nucurrent
ADVANCED WIRELESS POWER

Slotted Power Development Kit Software Manual

Rev 1.0.5

31-Jul-2020

1 Table of Contents

2 Revision History

Revision	Description	Date
1.01	Initial Draft	8/22/2019
1.02	Included CK Sections	9/3/2019
1.03	Restructure of the document	7/28/2020
1.04	Restructured sections 3 & 4 and updated the remainder.	07/30/2020
1.05	Additional corrections from document review	07/31/2020

3 Purpose

The purpose of this document is to describe the basic functionality of the NuCurrent Slotted Power Development Kit and to document the software protocol used by the development kit.

It includes an introduction to *slotted power* and complete documentation on the software protocol used by the development kit.

The NuCurrent Slotted Power Development Kit is based on the Ki Cordless Kitchen Standard which is maintained by the Wireless Power Consortium

"This standard defines transmitters and versatile cooktops that wirelessly deliver up to 2200 watts of power to smart cordless kitchen appliances –allowing them to operate without the clutter of cords. These small appliances, such as rice cookers, toaster, blenders, coffee makers, air fryers and more, are powered by simply placing them over power transmitters installed in enabled induction cooktops or neatly hidden beneath any standard non-metal countertop surface, cooktop or table. The appliances are then powered by inductive power transfer with no cords to get in the way."

For more information on the standard please see the homepage of the Ki Cordless Kitchen Standard (https://www.wirelesspowerconsortium.com/kitchen/).

Where ever the term *Ki* is used this refers to the Ki Cordless Kitchen Standard as outlined above.

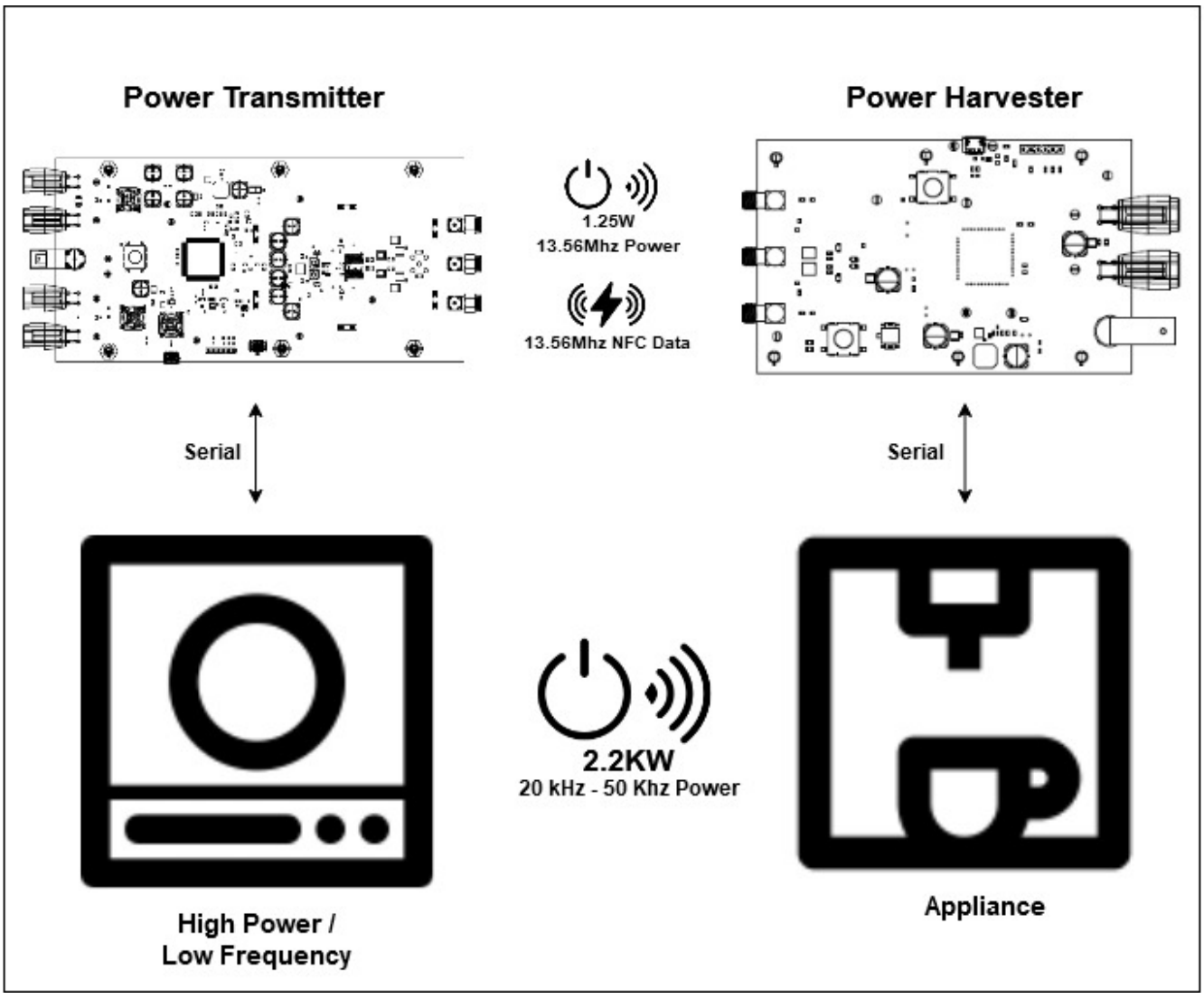
4 What is the Ki Cordless Kitchen?

The Ki Cordless Kitchen is system designed to wirelessly power a variety of kitchen appliances such as a toaster, coffee maker, oven, cook pan, blender, etc.

The Ki cordless is provides this wireless power via a “power mat” that the appliance is placed on. This eliminates the need for power cords and outlets.

The Ki Cordless Kitchen consists of 4 different subsystems.

- Power Transmitter
- Power Harvester
- High Power / Low Frequency
- Appliance



Ki Cordless Kitchen Subsystem Diagram

Power Amplifier

This refers to the Slotted Power subsystem that communicates with the High Power Low Frequency subsystem, provides up to 1.25W of NFC 13.56MHz power and initiates & controls the NFC communications between the Power Amplifier and Power Harvester.

This is one of the two board sets that is part of the NuCurrent Slotted Power Development Kit.

Power Harvester

This refers to the Slotted Power subsystem that communicates with the Ki compatible Appliance (i.e. toaster, oven, blender, etc.) and communicates with the Power Amplifier subsystem via NFC communications.

The Power Harvester can operate using the 1.25W High Frequency Low Power NFC 13.56M Hz field. This can also be used to power the Appliance's microprocessor and user interface. In most cases this low level of power is not enough to power the Appliance for full functionality.

This is one of the two board sets that is part of the NuCurrent Slotted Power Development Kit.

High Power / Low Frequency Subsystem

This refers to the low frequency (20 kHz to 50kHz) 2.2KW power transmitter that is intended to power the Appliance for full functionality.

This subsystem communicates with the Power Amplifier and through the Power Amplifier to the Power Harvester and Appliance.

This subsystem is not part of the Nucurrent Slotted Power Development Kit

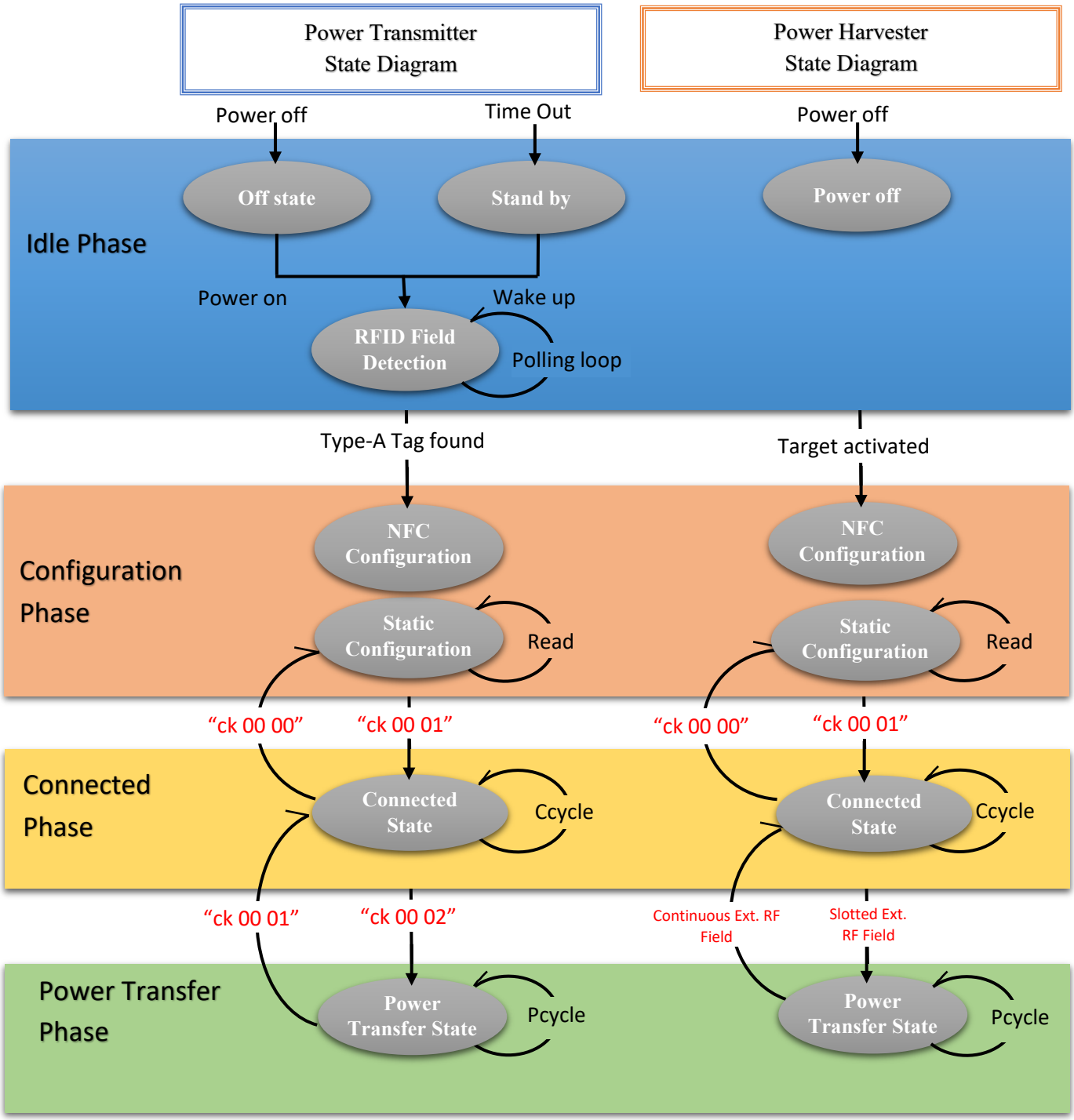
Appliance

This refers to the actual device that uses the power from the High Power / Low Frequency subsystem. For example: a Toaster, Oven or Blender.

This subsystem communicates with the Power Harvester and thru the Power Harvester to the Power Amplifier and High Power / Low Frequency Subsystem.

