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• COMMANDS USER MANUAL XTR-ZB1 AUREL MODULE

o General considerations

Coordinator, routers and End Devices has three different firmware and each devices has jointed to an univocal 64 bit MAC address, programmed by AUREL and not alterable. Radio transmission always occur at 0 dBm for version XTR-ZB1-xLI (Low Power) and at 13dBm for version XTR-ZB1-xHI (High Power)..
Modules interfacing happening through UART with the following settings: baud mrate 38400bps, Hardware flow control RTS/CTS enabled, 8 data bits , 1 stop bits.

The standard procedure to give commands to the system via serial line is the following:
command:parameter_1:....: parameter_n;

- All the inserted commands and parameters shall be ASCII character
  Example: **CMD:0e:0001;** correspond to the following bytes forwarded via serial line **<0x43> <0x4D> <0x44> <0x3A> <0x30> <0x45> <0x3A> <0x30> <0x30> <0x30> <0x31> <0x3B>**

- Between both parameter is necessary put “**:**” (colon)

- As per last character (termination) is necessary put “**;**” (semicolon)

Unlike others commands , SNT command(SeNd To) allow to send any types of data and not only ASCII character.
In consequence of a command execution, the system replies giving back a value that suggests the correct execution, or in case of error, showing the error code (see the termination codes Tab.) At the end of any data string, will put a “**;**” (semicolon) as per string termination

Example:

CMD:17; Battery reading
Gives back correct/incorrect execution code followed by “;” (semicolon).
In case of correct execution, the sampled value followed by “;” (semicolon) is memorized into the output buffer ready to be sended via serial line or radio transmission.

CMD:15:0c:03:00; ADC line sampling
Gives back correct/incorrect execution code followed by “;” (semicolon).
In case of correct execution, the sampled value followed by “;” (semicolon) is memorized into the output buffer ready to be sended via serial line or radio transmission.

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It is not possible to assure the max. execution time, because it is due to many factors as dimension, network topology and CPU status of the chip. It is not useful indicate the commands execution time that use the radio channel, because the acces methodologyto the channel, defined by the ZigBee standard is aleatory, strongly influenced by the numbers of net nodes, network topology, and environment factors .

At the ignition of the device is sent to serial line the *termination code* --> 0x46 (system on). Is necessary waiting the device joining further described

o Termination code Tab.

Name	Value	Meaning
no_error	0x30	No error
cmd_error	0x31	Command error
prm_error	0x32	Parameters error
num_prm_error	0x33	Error in parameters number
no_resp	0x34	No response after 3 attempts (see note 1)
lost_ping	0x35	No response at ping command (see note 1)
lost_MAC	0x36	No response at MAC address request (see note 1)
lost_startTx	0x37	No response at TX start command (see note 1)
ack_received	0x38	Acknowledge Received
startCyclicTx	0x39	Tx start cyclic command sent
system_busy	0x40	The system was unable to move to the level below, the requested operation
mem_overflow	0x41	Buffer overflow
paninfo_error	0x42	Device is not part of the network

no_resp_cyclic	0x43	Acknowledge not Received after the cyclical transmission (see note 1)
msg_too_long	0x44	Message limit exceeded
cmd_too_long	0x45	Command limit exceeded
system_on	0x46	Deviced initialized
no_brdt_allowed	0x47	Broadcast not allowed
data_error	0x48	Error in data cyclical transmission
lost_set_reset	0x49	No response to the set/reset pin command (see note 1)
lost_short	0x50	No response to the short address request (see note 1)
lost_update_nwk	0x51	No response to the network update
no_more_devices	0x52	Devices adding is not allowed
device_already_inserted	0x53	Device already inserted
no_dev_added	0x54	No devices added

