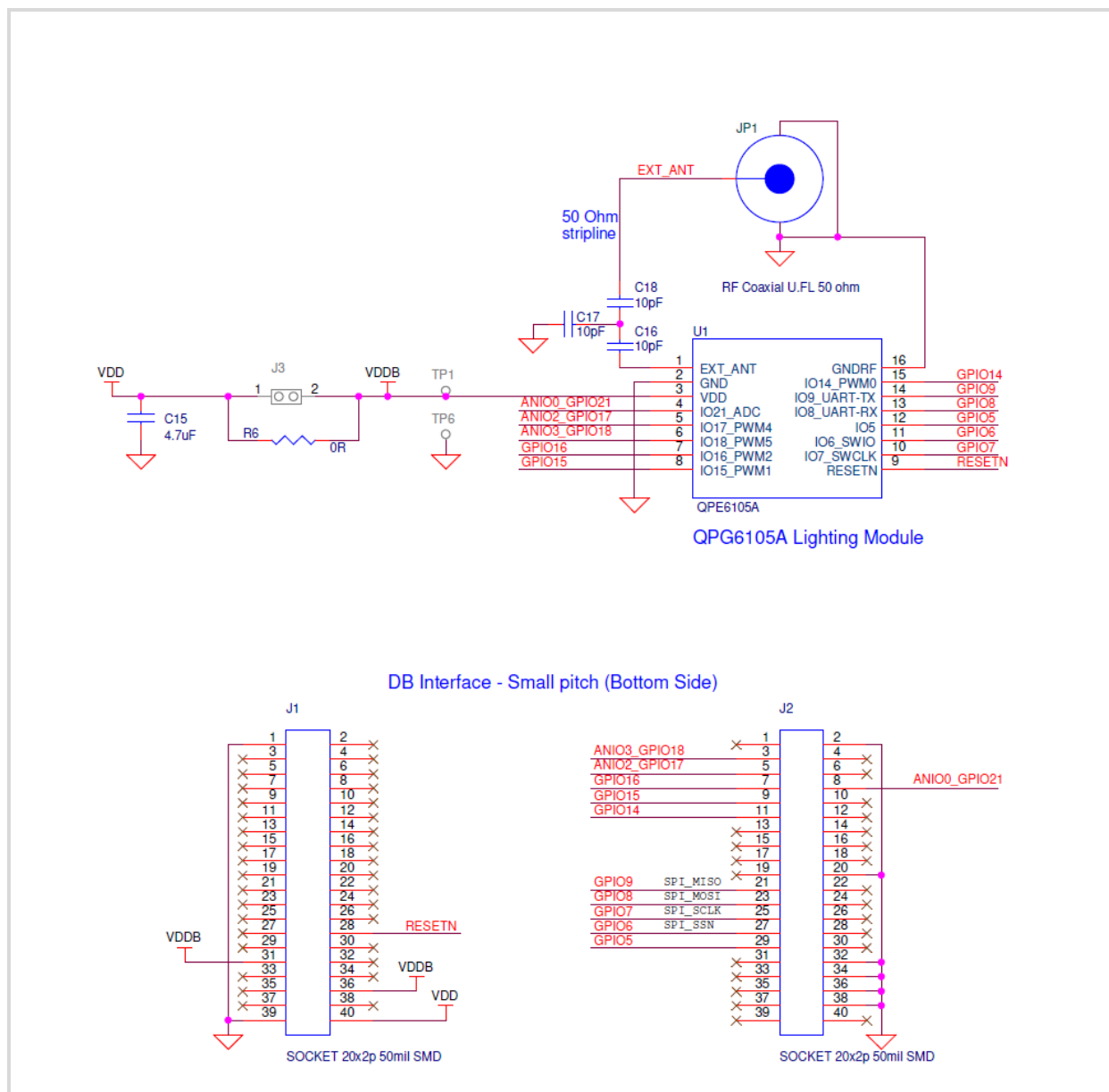


Figure 5: Pin Mapping QPE6105A Radio Adaptor Board

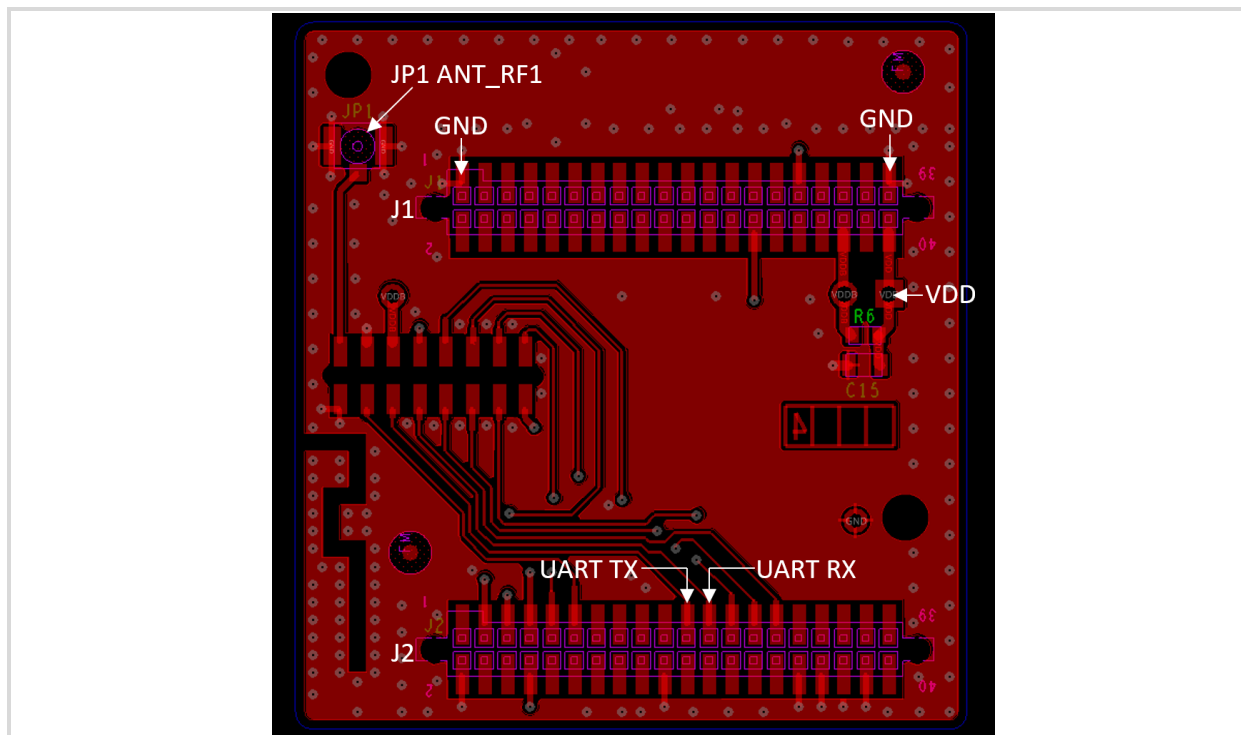


Figure 6: Connecting Power Supply and UART Interface on Radio Adaptor Board

Connecting power supply and UART interface on adaptor board:

- 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

5.2 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 start of the test the intended PHY needs to be selected. 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 / Matter) PHY.
I	Show the current settings/state of the chip.
AN 0	Select antenna port 0, port 0 to 1 can be selected. Note: the datasheet(s) designates port 0 for Ant.1 and port 1 for Ant. 2.
CH 20	Set channel to channel 20, in RF4CE mode channel 11 to 26 can be selected.
W 10	Set TX power to 10 dBm. Supported parameter values: 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.
RXP ON/OFF	Switch display of received packets ON or OFF.
P	Show packet statistics.
R	Reset packet statistics.
TXR <number> <interval> <length> ON/OFF	Transmit packets with random payload. The number of packets, transmission interval and the length of the packet can be set by this command. e.g., “TXR 10 100 15 ON” will send 10 packets with 15 bytes (max. 125 bytes) payload at an interval of 100 ms.
MR <number>	Number of retries 0 to 5. This command sets the number of times a packet will be retransmitted by the MAC if an acknowledgement was requested but not received.
SETTXDATA	6..250-character string where each character is interpreted as a hexadecimal value for a nibble.
TX <number> <interval> ON/OFF	Transmits packets with a payload from SETTXDATA command. The number of packets and the transmission interval can be set by this command, e.g., “TX 10 100 ON” will send 10 packets at an interval of 100 ms. The minimum interval is 1 ms. The software does not consider any bus transfers and medium access delays. Therefore, the actual inter packet delay will always be larger than <i>interval</i> .