This is not part of the NuCurrent Slotted Power Development Kit

5 Operational Modes

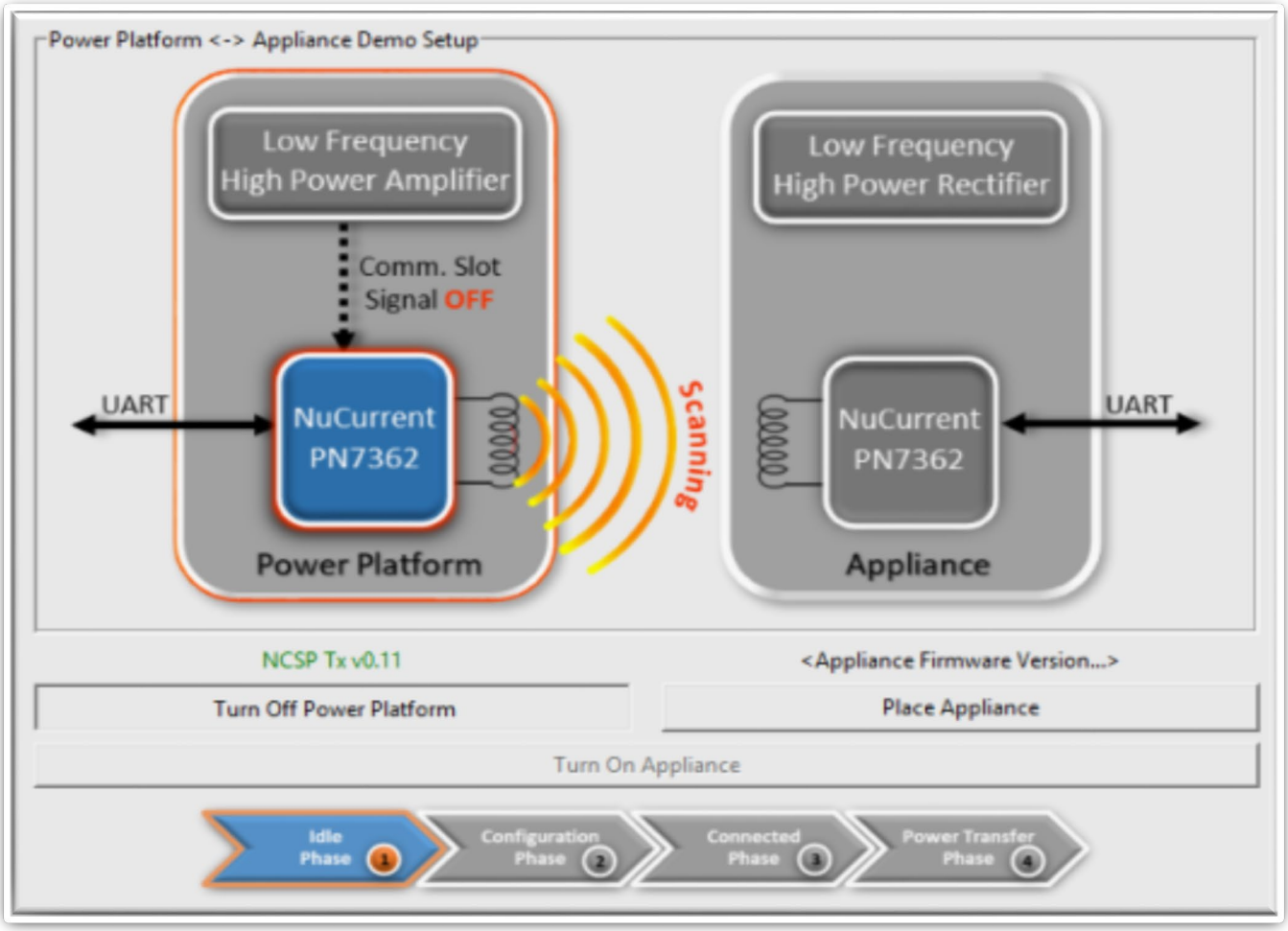


Phase Change State Diagram

5.1 Idle Phase

In the Idle Phase the power transmitter continuously searches for an NFC compatible device (card, tag, appliance, etc.) to be detected.

When an NFC device is detected the phase changes to the Configuration Phase.



Idle Phase

5.2 Configuration Phase

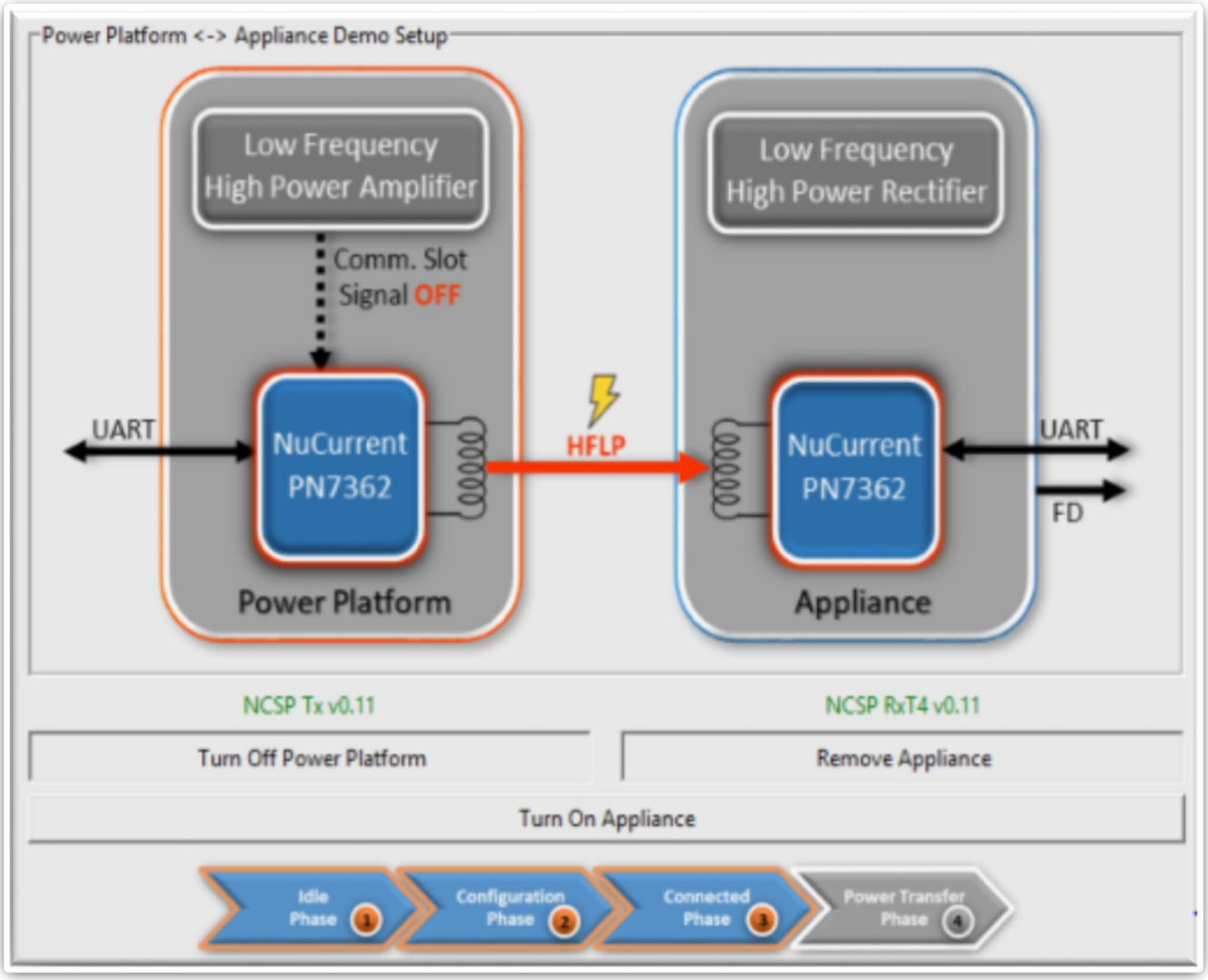
In the Configuration Phase the NFC device detected in the Idle Phase is queried to see if it is a Ki compatible device. If the device is Ki compatible device the phase is changed to the Connected Phase.

If the device is not a Ki Cordless Kitchen device, the phase is changed to the Idle Phase.

5.3 Connected Phase

In the Connected Phase both power platform and appliance are connected via the NFC protocol.

Communications between the Power Transmitter and Power Harvester is enabled. When the Power Transmitter receives a command to turn on the High Power / Low frequency the Power Transmitter will change the mode to the Power Transfer Phase and communications will change from standard NFC communications to Slotted Power Mode NFC communications.



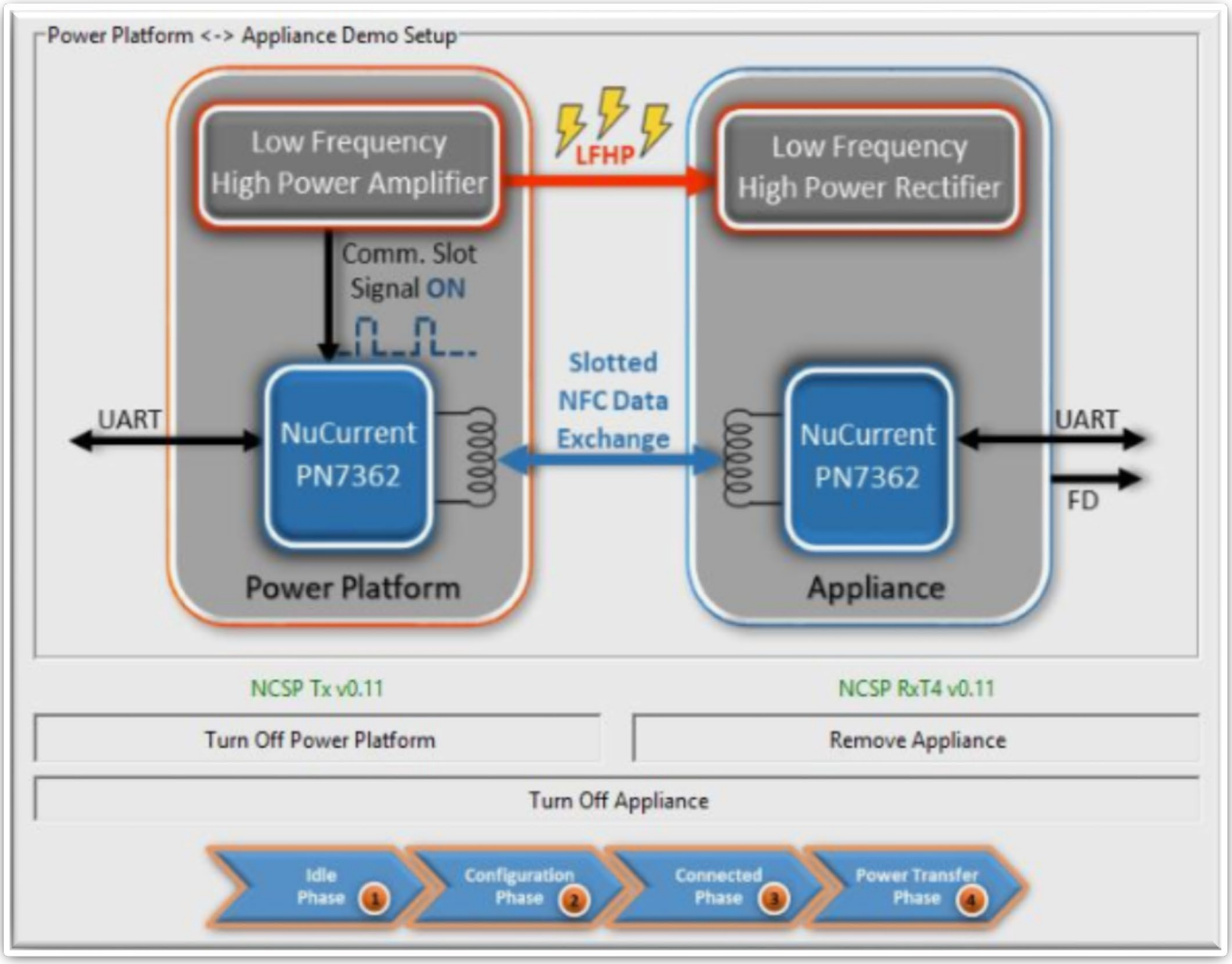
Connected Phase

5.4 Power Transfer Phase

In the Power Transfer Phase the High Power / Low Frequency amplifier is delivering power to the Appliance and is using Slotted Power NFC communications to communicate with the Power Transmitter.