NOTE 1: Every times a radio message is sent so that the transmitter is waiting for a response, in the absence of it, will be performed three attempts at a distance of about 800ms one another.
If following to the three attempts, no reponse was received, will be sent via serial line of the transmitter a code of non-receipt notification. Such notification is different according to the sent command (see the termination code Tab.). In case of the radio packet receiver is a router, the reason of no response could be attributed to a problem upon the remote device (for ex. Switched off) or a lack of radio visibility between transmitter and receiver.
In case the receiver is an End Device, the reason of no response could be attributed, besides the same causes explained for router, also to the possibility that it is in power down
The goal of End Device is to keep low the consumption, and it is in power down mode most of the time, and it wake up cyclically after every interval called Poll Rate (better described further).
When the End Device is in power down mode, radio communication is over, and it can’t receive data packets. At wake up time, every Poll Rate, it call is associated router asking for messages addressed to it. In case messages are present, router provides to forward it to the End device.
If the forwarded messages needs a response, following to that, End Device provides to sent one back to the transmitter.
To obtain a response from an End Device, it is necessary waiting the Poll Rate time.
Therefore if a message will send to an End Device could happen that transmitter has to do the three attempts, and its non-receipt notification, that it’s received at the End Device wake up time .

o MsgType commands Tab.

Name	Value
Generic radio Msg	0x02
Ping Msg	0x04
Ask Extended Add Msg	0x06
Send Cycle	0x08
Get Software Version	0x09
Alarm	0x20
Set/Reset pin	0x21
Getbattery	0x01
GetTemp	0x03
Get Short Address	0x05
Get Extended Address	0x07
Pan Info	0x11
Get ADC Value	0x13
Ask Nwk Address	0x15
Set Keep Alive ack	0x17
Set Poll Rate	0x19
Show key	0x0A

o *Devices types Tab.*

Device	Code
Coordinatore	0x09
Router	0x07
End Device	0x06
Rejoin End Device	0x04

COMMANDS TYPES

o Commands summary Tab.

In the tab. below are summaries all the commands.
Some of the following commands are reserved to the coordinator only, some are impartible via serial line even to the Routers and End Devices.
SNT command is the only one that it can be used to the End Devices (besides Reset command)
Before sending this command to the End Device, it is necessary start up the device, since it is practically still in Power Down, bringing low the PWD

Sintax	Command	Coord	Router	End Dev
CMD:01;	Reset	√	√	√
CMD:02:1234;	Set PanId	√	√	
CMD:03:00:12:4B:00:00:01:02:03;	Add Item	√		
CMD:04;	Start Net	√		
CMD:05:0001:0010;	New Rate	√		
CMD:06:0001;	Start Tx	√		
CMD:07:0B;	Set Channel	√		
CMD:08:0001:00;	Set Keep Alive	√		
CMD:09:796F:FFFF;	Set Poll Rate	√		
CMD:0A:FF;	Lock Net	√		
CMD:0B:0001:1;	Set Pin	√	√	
CMD:0C:0001:1;	Reset Pin	√	√	
CMD:0D;	Pan Info	√	√	
CMD:0E:0001;	Ping	√	√	
CMD:0F:0001;	Ask Extended Address	√	√	
CMD:10;	Get Short Address	√	√	
CMD:11;	Get Extended Address	√	√	
CMD:12;	Send Over UART		√	
CMD:13;	Get Software Version	√	√	

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CMD:14;	Show Key	√		
CMD:15:0C:03:00;	Get Adc Value		√	
CMD:16;	Get Temperature Value		√	
CMD:17;	Get Battery Value		√	
CMD:18:0001;	Send Battery Value		√	
CMD:19:0001;	Send Temp Value		√	
CMD:1A;	Start Tx		√	
CMD:1B;	Stop Tx		√	
ASA:00:12:4B:00:00:01:02:03;	Ask Short Address	√	√	
SNT:0001:5:34RST;	Send To	√	√	√

o Device Joining

At the First ignition of the device coordinator perform a scanning complete on each available channels (from 11 to 26) and create a network upon the most noise-free channel. This network will characterized by a 14 bit identifier (PAN ID) alike to 14 LSB of coordinator MAC address, and alterable by proper command. At the network creation, coordinator choose, through an algorithm of randomly number generator, 128 bit key of data encryption. From that moment the coordinator is waiting to be connected to the AUREL devices. To others ZigBee devices doesn't made by AUREL, is not allowed joining the network .