6 RF Testing

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

6.1 Select PHY Mode

Make sure that RF4CE is selected:

PHY RF4CE select RF4CE (default)

6.2 Select RF Port/Antenna

Select the antenna port:

AN0 select RF1 port

AN1 select RF2 port

NOTE: Port/Antenna selection **disables** Antenna Diversity (see also section 3.4).

6.3 Set-Up Procedure for TX Modes

6.3.1 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 this will display content of register 0x008e.

6.3.2 Select Output Power Level

W 10 (set power to 10 dBm)

NOTES:

- The default setting for output power is +10 dBm which is also the default setting for FCC certification.
- The power setting that can be used on CH 26 may depend on the maximum TX duty cycle in a 100 ms observation interval as allowed by the application SW. See also section 4.4.

6.3.3 Select RF Channel

CH 11 low channel

CH 20 mid channel (default at start up)

CH 26 high channel

Enter “I” at the console to verify if DUT has changed channel.

6.3.4 Turn TX On, (un-)Modulated CW

CW U select **un**modulated CW

CW M select modulated CW

SETCW ON set continuous wave to ON

SETCW OFF set continuous wave to OFF

6.3.5 Transmit Packets

Demo the maximum duty cycle in Zigbee / Matter End Node mode is $(4 * 4256) \div 100 = 17\%$:

TXR 4 1 125 ON transmit 4 packets, interval between packets: 1+0.5 ms, length: 125 bytes random payload

Demo absolute maximum TX duty cycle:

Mechanism: send maximum length packets with minimum packet interval and at the same time enable that the packets should be confirmed by an ACK.

If the ACK is not received the chip will very quickly send a MAC/PHY level retry, retrying packets can be done with a shorter turnaround time than sending new packets.

SETTXDATA 618801aa1affff44330123456789abcdef define packet content

MR 5 set MAC level retry to 5

TX 10 1 ON send 10 packets with defined packet content and with 5 retries per packet and with 1 ms (+ delay) interval between the packets.
In case of a QPG6105 the delay is ~ 0.73 ms.

The “6” in the packet content is crucial to be sure that the ACK request bit is set to enable ACK confirmation.

Extend the packet content to maximum 250 characters by adding characters between 0 and f at the end of the packet.

The maximum TX duty cycle occurs under the following conditions:

- set MR to the maximum value (5), and
- use the maximum packet length (250 characters hexadecimal), and
- use minimum gap between the packets (1 ms).

6.4 Set-up Procedure for RX Modes

6.4.1 Select RF Channel

See section 6.3.3 to select an RF channel.

6.4.2 Turn RX On

Make sure TX is OFF. In case of doubt, switch power OFF and ON.

RX ON switch receiver ON

RXP ON enable display of received packets

6.4.3 Print Packets Sent/Received in RF4CE Mode

P print (show) number of received packets

R reset the number of the sent/received counter

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 Bluetooth Low Energy mode
GP_P335_UM_20021_FCC_Certification_Guide_QPE6105a_IoT_Controller_BLE_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	PSRR	Power Supply Rejection Ratio
DUT	Device Under Test	PTC	Product Test Component
FLL	Frequency Locked Loop	RCC	Radio Control Console
GLDO	Global Low Dropout Regulator	RCU	Remote Control Unit
LDO	Low Dropout Regulator	VCO	Voltage Controlled Oscillator
LNA	Low-Noise Amplifier		



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Document History

Version	Date	Section	Changes
1.0	Jul. 19, 2023		Released version.
1.01	Aug. 22, 2023	6.2.3 (old)	Removed low band-edge spurious mode.