When the Appliance has been removed and it can no longer to detected the Idle Phase will be entered.

Transitions to other phases can be accomplished when the Power Transmitter receives a command from the Power Harvester or the High Power / Low Frequency subsystem.

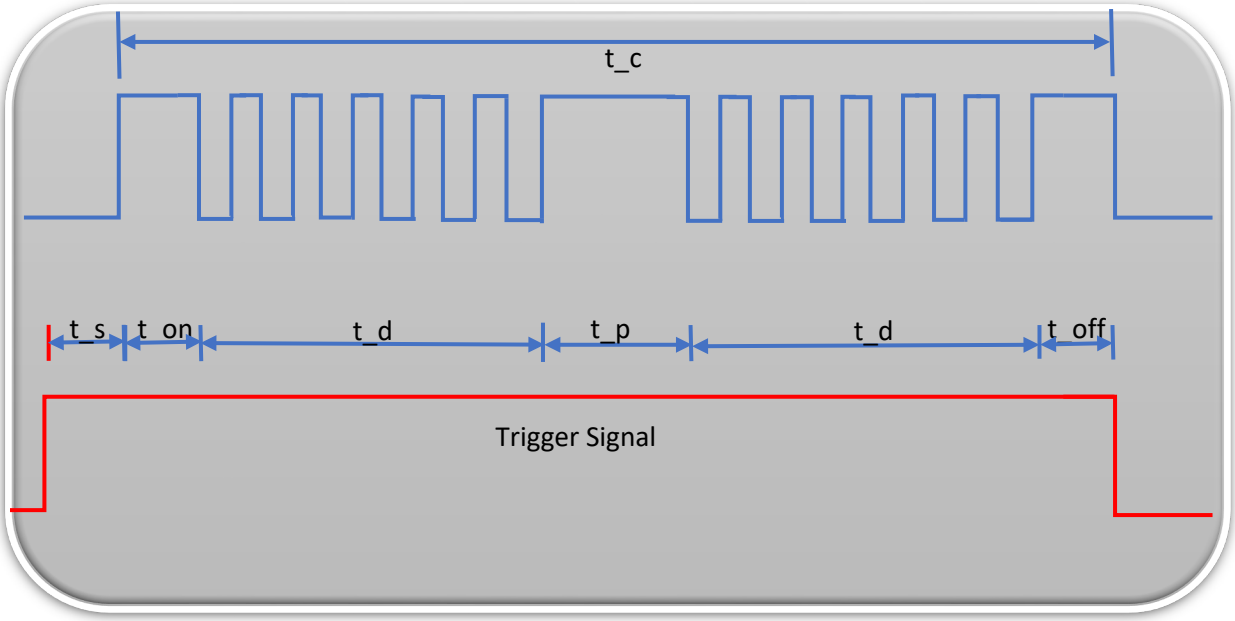


Power Transfer Phase

6 What is Slotted Power

During the Power Transfer Phase, a strict timing requirement is necessary in order to achieve stable NFC communications. For this reason, the messages are exchanged only during short slots of time.

Time slot for data exchange in power transfer phase is shown below.



NFC Communication Timings

Timings	Time [µs]	Comment
t_c	1500	The time slot within NFC communication has to be done. Required by active power transfer, not to be exceeded because of harmonics.
t_s	50	Detecting the rising edge of the trigger signal until the Power Transmitter turns own the 13.56MHz field.
t_on	250	The Guard Time the Power Transmitter has to wait before starting to send a frame. It has to be big enough to ensure that the Power Harvester has detected the 13.56MHz Field and is ready to receive a frame.
t_d	variable	The minimum time to transfer the data depends on the baud rate and the amount of data to be sent. The maximum time is fixed by the width of the trigger pulse.
t_p	variable	The time which the Power Harvester has to process, validate and start to answer to the received frame. t_p = t_c – (t_on + t_off + (2 x t_d)) The system requires a minimum t_p of 250µs.

t_off	20	The Power Transmitter has to be sure that the transmission was completed or aborted before turning off the 13.56MHz Field. This time allows for a smooth transition out of the communications “slot”.

6.1.1 Trigger Signal

To synchronize the Power Transmitter with the High Power / Low Frequency field, a “Trigger Signal” is used. The purpose of the trigger signal is to let the Power Transmitter know that it is allowed to turn on its own NFC RF-Field. The slotted communication has very strict timing requirements and the trigger signal shall align with following rules.

This signal is captured at the GPIO number 7 on the Power Transmitter.

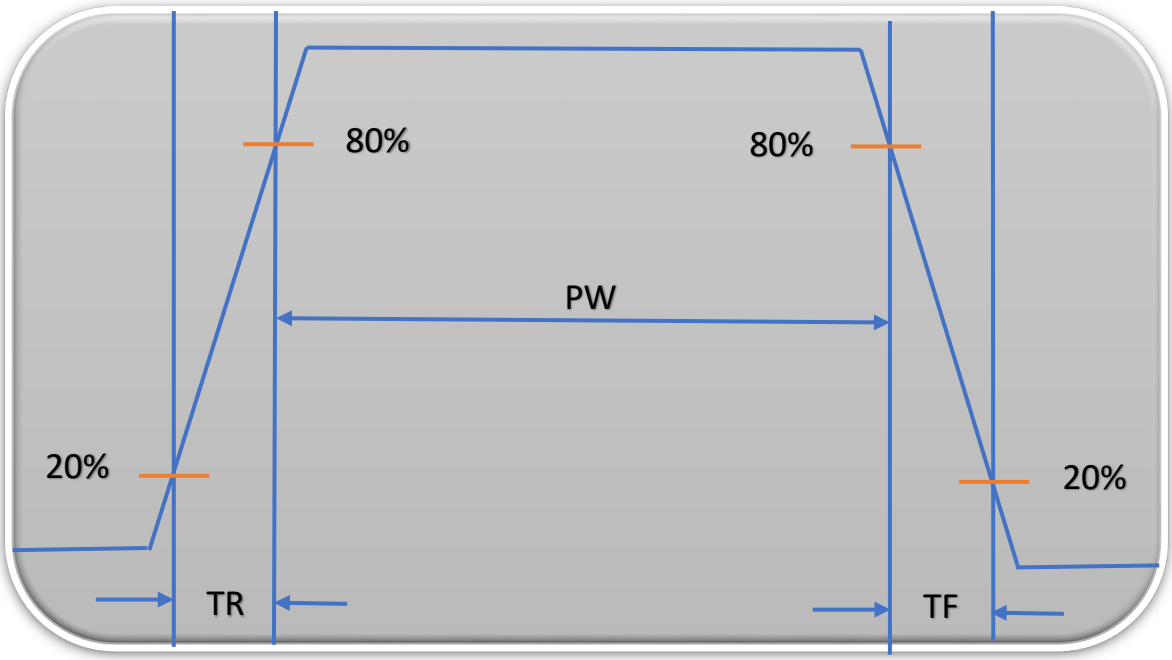


Figure 1: Trigger Signal Waveform

Timings	Time	Comment
TR (Rise Time)	Min: 1.0ns Max: 3.5ns	This is the rise time of the trigger signal. The Power Transmitter can turn on the 135.56MHz field when the trigger signal reaches 80% of its active high voltage.
PW (Pulse Width)	1500µs	The pulse width (end of rising time until start of falling time) shall be at least 1500µs and represents the time slot for the Slotted NFC Communications.
TF (Fall Time)	Min: 1.0ns Max: 3.5ns	This is the fall time of the triggering signal. The Power Transmitter must initiate turning off the 13.56MHz field when this signal reaches 80% of its active high voltage.

7 Binary Packet Format

The protocol will use standard serial 8-N-1 (1 start bit, 8 data bits, 1 stop bit, no parity) communications. The default baud rate 115200 bits/second.

The baud rate can be changed using the Write EEPROM command.

The protocol sends the data as a binary data stream with unique Start of Frame (STX) and End of Frame (ETX) bytes.

8 Binary Packet Layout

This chapter contains all requirements of the binary protocol commands. This protocol was developed for industrial usage including synchronization and frame checking. Data is transmitted in binary. There is no timeout for receiving data.

STX	Type	Station ID	Length	Data	BCC	ETX
1 Byte	1 Byte	1 Byte	2 Byte	Various length	1 Byte	1 Byte

This is an example of use getting the version of the firmware inside the device:

STX	Type	Station ID	Length	Data	BCC	ETX
02h	01h	FFh	0001h	76h ('v')	89h	03h

STX	Type	Station ID	Length	Data	BCC	ETX
02h	02h	00h	0018h	4E75432E53507030 2E303030302E3230 31392E30382E3133 (HEX)	0Fh	03h

The Data converted to ASCII shows the following string: "NuC.SPp0.0000.2019.08.13"

8.1 STX

This byte determinates the beginning of the frame:

STX Code	Meaning
0000 0010b (02h)	Start of the frame

8.2 Type

The following table defines the different possible types of frame:

Type Code	Meaning	Message Direction
0000 0001b (01h)	Command	Host to Reader
0000 0010b (02h)	Response	Reader to Host
0000 0100b (04h)	Notification	Reader to Host
0000 1000b (08h)	Debug	Both ways
0001 0000b (10h)	Response with Chaining	Reader to Host
1110 0000b (E0h)	RFU	-

8.3 Station ID (Unique ID of the device)

The following table defines the different possible station ID's for assembly the frame:

Station ID Code	Meaning
00h	Reserved for the bus master.
FFh	Broadcast message. All devices will process the command sent with broadcast.
01h-FEh	Station ID's for devices. The device will only process a command if the received station ID either matches the station ID of the device or is FFh.

8.4 Length (2 Bytes)

Determines the length of the Data block.

8.5 Data

This part contains the command and data. The length of the command block depends on the instruction.

8.6 BCC

The BCC is used to detect transmission errors. To calculate the BCC XOR all of the bytes in the message between (but not including) the STX & ETX bytes.

BCC = Type XOR **StationID** XOR **Length** XOR **DATA0** XOR … XOR **DATAN**

8.7 ETX

ETX shows the End of the frame.

ETX Code	Meaning
0000 0011b (03h)	End of the frame

9 Binary Commands

9.1 Slot Mode Binary Commands

All Cordless Kitchen related commands shall start with the characters ‘ck’.

The Cordless Kitchen specific commands are listed in the table below:

Name	Command
Go to Phase…	“ck” 0x00 [Value]
Read Data	“ck” 0x02 [Address]
Set Data	“ck” 0x03 [Payload]
Get Current Phase	“ck” 0x04
Store Current RF Field Load	“ck” 0x09
Set Foreign Object Detection Threshold	“ck” 0x09 [Threshold]
Get Current Field Load	“ckm”
Cordless Kitchen Select	“cks” [Bitrate]
Register Access	“ckr” [Register]
Test B	“ckt”

9.1.1 Go to Phase…

With this command, it is possible to go from one phase to the next or previous one. It is not possible to jump from Configuration Phase to Power Transfer Phase or vice versa.

Only the Power Transmitter can choose when to go to Power Transfer Phase from Connected Phase or to Connected Phase from Power Transfer Phase. The following table shows the command and its response.

Command		
Command	Opcode	Value
"ck"	0x00	0x00 → Go to Configuration Phase 0x01 → Go to Connected Phase 0x02 → Go to Power Transfer

Response	
Data	Description
0x00 (1 byte)	The device went correctly to the specified phase
‘E’ (1 byte)	Error

9.1.2 Read Data

This command is used to read the previously stored data, by a Write Data command or stored in the EEPROM. It is useful only for T2T mode. It is used to indicate which block address you want to read from.