When a remote device (Router or End Device) will be started for the first time, it will perfom a scanning upon all channels, without any constraint, a network whose join in.

When a remote device (Router or End Device) had been joined, a Short address (16 bit) will be awarded to it, and this is the way the network packets are addressed with (coordinator is always address with 0x0000).
The Short address will be the same for Routers, unless a device reset will performed (see section "Interrupts Management").
The End Device change its Short address according to the joined Router (called "Father"). So If the End device leaves the radio field range of its "Father", and join another Router, the Short address surely change.
At the same time if its Father will be turned off, and the End Device will found another router to join in, a new Short address will awarded to it.
NOTE: 0xFFFF is the inner network broadcast address. A packet sended with that address, will be received from all the Routers joined to the network but not from the End Devices.

Some of the commands gives to the users the chance to use a broadcast address, some of them no. It's strongly advised, specially for the most important network commands, to don't use broadcast address, performing a polling towards all the devices. In this way each device certainly sent or not a response.
When a device (Router or End Device) is joined to the network (at the same way when an End Device change its Father) , coordinator will send a message through serial line as follow described:

Command output on coordinator
MsgType --> 1 byte ● 0xCC --> Nwk update 16bits address of node --> 2 byte 64bits address of node --> 8 byte Addressed device type –> 1 byte (see the device types Tab.) semicolon --> 1 byte

In case of joining problems, due to the absence of radio field for example, no one notification is sent to the coordinator serial line.
The absence of any joining is underlined by the remote node through the OUT R line. After the starting of a device, (router or End Device) such line will remain Up till a device joining.
After a network creation at least composed by one joined device, coordinator, after a switch off-turn on, keep all the data related to the network itself, and don't create a new network with the scan process above described, but it setting itself on the same channel as before, with same PAN ID and the same key, keeping the information received by all the associated devices.
After the network joining, after to been switched off-turned on, a remote device (Router or End Device) keeps memorized all the data related to the network whom was associated before.
What happen at restarting time? Router consider itself as part of network recently belongings and it doesn't made any new joining, so keeping the same Short address, while the End Device will made a request to the Router Father to whom associates before the switching off.
If The Router gives back a response to the End Device, latter keep the Short address previously obtained (this will notified by CC string anyway). If Router doesn't gave any response, the End Device'll perform a subsequent attempt, and if also that did not give the correct result, it try to join to another Router, so it will have a different Short address.

Communication via serial of system_on (0x46). will remain on remote node, as the first starting.

NOTE:
As described before, the coordinator accepts a joining by the AUREL made devices only, besides it's possibile decide if let joining or not an AUREL device, performing a further setting upon the MAC.

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If the net is unlocked (to more details see CMD:0A) any AUREL device is accepted.
In case the net will be locked the only accepted devices are them who have Acceptable MAC's, that must be forwarded to the coordinator through command CMD:03 (see the command details)
Two way of network starting are available:

- Starting with the network unlocked (this is the default parameter after a reset)
- Starting with the network locked, fitting the authorized devices' MAC

Every time that the coordinator is shouted down and switched on, it is necessary perform one of the starting procedures described above.

• Coordinator reserved commands

o *Net Functions*

This section lists and describes all functions needed to characterize and manage the Net.

- **CMD:09:addr:rate;**

Description: Sets the new Poll Rate of the addressed End Device
Poll Rate is the time whom the End device spend to wake up and verify the Router presence, and if there are packets for it (usually the End Device is in Power Down)
Every wake up time from the Power Down status, the End Device will send a request to its Father.
If Router has stored messages for it, immediately will be transferred, otherwise the End Device went back immediately in Power Down status.
If the ED doesn't found any messages from its Father, it will try the next awakening till performing 2 attempts. If no messages are present to it once again, it feel “orphan” of its Father, it will search for a new father to whom join (see command CMD:08)
Poll rate time has a range from 100ms to 65535ms. It default value is setted to 60 seconds.