Command		
Command	Opcode	Address
"ck"	0x02	[0x00 – 0xFF] Only in T2T-Mode

Response	
Data	Description
4 bytes	T2T 4 bytes Block

9.1.3 Set Data

This command is used to store the T2T Tag data into the internal memory when using Standard Profile or the next frame to be exchanged when using Extended Profile (T4T).

Command				
Comman	Opcod	Address	Block number	Payload
"ck"	0x03	[0x00 – 0x1F] In T2T-Mode. [0x00] in T4T-Mode	[0x00 – 0x07] (Only useful in T4T-Mode)	<Payload>

Here, <Payload> is based on the appliance card type, whether it supports Standard profile (T2T Card) or Extended profile (T2T Card). Please refer the following sections as per card type for <Payload> related information,

1. For Standard profile (T2T Card): Section: 9.4
2. For Extended profile (T4T Card): Section: 9.5

NOTE: The block number shall be sequentially assigned by the Host, when using this Command. It will be ignored in T2T mode. This block number is not transmitted to the other device. It's only local and it's intended for flow control

The maximum Payload length depends on which over the air bitrate has been selected to communicate between the Power Transmitter and Power Receiver devices:

Bitrate used	Maximum payload length
106 kbps	5 Bytes
212 kbps (Only in Extended Profile)	17 Bytes
424 kbps (Only in Extended Profile)	40 Bytes
848 kbps (Only in Extended Profile)	80 Bytes

Response		
Device	Data	Description
CE Only	0x00 (1 byte)	Data message correctly set
Power Transmitter Only	0xA0 (1 byte)	ACK Response after a WRITE command (Extended Profile)
Power Transmitter Only	0x0A (1 byte)	ACK Response after a WRITE command (Standard Profile)
Power Transmitter Only	0xB0 (1 byte)	NACK Response due to an error (Extended Profile)
Power Transmitter Only	0x0B (1 byte)	NACK Response due to an error (Standard Profile)
Power Transmitter Only	Payload	Response after a READ command

9.1.4 Get Current Phase

This command returns the current phase in which a Cordless Kitchen device is:

Command	
Command	Opcode
"ck"	0x04

Response	
Data	Description
0x04 0x00 (2 bytes)	Configuration or Idle Phase
0x04 0x01 (2 bytes)	Connected Phase
0x04 0x02 (2 bytes)	Power Transfer Phase

9.1.5 Cordless Kitchen Select

This command tells the Power Transmitter device to do one single poll for NFC device Types A, B, F and V, and will return the activated Tag (or Power Harvester) information or an error message in case of a metallic object detection. It is also possible to specify the desired bitrate to work with.

Command	
Command	Bitrate
"cks"	0x00 → 106kbps 0x02 → 212kbps 0x04 → 424kbps 0x08 → 848kbps

Response	
Data	Description
TLV structure	Activated Tag or CE device information (See Appendix A: TLV Structure)
'N'	Nothing was detected
'M'	A metallic object was detected

9.1.6 Cordless Kitchen Register Access

This command provides low level access to the underlying NFC Contactless Interface (CLIF)

Registers can be read with “ckr” 0x00, and written with “ckr” 0x01. The Addr is a 2-byte register offset (MSB first). The Value is 4 bytes (MSB first). In either case, the register value is read back and returned in the response.

Command			
Command	Opcode	Data	Description
"ckr"	0x00	[Addr]	Read
“ckr”	0x01	[Addr] [Value]	Write

Response	
Data	Description
Value (4 bytes, MSB first)	Register value, 4 bytes (MSB first)
‘E’	Error

9.1.7 Cordless Kitchen Test B

This command currently does nothing. The response is 1 byte, 0x00.

Command		
Command	Data	Description
"ckt"	Any	Read
“ckr”	[Addr] [Value]	Write

Response	
Data	Description
0x00	OK

9.2 Standard Binary Protocol Commands

Apart from the Binary Commands dedicated only for the Cordless Kitchen project, there are a set of commands implemented in both Power Transmitter and Power Harvester devices. Here is the list:

Command	Value	Short Description
Reset	'x'	Device software reset
Select	's'	Select a single card found inside the electromagnetic field
Extended Select	"ns"	Select a single card found inside the electromagnetic field. This command return more information about the device wrapped in a TLV table structure (See Appendix C).
Transfer	't'	Send data to an external device
Transfer Layer 4	"t4"	Send data to an external device using application layer
Get Firmware Version	'v'	Obtain the Firmware Version
Get EEPROM Version	"ve"	Obtain the EEPROM Version
RF-Field On/Off	"pon" / "poff"	Turn on/off the electromagnetic field
Set User Ports	"pp"	Define the direction of the User Ports
Read User Ports	"pr"	Read the current state of the User Ports
Write User Ports	"pw"	Set any User Port as Output
Read EEPROM Register	"re"	Read a specific register in the EEPROM
Write EEPROM Register	"we"	Write a specific register in the EEPROM
Multitag Select	'm'	Show a list of UID's devices present during a polling cycle inside the electromagnetic field. Also, is possible to select one from the set of devices found in the electromagnetic field using it UID.
Extended Multitag Select	"nm"	Show a list of TLV tables, one per each device found in the electromagnetic field. This command will not select any device.
High Speed Select	'h'	Select a single device and establish the communication with the selected bitrate (if the device supports it)
Extended High Speed Select	"nh"	Select a single device and establish the communication with the selected bitrate, in case the device supports it. This command return more information about the device wrapped in a TLV table structure (See Appendix C).

Commands in Yellow are Reserved For Future Use

9.2.1 Reset

The Reset command triggers an immediate reset of the device. The response is the same as the version command.

This command represents one byte with the value of 'x'.

Command	
Command	Data
'x'	None

9.2.2 Select

9.2.2.1 Power Transmitter

The select command selects a single card in the field. The Power Transmitter returns the UID of the selected card.

- The command represents one byte with the value of 's'. Additionally, it is possible to specify which technologies to poll for by using an extra byte of information, with a bit- mask as follows:
  - 0000 0001b – Poll for Technology A
  - 0000 0010b – Poll for Technology B
  - 0000 0100b – Poll for Technology F
  - 0000 1000b – Poll for Technology V

Otherwise, if no extra byte is sent, the Power Transmitter will poll for all four technologies.

- In case of success, the device is activated until its final layer (e.g. Layer 4 for DESFire) and afterwards, the response will contain the UID of this card.
- In case no card is detected or it could not be activated, the response will be a single byte with the value of 'N'.
- If the command sent has an invalid format, the response will be a single byte with the value of 'E'.

Command	
Command	Bit-Mask to indicate which technologies to poll (Optional)
's'	(1 Byte) for: 01h – Poll for Technology A 02h – Poll for Technology B 03h – Poll for Technology A and B 04h – Poll for Technology F 05h – Poll for Technology A and F 06h – Poll for Technology B and F 07h – Poll for Technology A, B and F 08h – Poll for Technology V 09h – Poll for Technology A and V 0Ah – Poll for Technology B and V 0Bh – Poll for Technology A, B and V 0Ch – Poll for Technology F and V 0Dh – Poll for Technology A, F and V 0Eh – Poll for Technology B, F and V 0Fh – Poll for Technology A, B, F and V

Response	Description
[UID] (Various length)	UID of the Tag (length according to the used Tag specification)

Error codes	Description
'N'	No Tag found / Tag not activated
'E'	General Error

9.2.2.2 Power Harvester

The select command activates the Ki capabilities of the Power Harvester device.

- The command represents one byte with the value of ‘s’ and one byte to choose the supported protocol (T2T for Standard Profile or T4T for Extended Profile) and the maximum bitrate that the Power Harvester can communicate with.
- If the command was correctly set, an OK response (0x00) will be sent to the host.
- If the command sent has an invalid format, the response will be a single byte with the value of ‘E’.
- After a correct activation from the Power Transmitter device, the Power Harvester will send an Event with the ‘A’ byte as payload to the host.

Command	
Command	Data (Optional)
's'	(1 Byte) Bit-Mask to indicate the supported protocol and the maximum bitrate: 0x10 → T2T Protocol and 106 kbps 0x20 → T4T Protocol and 106 kbps 0x22 → T4T Protocol and 212 kbps 0x24 → T4T Protocol and 424 kbps 0x28 → T4T Protocol and 848 kbps

Response	Description
0x00 (1 byte)	The CE mode was correctly set

Event	Description
‘A’	The CE device got correctly activated by the Power

Error codes	Description
‘N’	A previously detected RF Field is no longer present
‘E’	General Error

9.2.3 Extended Select (Power Transmitter)

This command works like the 's' command but it returns more data in a TLV structure. For details of the structure see Appendix C.

Command	
Command	Data (Optional)
"ns"	(1 Byte) Bit-Mask to indicate which technologies to poll for: 01h – Poll for Technology A 02h – Poll for Technology B 03h – Poll for Technology A and B 04h – Poll for Technology F 05h – Poll for Technology A and F 06h – Poll for Technology B and F 07h – Poll for Technology A, B and F 08h – Poll for Technology V 09h – Poll for Technology A and V 0Ah – Poll for Technology B and V 0Bh – Poll for Technology A, B and V 0Ch – Poll for Technology F and V 0Dh – Poll for Technology A, F and V 0Eh – Poll for Technology B, F and V 0Fh – Poll for Technology A, B, F and V

Response	Description
TLV structure	TLV structure with the information of the found Tag (see Appendix C)

Response

Error codes	Description
'N'	No Tag found / Tag not activated
'E'	General Error

9.2.4 Transfer

This so-called “transfer command” sends any command in ISO/IEC 14443-3 format to an NFC device. If an ISO/IEC 14443-4 Tag is activated the host is responsible for the higher level protocol handling (PCB, CID byte, etc.).

- The valid response consists in (at least) two bytes: Length + Data
- In case of no valid response, a byte with the value of ‘F’ will be returned meaning “General Failure”
- If the command sent has an invalid format, the response will be a single byte with the value of ‘E’

Command					
Command	Length	Data			
		PCB (optional)	CID (optional)	NAD (optional)	INF
‘t’	1 byte	1 byte	1 byte	1 byte	Variable length

Response		Description
Length	**Data**	A valid Response from Tag
1 byte	Various Length	

Error codes	Description
‘F’	General Failure
‘E’	General Error

9.2.5 Get Version

This command returns the current version of the Firmware and EEPROM.

- The command represents one byte with the value of 'v'.
- The response contains the Firmware version.
- If the command sent has an invalid format, the response will be a single byte with the value of 'E'.

Command	
Command	Data
'v'	None

Response	Description
Data (23 bytes)	Firmware version string

Error codes	Description
'E'	General Error

9.2.6 RF-Field On/Off

By issuing this opcode the internal 15.56MHz RF-Field can be turned On/Off. If the RF-Field is already in the current state of the issued command the RF-Field does not change and no error is returned.

a) RF-Field On

- The RF-Field On command consists in 3 bytes with the value of "pon"
- If not error occurred, and also no external field RF-Field was present, the response shall consist in one byte with the value of 'P' and afterwards, the field may be switched on.
- In case of an external field was present, a byte with the value of 'F' will be returned meaning "General Failure" and the RF-Field will not be switched on.
- If the command sent has an invalid format, the response will be a single byte with the value of 'E'.

Command	
Command	Data
"pon"	None

Response	Description
Response 'P' (1 byte)	Electromagnetic Field enabled

Error codes	Description
'F'	General Failure
'E'	General Error

b) RF-Field Off

- The RF-Field Off command consists in 4 bytes with the value of “poff”
- If not error occurred the response shall consist in one byte with the value of ‘P’ and afterwards, the field may be switch off.
- There is no error returned if this command is sent meanwhile the RF-Field is off.
- If the command sent has an invalid format, the response will be a single byte with the value of ‘E’.

Command	
Command	Data
“poff”	None

Response	Description
Response ‘P’ (1 byte)	Electromagnetic Field disabled

Error codes	Description
‘E’	General Error

9.2.7

9.2.8 High Speed Select (Power Transmitter)

This command modifies the air bitrate speed to allow higher over the air communication speeds between the Power Transmitter and the Power Harvester, or other NFC device, if this bitrate is supported by the device. The result will be the activation of the device with the bitrate in the command. In case the device is not capable with the bitrate in the command, this command will activate the device with the lowest air bitrate possible (106 Kbits/s). In other cases, the Power Transmitter will return and error code.

Command	
Command	Data
'h'	0x00 →106 Kbits/s 0x02 →212 Kbits/s 0x04 →424 Kbits/s 0x08 →848 Kbits/s

Response	Description
[UID] (Various length)	UID of the Tag (length according to the used Tag specification)

Error codes	Description
'N'	No device found
'E'	General Error

9.2.9 Extended High Speed Select (Power Transmitter)

This command works like the High Speed Select command but it returns more data in a TLV structure. For details of the structure see Appendix C.

Command	
Command	**Data (Optional)**
"nh"	0x00 →106 Kbits/s 0x02 →212 Kbits/s 0x04 →424 Kbits/s 0x08 →848 Kbits/s

Response	Description
TLV structure	TLV structure with the information of the found device (see Appendix C)

Error codes	Description
'N'	Device not activated
'E'	General Error

9.3

9.4 Events

In this chapter, the Events sent to the Host are described. At this moment, only the "Received Data Event" has been defined.

9.4.1 Received Data Event

After receiving a frame through NFC communications (Connected and Power Transfer phases ony), the received data will be sent to the Host in this Event. It also indicates if the previous message stored by using the Set Data command was successfully sent via NFC Communications or if an Error happened.

Event		Description
Status Byte	Data	Data message received from the other device
1 Byte	(n bytes)	

9.4.2 Phase Change event

This event is sent from a Cordless Kitchen device to its Host when there is an automatic transition, due to RF Field change or disconnection, between Connected Phase and Power Transfer Phase or vice versa.

Event		
Opcode	Value	Description
0x04	0x01	Transition to Connected Phase
0x04	0x02	Transition to Power Transfer Phase

9.5 Standard Profile (T2T Protocol)

Standard Profile uses the ISO14443 Type 2 Tag standard as communication protocol. This means no header is sent within the frames. It is a simple way of exchanging information between Power Transmitter and Power Harvester but implies slow data bandwidth, as it works only at 106 kilobits per second.

9.5.1 Commands for Standard Protocol

With the standard ISO14443 Type 2 Tag commands the transmitter is limited to fixed amount of blocks of 4 bytes with each command. The dedicated commands for Cordless Kitchen are shortened versions of the standard T2T READ and WRITE commands, in order to make the transmission of data during the limited slot time, in Power Transfer Phase, possible.

These commands are sent by the transmitter host by using the Set Data command, explained below

The appliance device emulates a T2T memory of 32 pages with 4 bytes each (total of 128 bytes). The appliance host can set new data or read it by using the same Set Data command as for the transmitter device or the Read Data command, explained below.

9.5.2 READ_BUFFER Command (0x3A)

The READ_BUFFER command is a frame that starts with the value 0x3A and includes the start and end addresses to read from. (At this moment, only one block can be read at a time) The answer to this command is the information stored in the appliance device memory in the memory address passed in the READ_BUFFER command.

Following tables show the frames exchanged in the RF interface during one Slot:

Code	Start Address	End Address	CRC
0x3A	y	y + 1	
1 byte	1 byte	1 byte	2 bytes

Data	CRC
4 bytes	2 bytes

9.5.3 WRITE_BUFFER Command (0xA6)

The WRITE_BUFFER command starts with a byte with the value 0xA6, followed by the starting address where the information shall be stored and the data itself. (At this moment, only one block can be written at a time)

The answer to this command is either an ACK (0xA) if the message was correct, or a NACK (0xB) if there was an error.

Following tables show the frames exchanged in the RF interface during one Slot:

Code	Start	End Address	Data	CRC
0xA6	y	y + 1		
1 byte	1 byte	1 byte	4 bytes	2 bytes