NOTE: Router called “Father” keep stored only one message to each ED and each poll rate. Within every Poll Rate, The ED can receive only one message from its Father.

Parameters	***Parameter Types***	***Command Outputs***
Addr: 16bits short address of ED node that will receive the command . *Rate:* New poll rate value.	*Addr* -->--> 4 bytes, in ASCII characters, for hexadecimal address of destination node. *rate* -> 4 bytes, in ASCII characters, for hexadecimal value of poll rate *ms* to be set.	*termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> error in Parameters ● 0x33 --> error in Parameters number ● 0x47 --> broadcast not available *semicolon* --> 1 byte

Example:

CMD:09:796f:2710;

Sets to 10 seconds (10000 ms) the ED Poll Rate, that has the short address 796f.
If addressed device properly receives the command, this will deliver to source node a confirmation of it. Source node will output on serial line:

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Command Outputs on local node
MsgType --> 1 byte ● *0x19 --> set poll rate* *Type of addressed node --> 1 byte* *16bits address of remote node -->* 2 byte *semicolon --> 1 byte*

- **CMD:08:addr:status;**

Description: set up/close down the “keep alive” function of the addressed device.
When “keep alive” function is active, Router will submit a packet (clear to the user) every 20 seconds towards the coordinator, waiting for a response. Unless it will receive 6 (six) consecutive response from the Coordinator, Router will execute an Half Reset (see “Interrupts Management” section) and it will try to connect a new network having the same PANID, while performing a complete scan on all channels.

If the keep alive on the Router is not active, it does not running any radio activity, unless it will be forced through application level, and it can’t feel the presence of coordinator

Starting up the keep alive function on the ED, after 2 (two) poll rate cycles (see sommand CMD:09) without find its Father, It runs an Half Reset searching for a new join into the same network through performing a complete scan on all channels.

If the keep alive on the EDr is not active, after 2 (two) poll rate cycles (see sommand CMD:09) without find its Father, It tries to search a new Router that can support it.

To sum up it’s essential bring the keep alive active in every single devices to obtain an automatic channel exchange.
If it does not active, and a reset or channel exchange will run on the coordinator, in order to have a new device joining to the new network created by the coordinator, will be necessary perform a local Half Reset on the remote node.

Parameters	*Parameter Types*	*Command Outputs*
Addr: 16bits short address of node that will receive the command . *On/Off:* required status *0x00* --> not active keep alive *0xFF* -->active keep alive	*Addr* -->4 bytes, in ASCII characters, for hexadecimal address of destination node. *On/Off* --> 1byte	*termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> error in Parameters ● 0x33 --> error in Parameters number *semicolon* --> 1 byte ● 0x34 --> no response ● 0x40 --> system busy *semicolon* --> 1 byte

Example:

CDM:08:0001:00;
Deactivates the keep alive function on the device having the short address 0x0001.

In case of correct data reception, remote device send to the source node a confirmation, whose wrote to the serial line:

Command Outputs on local node
MsgType --> 1 byte ● *0x17 --> set keep alive ack* *16bits address of remote node* --> 2 byte *semicolon --> 1 byte*

- **CMD:05:addr:rate;**

Description: Sets a new network concerned the cyclical data transmission from ED or Router to Coordinator. (see command CMD:06).
Every time a cyclical data transmission is required, it is necessary to set the transmission rate through this command, and then, start the transmission with the command CMD:06
In order to stop it, it is necessary to set the transmission rate to Zero (CMD:05:addr:0000)
Maximum setting value is 60 minutes (3C00)
It default value is setted to 10 seconds.

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Parameters	*Parameter Types*	*Command Outputs*
Addr: 16bits address of node that will receive the command Rate--> Cyclical activity rate in minutes (2 bytes) and seconds (2 bytes)	*Addr* --> 4 bytes, in ASCII characters, for hexadecimal address of destination node *Minutes (hexadecimal)* -> 2 bytes *Seconds (hexadecimal) -> 2 bytes*	*termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> error in Parameters ● 0x33 --> error in Parameters number ● 0x47 --> broadcast not available *semicolon* --> 1 byte

Example:

CMD:05:0001:0A1E;

It sets the cyclical transmission rate to 10 minutes (0A) and 30 seconds (1E).