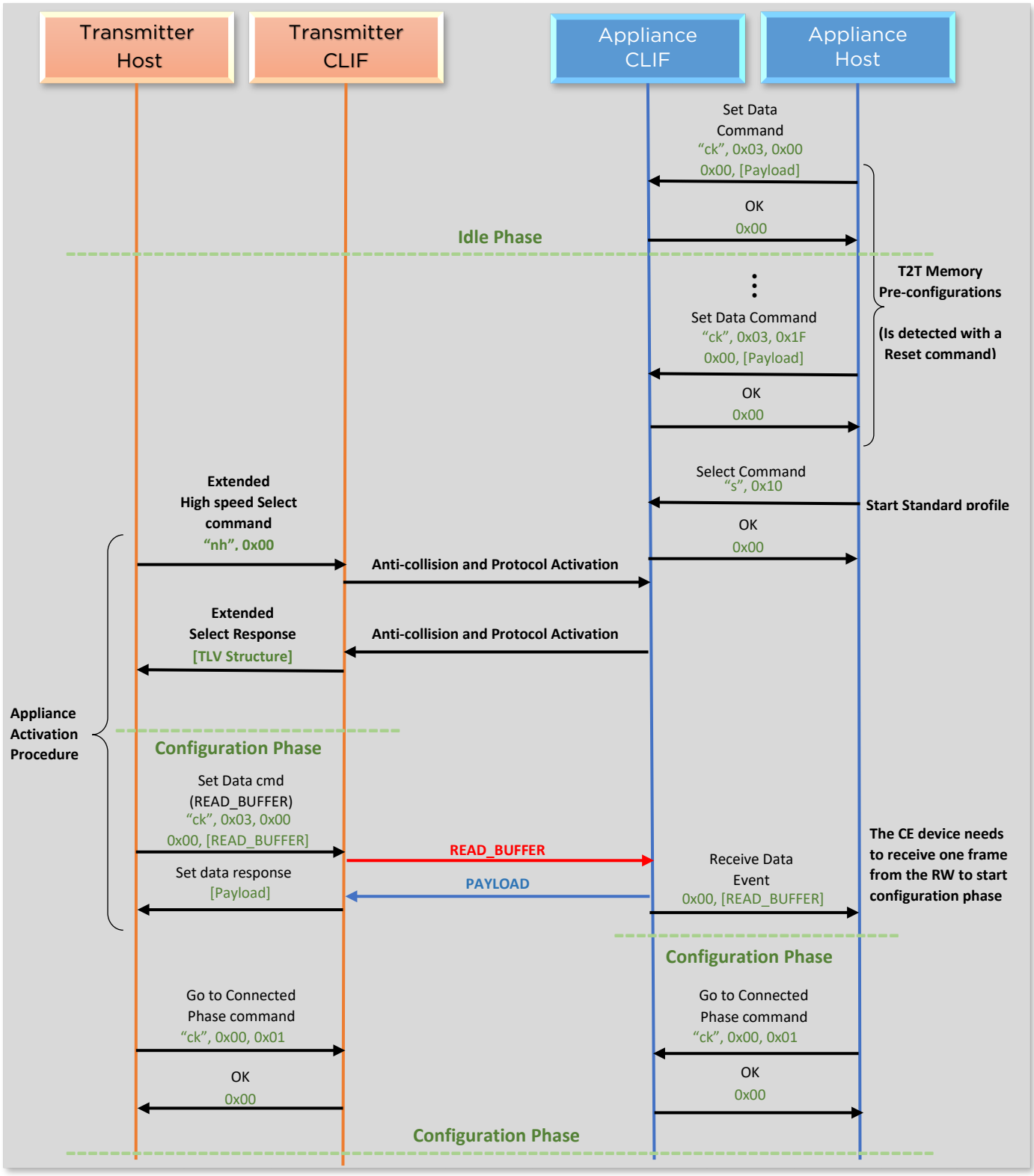
ACK
1010b
4 bits

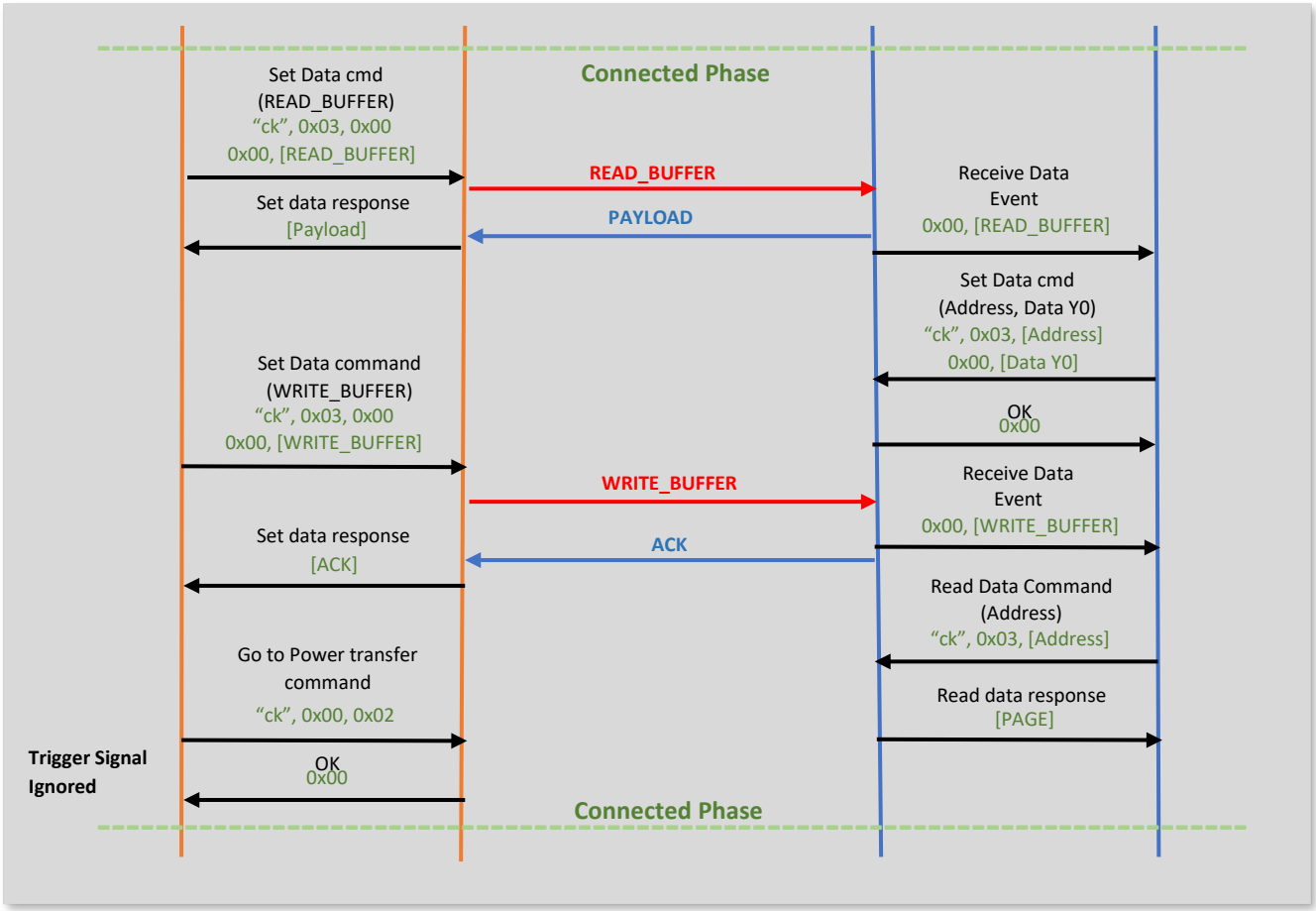
9.5.4 Communication Sequence

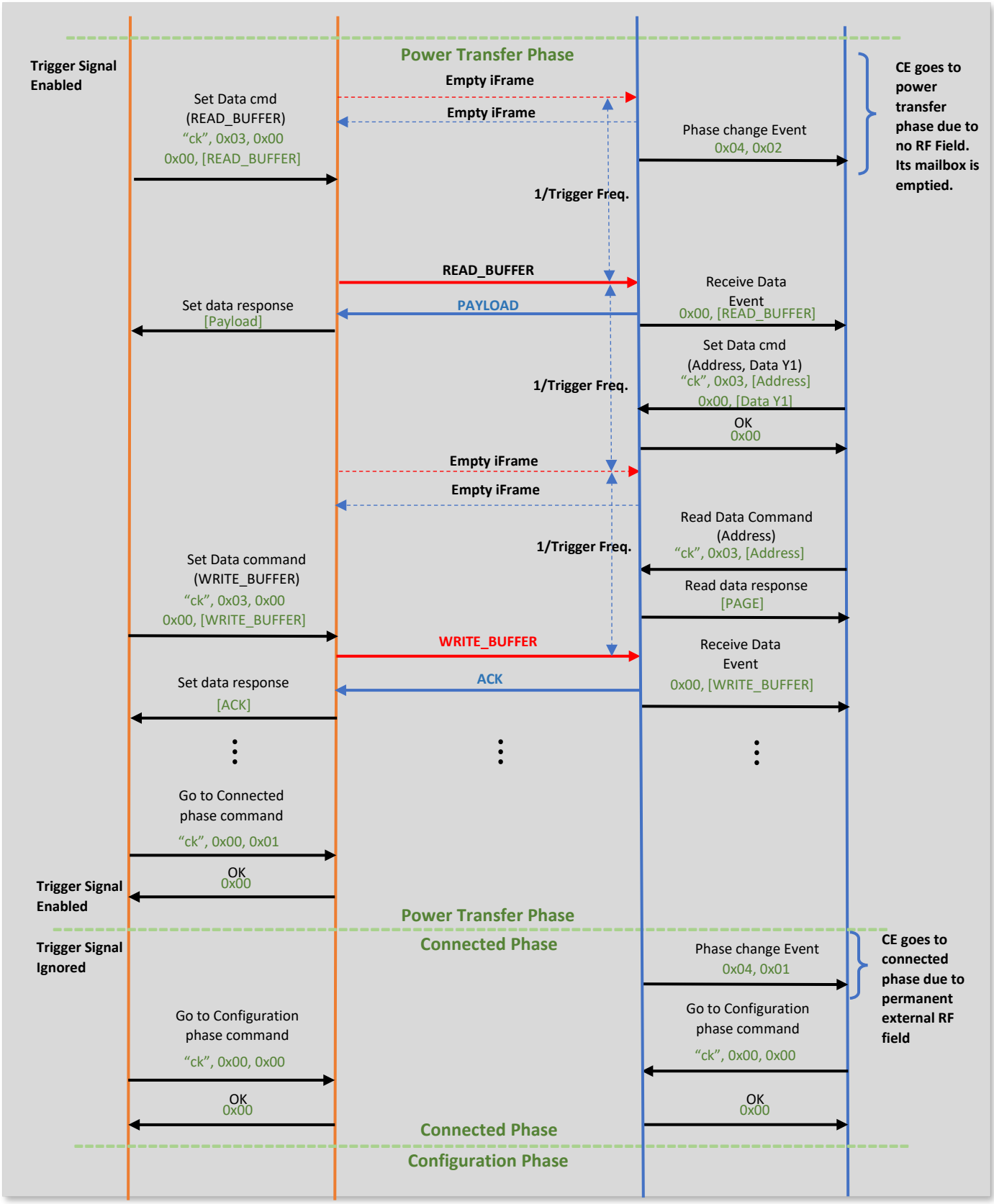
By using the commands described in previous chapter (READ_BUFFER and WRITE_BUFFER), it is possible to communicate between Power Transmitter and Power Harvester.

Every time the Power Transmitter sends a message and it is correctly received by the Power Harvester, the Power Harvester host will be notified with an event.

In following diagram (next page), an example of the communication process is shown:


Transmitter Host
Transmitter CLIF
Appliance CLIF
Appliance Host
Set Data Command
"ck", 0x03, 0x00
0x00, [Payload]
OK
0x00
Idle Phase
T2T Memory Pre-configurations
(Is detected with a Reset command)
Set Data Command
"ck", 0x03, 0x1F
0x00, [Payload]
OK
0x00
Select Command
"s", 0x10
Start Standard profile
OK
0x00
Extended High speed Select command
"nh", 0x00
Anti-collision and Protocol Activation
Extended Select Response
[TLV Structure]
Anti-collision and Protocol Activation
Appliance Activation Procedure
Configuration Phase
Set Data cmd (READ_BUFFER)
"ck", 0x03, 0x00
0x00, [READ_BUFFER]
READ_BUFFER
PAYLOAD
Set data response
[Payload]
Receive Data Event
0x00, [READ_BUFFER]
The CE device needs to receive one frame from the RW to start configuration phase
Configuration Phase
Go to Connected Phase command
"ck", 0x00, 0x01
OK
0x00
Go to Connected Phase command
"ck", 0x00, 0x01
OK
0x00
Configuration Phase


Connected Phase
Set Data cmd
(READ_BUFFER)
"ck", 0x03, 0x00
0x00, [READ_BUFFER]
READ_BUFFER
Receive Data
Event
0x00, [READ_BUFFER]
Set data response
[Payload]
PAYLOAD
Set Data cmd
(Address, Data Y0)
"ck", 0x03, [Address]
0x00, [Data Y0]
Set Data command
(WRITE_BUFFER)
"ck", 0x03, 0x00
0x00, [WRITE_BUFFER]
OK
0x00
WRITE_BUFFER
Receive Data
Event
0x00, [WRITE_BUFFER]
Set data response
[ACK]
ACK
Read Data Command
(Address)
"ck", 0x03, [Address]
Go to Power transfer
command
"ck", 0x00, 0x02
Read data response
[PAGE]
Trigger Signal
Ignored
OK
0x00
Connected Phase


Power Transfer Phase
Trigger Signal Enabled
Empty iFrame
Empty iFrame
Set Data cmd (READ_BUFFER) "ck", 0x03, 0x00 0x00, [READ_BUFFER]
Phase change Event 0x04, 0x02
CE goes to power transfer phase due to no RF Field. Its mailbox is emptied.
1/Trigger Freq.
READ_BUFFER
PAYLOAD
Receive Data Event 0x00, [READ_BUFFER]
Set data response [Payload]
Set Data cmd (Address, Data Y1) "ck", 0x03, [Address] 0x00, [Data Y1]
1/Trigger Freq.
OK 0x00
Empty iFrame
Empty iFrame
Read Data Command (Address) "ck", 0x03, [Address]
1/Trigger Freq.
Set Data command (WRITE_BUFFER) "ck", 0x03, 0x00 0x00, [WRITE_BUFFER]
Read data response [PAGE]
WRITE_BUFFER
ACK
Receive Data Event 0x00, [WRITE_BUFFER]
Set data response [ACK]
Go to Connected phase command "ck", 0x00, 0x01
OK 0x00
Trigger Signal Enabled
Power Transfer Phase
Trigger Signal Ignored
Connected Phase
Phase change Event 0x04, 0x01
CE goes to connected phase due to permanent external RF field
Go to Configuration phase command "ck", 0x00, 0x00
Go to Configuration phase command "ck", 0x00, 0x00
OK 0x00
OK 0x00
Connected Phase
Configuration Phase

9.6 Extended Profile (T4T Protocol)

Extended Profile uses the ISOType 4 Tag standard to communicate between Power Transmitter and Power Harvester. It allows a higher bandwidth, as it is possible to use up to 848kbps as bitrate.

There are two commands that shall be used in order to exchange messages between devices, the READ_T4 and WRITE_T4.

The way to send these commands via the air interface is by using the Binary command “Set Data”.

9.6.1 Commands for Extended Profile

The standard Type 4 Tag commands are using ISO/IEC7816-4 commands (APDUs) encapsulated within I-blocks. Due this fact, too much overhead is created for that use-case. The dedicated commands, explained below, allow the transmitter to exchange data in a more time efficient way. The dedicated commands are encapsulated into I-Blocks.

In comparison to the “Basic profile”, the transmitter is determining the amount of bytes for the WRITE_T4 command, whether the appliance determines the amount of exchanged bytes for the READ_T4 command.

9.6.2 READ_T4 Command (0x3A)

The READ_T4 command is just one byte with the value 0x3A.
The answer to this command will be the current information stored in the appliance device memory, starting with a length byte. In case the appliance device didn’t set any data yet, the answer will be the length byte with the value 0x00 and no payload.

Following tables show the frames exchanged in the RF interface during one Slot:

Prologue field	Information field	Epilogue field
PCB	Read command	EDC
1 byte	1 byte	2 bytes

Prologue field	Information field		Epilogue field
PCB	Length	Payload	EDC
1 byte	1 byte	n bytes	2 bytes

9.6.3 WRITE_T4 Command (0xA6)

The WRITE_T4 command starts with a byte with the value 0xA6, followed by a length byte and the payload.

The answer to this command is either an ACK (0xA0) if the message was correct or a NACK (0xB0) if there was an error.

Following tables show the frames exchanged in the RF interface during one Slot:

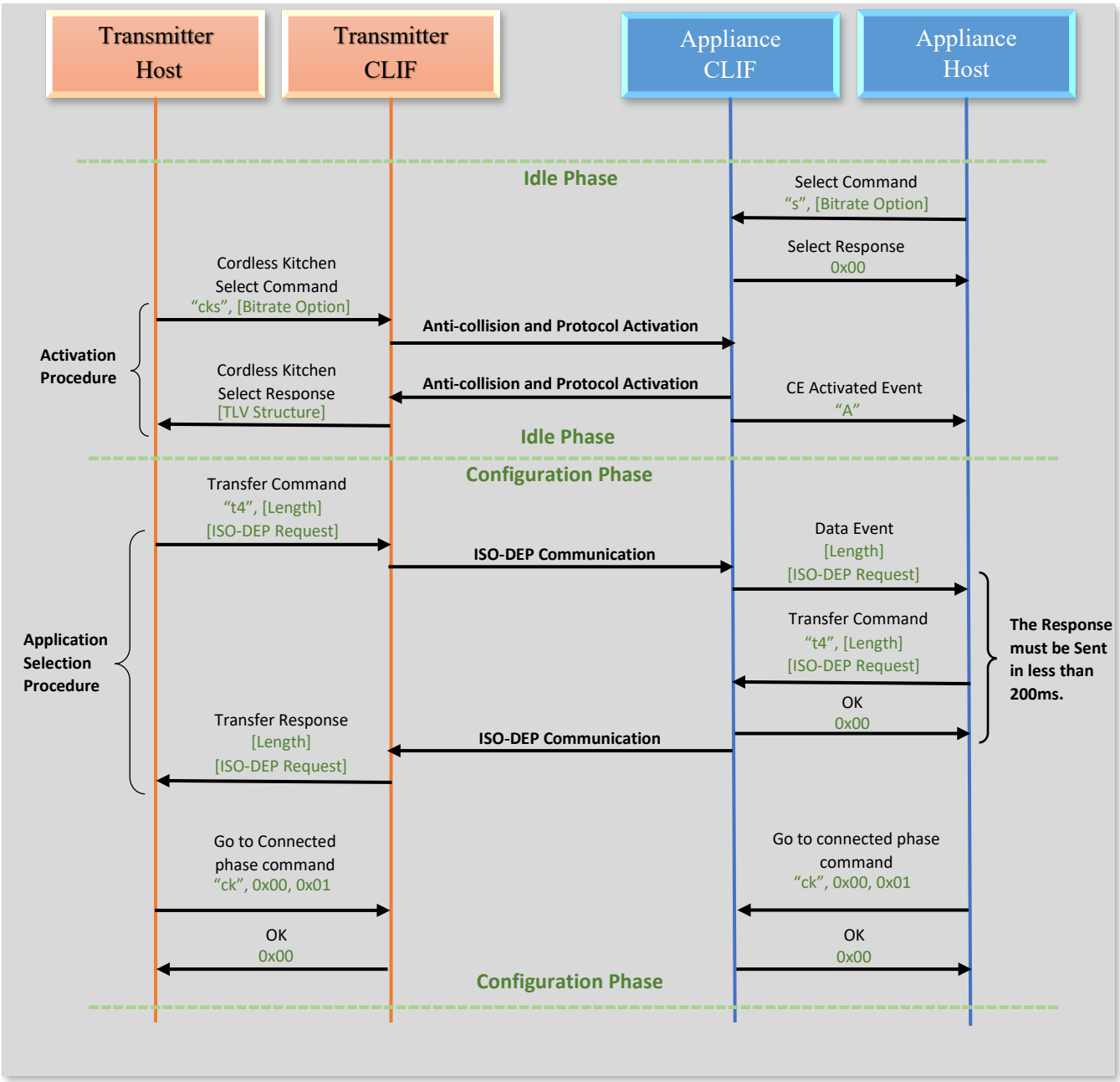
Prologue field	Information field			Epilogue field
PCB	Write command	Length	Payload	EDC
1 byte	1 byte	1 byte	n bytes	2 bytes