- **CMD:03:MAC addr;**

Description:

Inserts the Mac address of the authorized device to be connected to the network
When the network is locked (se the command CMD:0A) the coordinatore will accept the association of the devices authorized with MAC address.
This authorization occur through the sending of a series of commands to the coordinator, containing acceptable MAC as parameter for the network.
<u>The maximum value of associable devices are 200</u>

Parameters	*Parameter Types*	*Command Outputs*
MAC addr: MAC address (64 bits) of node that has been authorized to be part of network .	*MAC addr* -->16 bytes, in ASCII characters, for hexadecimal address of destination node	*termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> error in Parameters ● 0x33 --> error in Parameters number ● 0x52 --> no more devices ● 0x53 --> device already present *semicolon* --> 1 byte

NOTE: Parameter must be sended as 8 values of 2 bytes divided by colon (“:”) as the follow example explain:
CMD:03:00:12:4B:00:56:ED:12:09;
Authorized MAC list that can be part of network , shall be sended to the coordinator after every ignition and after every reset performed (also for the channel tuning).
Then it’s necessary start up the network with the command CMD:04

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- **CMD:07:channel;**

Description: Sets the new channel where will found the network.
After starts this command, coordinator perform a full reset (see section Interrupts Management)and will create a new network in the founded channel.
If the parameter "channel" is set up on 1B, a complete scan on all the channels will be run, and the new network will create upon the most noise-free channel.
Further this command, a reset on all the remote devices must be run, option that can be automatic if the keep alive it has been set on.

Parameters	***Parameter Types***	***Command Outputs***
Channel: new channel where will found the network.	*Channel* -> 2 bytes, in ASCII characters, for hexadecimal channel address. *Available channels are:* from 11 (0x0B) to 26 (0x1A). Punching 1B (0x27) the scan has been set.	*termination code* --> 1 byte ● 0x32 --> error in Parameters ● 0x33 --> error in Parameters number *punto e virgola* --> 1 byte

Example::

CMD:07:0C;

Runs a full reset on the coordinator that create the new network (the same PAN ID of before) on the channel 12 (0x0C)

- **CMD:04;**

Description: Network start-up.
When coordinator it's powered or reset, after the possibile network creation, radio side will close down. In order to set up it is necessari to send this command after at least a command CMD:03 quite the contrary command will not accept (error 0x54).

Parameters	***Parameter Types***	***Command Outputs***
No imput parameters requested		*Termination code* --> 1 byte ● 0x30 --> no_error ● 0x33 --> error in Parameters number ● 0x54 --> No devices added CMD:03. *Semicolon* --> 1 byte

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- **CMD:0A:status;**

Description: enables/disabile the coordinator's reception of any AUREL devices to joining the net.

Parameters	***Parameter Types***	***Command Outputs***
Status : Status to be set *00* --> no devices can be joined to the net (except them with authorized MAC, CMD:03) *FF --> Any AUREL devices can be added to the net*	*Status--> 1byte*	*Termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> error in Parameters ● 0x33 --> error in Parameters number ● 0x40 --> system busy *semicolon* --> 1 byte

Example:
CMD:0A:FF;
Gives to the coordinator chances to accept joining from any AUREL devices.

- **CMD:14;**

Descrizione: Gives back 128 bit encryption key installed on the device.
Network uses a 128 bit encryption key for data encoding. This key is choosen with an algorithm that produces numbers randomly from the coordinator, communicated to the remote devices at the joining time. This key will changed by the coordinator every reset, whereas will kept in case of shout down.

Parameters	***Parameter Types***	***Command Outputs***
No imput parameters requested		*Termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> error in Parameters ● 0x33 --> error in Parameters number Semicolon -- > 1 byte *MsgType --> 1 byte* ● *0x0A--> Show key* *128 bit encryption key* --> 16 bytes that meaning the 128 bit encryption key *semicolon* --> 1 byte

o *Radio Section*

- **CMD:06:addr;**

Description: starts the cyclical data transmission of sampled data from the device with short address specified towards the coordinator .

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Parameters	***Parameter Types***	***Command Outputs***
Addr: 16bits address of node that will receive the command	*addr* --> 4 bytes, in ASCII characters, for hexadecimal address of destination node	*Termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> error in Parameters ● 0x33 --> error in Parameters number ● 0x40 --> system busy ● 0x47 --> broadcast not available ● 0x37 --> No response at TX start command *semicolon* --> 1 byte

Example:

CMD:06:0001;

starts the cyclical data transmission to the device with short address 0x0001.

The addressed device will output on serial line:

Remote command Output
Termination code --> 1 byte ● 0x39 --> StartCyclicTx (cyclical start reception) *semicolon* --> 1 byte

Owing to the performed command will be activated the clyclical transmission from the addressed device. On detail, the following data will forwarded to the coordinator:

Command Outputs to the coordinator	
For good data reception: *MsgType --> 1 byte* ● *0x08 --> send cycle* *Source address--> 2 bytes* *Battery value in millivolts --> 2 bytes* *Temp. Value* (to be converted using Formula Nr. 1) --> *2 bytes* *ADC1,res Value=max,ref=1,25 --> 2 bytes* *ADC2,res Value =max,ref=1,25 --> 2 bytes* *ADC3,res Values=max,ref=1,25 --> 2 bytes* *ADC4,res Value=max,ref=1,25 --> 2 bytes* *Digital I/O status --> 1 byte* *semicolon --> 1 byte*	*For incorrect data reception* put on queuing: *termination code* --> 1 byte ● *0x48 --> data error* *semicolon --> 1 byte*

NOTE: Less significant 5 bits meaning the outputs status (OUT R., OUT 1, OUT 2, OUT 3 e OUT 4), and the others 3 bits meaning the imputs status (IN 1, IN 2, IN 3)

Formula 1:

```
CONST = 0.61065
OFFSET = 779.75
TEMP_COEFF 2.43

Temperatur = ((outputVoltage x CONST) – OFFSET) / TEMP_COEFF
```

Where OutputVoltage is the ADC value

In case of correct data reception, coordinator send to the device the rate value that should mantained for the transmission (default =10 sec).

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• Coordinator/Router reserved Commands

o *Net Functions*

This section lists and describes all functions needed to characterize and manage the Net.

• CMD:02:PanId;

Description: Sets Net PAN ID.
A Coordinator unit, at reception of this command, will execute a Reset and will create a new Net with PAN ID as specified in the instruction, while performing a complete scan on all channels.
A Router unit, at reception of this command, will execute an Half Reset (see section “Interrupt Management”), then will try to associate to a Net identified from provided PAN ID, while performing a complete scan on all channels.
PAN ID default value on coordinator is equal to Less Significant 14 bits of its MAC.
PAN ID default value on router is 0xFFFF (broadcast), therefore router will try to associate to any Net, not taking PAN ID into consideration.

Parameters	***Parameter Types***	***Command Outputs***
PanId: PAN ID number to set	*PanId* -> 4 bytes, in ASCII characters, equal to hexadecimal value of PAN ID to be set. NOTE. 0xFFFF is taken as default value.	*termination code* --> 1 byte ● 0x32 --> parameter error ● 0x33 --> error in number of parameters *semicolon* --> 1 byte

Example:

CMD:02:0513;

Will set PAN ID to value 0x0513.

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- **CMD:0D;**

Description: gives back information on Net associated to node:
- Physical channel used from associated Net (possible channels 11 to 26)
- associated Net identifier (PAN ID).

Parameters	***Parameter Types***	***Command Outputs***
No parameter requested		*termination code* --> 1 byte ● 0x30 --> no error ● 0x33 --> error in number of parameters ● 0x42 --> node is not associated to Net *semicolon* --> 1 byte *MsgType* --> 1 byte ● 0x11 --> Pan info *Net working channel* --> 1 byte *Net Identifier (PAN ID)* --> 2 bytes *semicolon* --> 1 byte

- **CMD:0E:addr;**

Description: sends Ping request to node specified, as short address, as parameter.