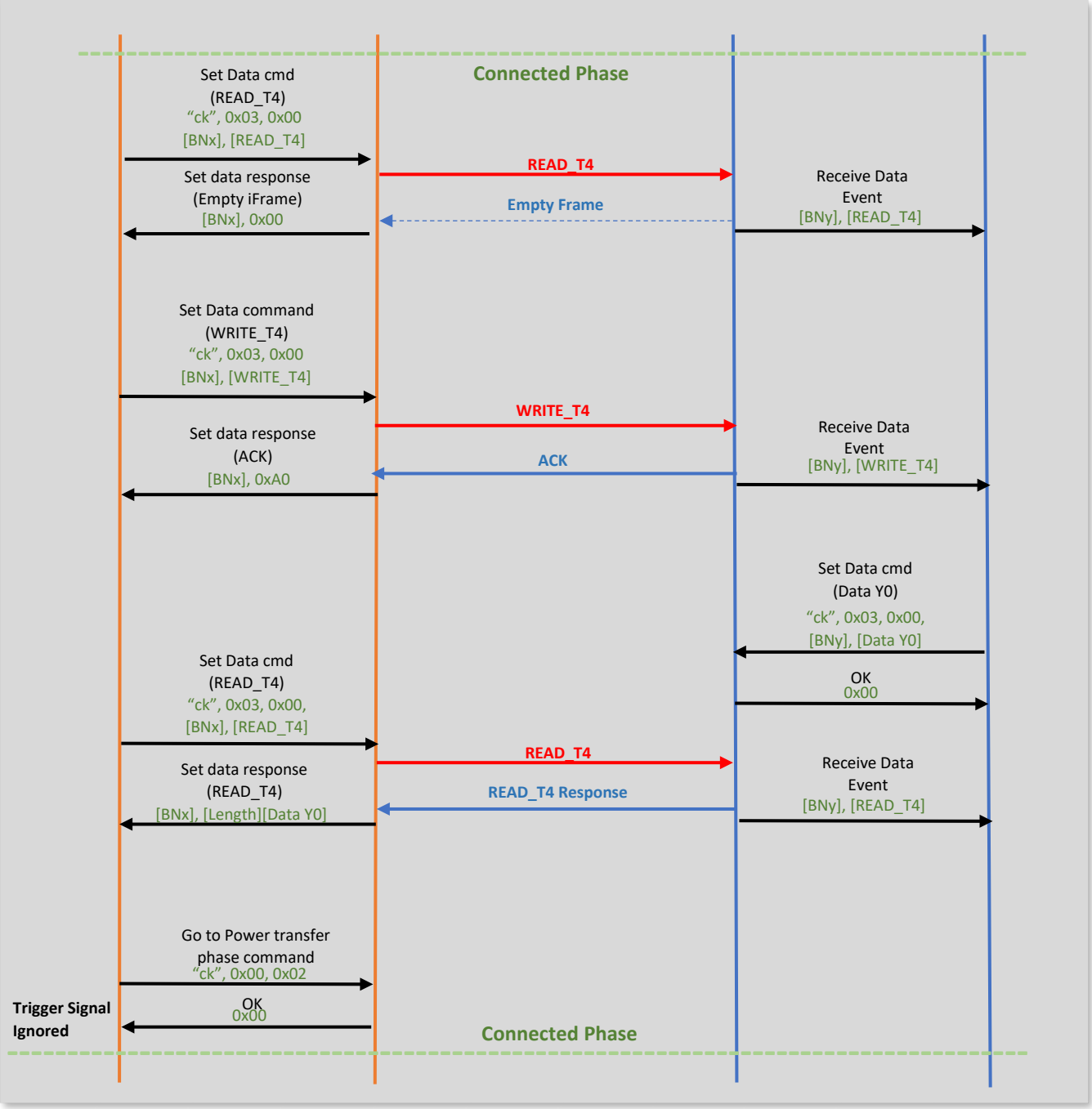
Prologue field	Information field	Epilogue field
PCB	ACK / NACK	EDC
1 byte	1 byte	2 bytes

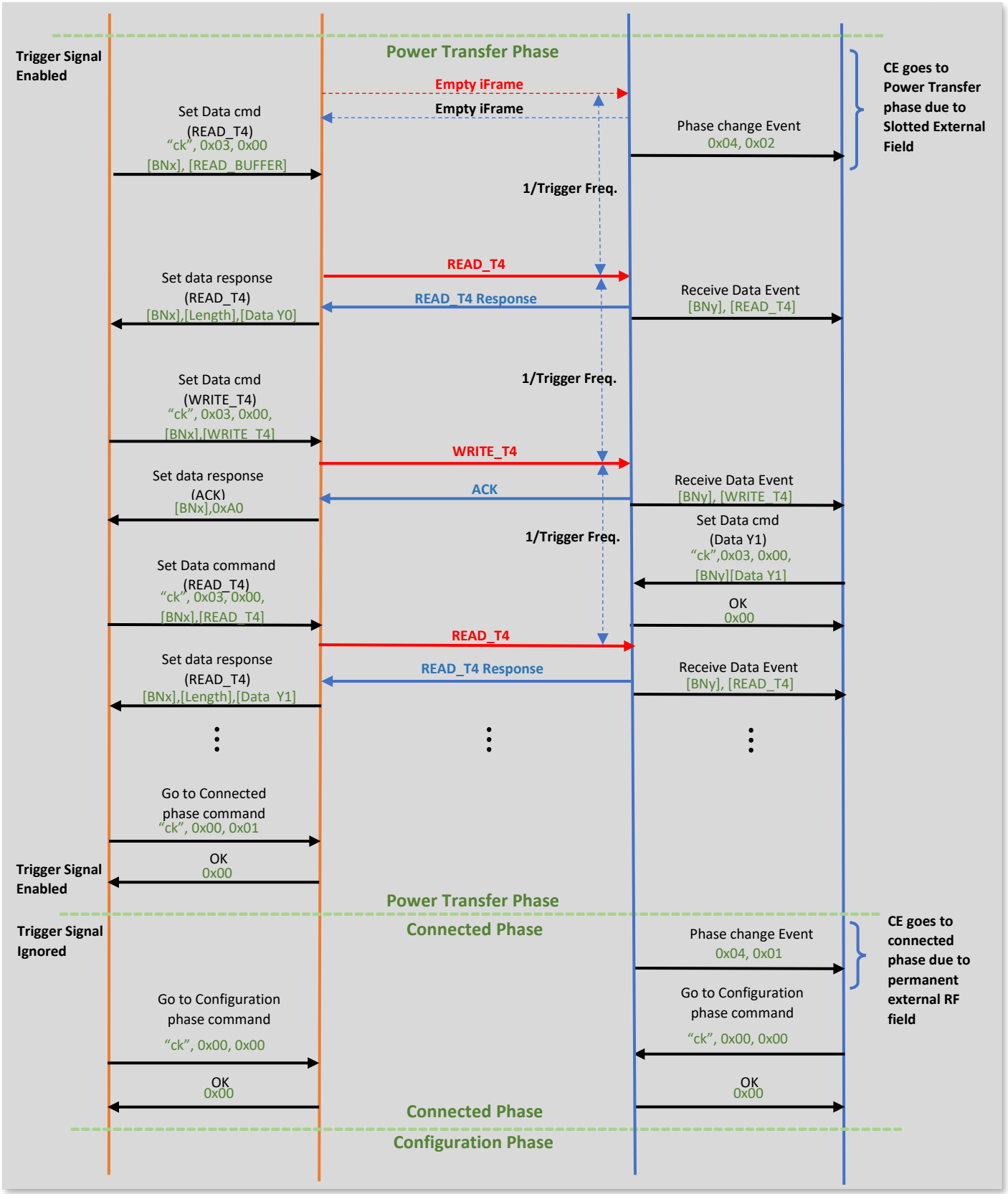
9.6.4 Communication Sequence

By using the commands described in previous chapter (READ_T4 and WRITE_T4), it is possible to communicate between Power Transmitter and Power Harvester. Only the Power Transmitter device is in charge of sending those commands, while the Power Harvester can just set new information in its memory buffer by using a "Set Data" command, described in section 9.1.3. Every time the Power Transmitter sends a message and it is correctly received by the Power Harvester, the Power Harvester host will be notified with an event.