Parameters	***Parameter Types***	***Command Outputs***
Addr --> 16bits address of node that will receive the command. *ffff* --> broadcast address	*Addr* --> 4 bytes, in ASCII characters, for hexadecimal address of destination node.	*Termination code* --> 1 byte ● 0x30 --> no error ● 0x32 --> error in Parameters ● 0x33 --> error in Parameters number ● 0x35 --> lost ping ● 0x40 --> system busy *semicolon* --> 1 byte

Example:

CMD:0e:0001;

Sends PING request to router addressed in short 0x0001.

If addressed device properly receives the command, this will deliver to source node a confirmation of it. Source node will output on serial line:

Local node Command Outputs
MsgType --> 1 byte ● 0x04 --> ping msg *LQI* --> 1 byte *Remote node 16bits address* --> 2 bytes *Addressed device type* –> 1 byte *semicolon* --> 1 byte

LQI: Link Quality Indicator. Values from 100 to 200 are considered indication of good radio link.

- **CMD:0F:addr;**

Description: sends to a Net node the request of MAC address identification, via short adress.

Parameters	*Parameter Types*	*Command Outputs*
Addr --> 16bits address of node that will receive the command. All 16bits Parameters are valid *ffff* --> broadcast address	*Addr* --> 4 bytes, in ASCII characters, for hexadecimal address of destination node.	*Termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> Parameters error ● 0x33 --> error in Parameters number ● 0x36 --> lost IEEE ● 0x40 --> system busy *semicolon* --> 1 byte

Example:

CMD:0F:0001;

requests MAC Address to router with short address 0x0001.

If addressed device properly receives the command, this will deliver to source node a confirmation of it. Source node will output on serial line:

Command Outputs on local node
MsgType --> 1 byte ● 0x06 --> Ask extended address msg *64bits IEEE of remote node* --> 8 bytes *16bits address of remote node* --> 2 bytes *Type of addressed node* –> 1 byte *Semicolon* --> 1 byte

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- **ASA:MACaddr;**

Description: sends request of short address identification, via MAC address.
Considering that all packets, in the net, are addressed via short address, this command can be really usefull.
If MAC address of a device is known, to deliver a packet to it, it is also necessary to receive information of short address that is assigned from the net to it.
A router short address, once assigned at association time, will not undergo any change.
End device, on the other hand, changes its short address when it changes the associated “father” . This can easily happen when nodes are in relative movement.

NOTE: If End Device is not in active state (i.e. in power down), No answer will be given to instruction.

Parameters	***Parameter Types***	***Command Outputs***
MACaddr --> 16bits address of node that will receive the command.	*MACaddr* --> 16 bytes, in ASCII characters, for hexadecimal address of destination node. (8 2bytes Parameters divided with “:” characters)	*Termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> Parameters error ● 0x33 --> error in Parameters number ● 0x50 --> lost short ● 0x40 --> system busy *semicolon* --> 1 byte

Example:

ASA:00:14:5C:8F:4E:67:29:F5;

Requests to remote node, addressed with MAC address 0x00145C8F4E6729F5, the assigned short address.
If addressed device properly receives the command, this will deliver to source node a confirmation of it, giving out on serial line:

Command Outputs on local node
MsgType --> 1 byte ● 0x15 --> Ask short address msg *16bits address of remote node* --> 2 bytes *Type of addressed node* –> 1 byte *semicolon* --> 1 byte

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- **CMD:10;**

Description: supplies back local node short address.

Parameters	***Parameter Types***	***Command Outputs***
No parameter requested		*Termination code* --> 1 byte ● 0x30 --> no_error ● 0x33 --> error in Parameters number *semicolon* --> 1 byte *MsgType* --> 1 byte ● 0x05--> get short address *16bits address* --> 2 byte *semicolon* --> 1 byte

- **CMD:11;**

Description: supplies back local node MAC address.