In following diagram, an example of the communication process is shown:




Connected Phase
Set Data cmd
(READ_T4)
"ck", 0x03, 0x00
[BNx], [READ_T4]
READ_T4
Receive Data
Event
[BNy], [READ_T4]
Set data response
(Empty iFrame)
[BNx], 0x00
Empty Frame
Set Data command
(WRITE_T4)
"ck", 0x03, 0x00
[BNx], [WRITE_T4]
WRITE_T4
Receive Data
Event
[BNy], [WRITE_T4]
Set data response
(ACK)
[BNx], 0xA0
ACK
Set Data cmd
(Data Y0)
"ck", 0x03, 0x00,
[BNy], [Data Y0]
OK
0x00
Set Data cmd
(READ_T4)
"ck", 0x03, 0x00,
[BNx], [READ_T4]
READ_T4
Receive Data
Event
[BNy], [READ_T4]
Set data response
(READ_T4)
[BNx], [Length][Data Y0]
READ_T4 Response
Go to Power transfer
phase command
"ck", 0x00, 0x02
Trigger Signal
Ignored
OK
0x00
Connected Phase


Trigger Signal Enabled
Power Transfer Phase
Empty iFrame
Empty iFrame
Set Data cmd (READ_T4) "ck", 0x03, 0x00 [BNx], [READ_BUFFER]
Phase change Event 0x04, 0x02
CE goes to Power Transfer phase due to Slotted External Field
1/Trigger Freq.
READ_T4
Set data response (READ_T4) [BNx],[Length],[Data Y0]
READ_T4 Response
Receive Data Event [BNy], [READ_T4]
1/Trigger Freq.
Set Data cmd (WRITE_T4) "ck", 0x03, 0x00, [BNx],[WRITE_T4]
WRITE_T4
Set data response (ACK) [BNx],0xA0
ACK
Receive Data Event [BNy], [WRITE_T4]
1/Trigger Freq.
Set Data cmd (Data Y1) "ck",0x03, 0x00, [BNy][Data Y1]
Set Data command (READ_T4) "ck", 0x03, 0x00, [BNx],[READ_T4]
OK 0x00
READ_T4
Set data response (READ_T4) [BNx],[Length],[Data Y1]
READ_T4 Response
Receive Data Event [BNy], [READ_T4]
Go to Connected phase command "ck", 0x00, 0x01
OK 0x00
Trigger Signal Enabled
Power Transfer Phase
Trigger Signal Ignored
Connected Phase
Phase change Event 0x04, 0x01
CE goes to connected phase due to permanent external RF field
Go to Configuration phase command "ck", 0x00, 0x00
Go to Configuration phase command "ck", 0x00, 0x00
OK 0x00
OK 0x00
Connected Phase
Configuration Phase

In order to achieve the maximum bandwidth possible during Power Transfer Phase, there are some requirements to fulfil:

- The Power Transmitter host must have completely transmitted to the Power Transmitter device a READ_T4 or a WRITE_T4 command at least 2ms before the next time slot arrives.
- The Power Harvester host must have completely transmitted to the CE device the new data with a Set Data command at least 2ms before the next time slot arrives.
- Both devices shall use their highest over the air bitrate available (848 kbps). See chapter 9.1.3.
- Both hosts shall use UART baud rate of at least 460800 bauds. See chapter 9.2.13.

10Command Quick Reference

Command Code	Response	Description
0x3A	Data from EEPROM in device memory	READ_BUFFER
0xA6	ACK if data stored in memory, otherwise NACK.	WRITE_BUFFER
'ck'0x0000	0x00 if Phase change correctly, otherwise Error code	Go to Configuration phase
'ck'0x0001	0x00 if Phase change correctly, otherwise Error code 'E'	Go to Connected phase
'ck'0x0002	0x00 if Phase change correctly, otherwise Error code	Go to power transfer phase
'ck'0x02[Addr]	Returns value stored in Memory block	Read Data
'ck'0x03[Addr]	ACK Response after write command, if Error occurred gives NACK	Set data
'ck'0x04	Returns current phase of operation	Get Current Phase
'ck'0x09	0x00 when current load correctly set	Store Current RF Field load (RFU)
'ckm'	Returns Current RF field load	Get current field load (RFU)
'ck'0x09[Threshold]	0x00 when threshold correctly set	Set foreign Object detection threshold (RFU)
'cks'	Returns TLV structure of device when poll success.	Cordless kitchen select
'ckr'0x00[Addr]	Returns data stored in Register Address	Cordless kitchen register Read
'ckr'0x01[Addr][value]	Error code 'E' if write operation fails	Cordless kitchen register Write
'ckt'	0x00	Cordless Kitchen test
'x'	Reset the device, and return version string	Reader software Reset
's'[optional poll tech]	UID of device, if fails to found device return Error code	Select command for Reader/writer
's'[Optional supported protocol and bitrate]	0x00, if CE mode correctly set, otherwise returns Error code	Select command for Power Harvester
'ns'	Returns TLV structure	Extended Select
't'	Return length and data to be transferred	Transfer
't4'	Power Transmitter device - Return length and data to be transferred CE device - 0x00 When data is correctly set	Transfer layer 4
'v'	Returns version string	Get version
've'	Returns EEPROM version	Get EEPROM version (RFU)
'pon'	P - Electromagnetic Field Enabled	RF-Field On

‘poff’	P – Electromagnetic Field Disabled	RF-Field Off
‘pp’[I/O mask][Value]	Current Status of User port	Set user port (RFU)
‘pr’	Current status of User port	Read user port (RFU)
‘pw’[I/O mask][value]	Current status of User port	Write user port (RFU)
‘re’[station id]	EEPROM register value	Read EEPROM Register (RFU)
‘we’[EEPROM Addr] [Value]	EEPROM register value	Write EEPROM Register (RFU)
‘m’	UID’s of Multiple devices found	Multiple device select without payload (RFU)
‘m’[length+UID]	UID of the device	Multiple tag select with specific UID as payload (RFU)
‘nm’	TLV structure of Multiple the devices found	Extended Multitag select (RFU)
‘h’0x00	UID of the device with 106 kbits/s	High Speed Select
‘h’0x02	UID of the device with 212 kbits/s	High Speed Select
‘h’0x04	UID of the device with 424 kbits/s	High Speed Select
‘h’0x08	UID of the device with 848 kbits/s	High Speed Select
‘nh’[Optional protocol]	TLV structure of device	Extended High Speed Select
‘dd’	0x00, device correctly configured in Low power	Low power detect (RFU)
‘dx’	0x00, device correctly stops low power mode	Low power stop (RFU)

11 Glossary

Appliance: This is the actual kitchen appliance (oven, blender, coffee maker, etc) that is powered by the 2.2KW High Frequency/Low Power RF field.

This is also the Power Harvester host.

High Power / Low Frequency Amplifier
This is the main power source for the Appliance. This is capable transmitting up to 2.2KW of power between 20kHz and 50 kHz.

This is also the Power Transmitter host.

KI Cordless Kitchen Standard: See the *What is Ki cordless Kitchen* section of this manual.

NFC Near Field Communications.
This is the 13.56MHz communications and power transfer technology used by the Ki Cordless Kitchen.

The NFC Forum (https://nfc-forum.org/) is responsible for the high level communications in conjunction with several ISO standards (14443, 15693, 18000, 7816) [https://www.iso.org/home.html]

Power Harvester This the device, in the NuCurrent Slotted Power Development Kit that receives the 15.56MHz NFC communications from the Power Transmitter. The Appliance is usually the host for this device.

This is powered by both the 13.56MHz field and the High Power/Low Frequency field (not simultaneously).

Other terms for this are Receiver, Listener, Card Emulator.

Power Transmitter This is the device, in the NuCurrent Slotted Power Development Kit that drives the 13.56MHz field for low power delivery (1.25W) and communications.

Other terms for this are Transmitter, Poller, Reader/Writer.

12 Appendix A – TLV Structure

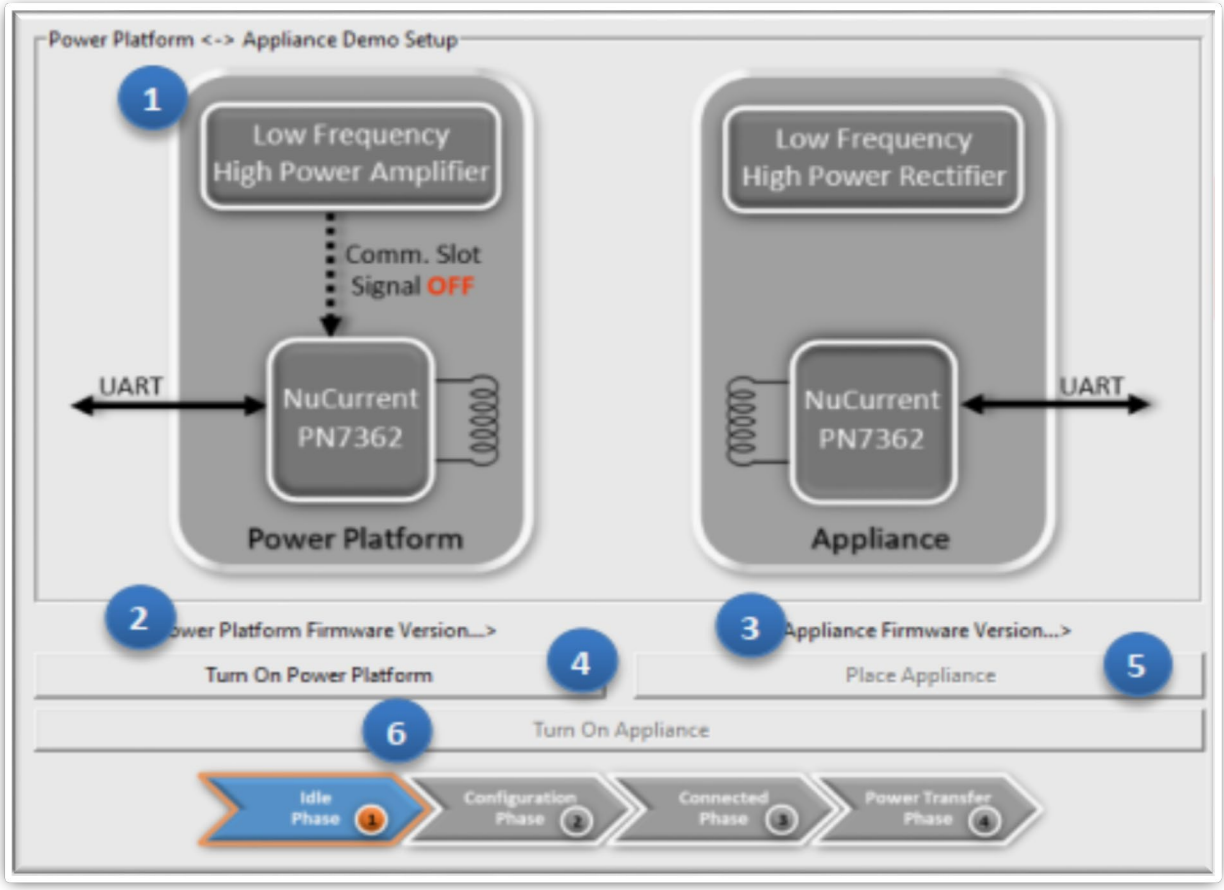
Type	Subtype	Name	Data size	Data
0xAC	0xAA	ATQA	2 bytes	ATQA
	0xAB	ATQB	12 bytes	ATQB
	0xC1	Cascade level	1 bytes	0x01 = CL1 0x02 = CL2 0x03 = CL3
	0xD1	Protocol	1 bytes	0x01 = ISO15963 0x02 = SR176 0x03 = Felica 0x0A = ISO type A 0x0B = ISO type B
	0xBA	SAK	1 bytes	SAK
	0x1D	UID	1+n bytes	UID length UID
	0xA5	ATS	1+n bytes	ATS length ATS
	0xD5	Baudrate of air interface	1Byte	Baudrates: 0x00 → 106kbaud 0x02 → 212kbaud 0x04

13 Appendix B – Demo Application

The following image is the snapshot of the NuCurrent Slotted Power Development demo application.

The demo application runs on a host PC platform and interacts with the NuCurrent Slotted Power Development Kit boards. The PC acts as the High Power/Low Frequency Amplifier and the Appliance.

The graphical images represent state of all operational modes.



Demo Setup GUI

1. Demo application GUI: Graphical interface to locate the changes on Power platform and Appliance during different modes of operation.

2. Power Platform Firmware Version: It will display the Power Platform current firmware version by communicating with the corresponding device when a user presses button element #4.

3. Appliance Firmware Version: It will display the Appliance Firmware Version by communicating with the corresponding device when a user presses button element #5.

4. Turn On/Off Power Platform: This button turns on/off the Power Platform device by sending the corresponding command to the device over UART. After a successful turn ON, power platform device will start scanning surrounding appliances.

5. Place/Remove Appliance: This button allows to place/remove the appliance by sending corresponding command to the device over UART. After a successful place operation, appliance will create connection with power platform devices and become ready for data transfer.

6. Turn On/Off Appliance: This button mimics the functionality of power transfer with the Low Frequency High Power subsystem and simultaneously performing data transfer between devices in slotted power mode.