Parameters	***Parameter Types***	***Command Outputs***
No parameter requested		*Termination code* --> 1 byte ● 0x30 --> no_error ● 0x33 --> error in Parameters number *semicolon* --> 1 byte *MsgType* --> 1 byte ● 0x07--> get extended address *64bits address* --> 8 byte *semicolon* --> 1 byte

o *Serial Comunication / Interfacing*

• CMD:0B:addr:#out;

Description: set OUT '#out' digital output of device at short address "addr" to One.

Parameters	***Parameter Types***	***Command Outputs***
Addr --> 16bits address of node that will receive the command. *#out* --> output to be set. Valid values: 1 to 4	*Addr* --> 4 bytes, in ASCII characters, for hexadecimal address of destination node. *#out* --> 1 byte, in ASCII characters, with number of output line to be set.	*Termination codee* --> 1 byte ● 0x30 --> no_error ● 0x32 --> Parameters error ● 0x33 --> error in Parameters number ● 0x40 --> system busy ● 0x49 --> lost set reset *semicolon* --> 1 byte

Example:

CMD:0B:0001:1;

Sets to value One the OUT 1 port of device short address 0x0001.

If addressed device properly receives the command, this will deliver to source node a confirmation of it. Source node will output on serial line:

Command Outputs on local node
MsgType --> 1 byte ● 0x21 --> set//reset pin *16bits address of remote node* --> 2 bytes *semicolon* --> 1 byte

• CMD:0C:addr:#out;

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Description: sets OUT '#out' digital output of device with short address "addr" to Zero.

Parameters	***Parameter Types***	***Command Outputs***
Addr --> 16bits address of node that will receive the command. *#out* --> output to be set. Valid values: 1 to 4	*Addr* --> 4 bytes, in ASCII characters, for hexadecimal address of destination node. *#out* --> 1 byte, in ASCII characters, with number of output line to be set.	*Termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> Parameters error ● 0x33 --> error in Parameters number ● 0x40 --> system busy ● 0x49 --> lost set reset *semicolon* --> 1 byte

Example:

CMD:0C:143E:2;

Sets to value Zero OUT 2 port of device short address 0x143E.

If addressed device properly receives the command, this will deliver to source node a confirmation of it. Source node will output on serial line:

Command Outputs on local node
MsgType --> 1 byte ● 0x21 --> set/reset pin *16bits address of remote node* --> 2 byte *semicolon* --> 1 byte

- **CMD:13;**

Description: gives back the device installed software version.

Parameters	*Parameter Types*	*Command Outputs*
No parameters requested		*Termination codee* --> 1 byte ● 0x30 --> no_error ● 0x32 --> Parameters error ● 0x33 --> error in Parameters number *semicolon* --> 1 byte *sw version* --> 3 byte *semicolon* --> 1 byte

Router reserved Commands

o Radio Section

- **CMD:18:addr;**

Description: delivers to specified address, via radio, the battery voltage value. This command should be preceded from CMD:17, as this last one reads the status of battery.

Parameters	***Parameter Types***	***Command Outputs***
Addr --> 16bits address of node that will receive the command. *ffff* --> broadcast address	*Addr* --> 4 bytes, in ASCII characters, for hexadecimal address of destination node.	*Termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> Parameters error ● 0x33 --> error in Parameters number ● 0x34 --> no response ● 0x38 –> ack received ● 0x40 --> system busy *semicolon* --> 1 byte

Example:

CMD:17;
Reads battery voltage status and memorizes into module internal buffer.

CMD:18:287b;
Sends battery status to device short address 0x287b.

Addressed node will output on serial line:

Remote Command Output	
For good data reception: *MsgType* --> 1 byte ● 0x01 --> Get Battery *source Address* --> 2 byte *received Data* –> 2 byte (V in millivolt) *semicolon* --> 1 byte	*For incorrect data reception:* *MsgType* --> 1 byte ● 0x48 --> data error *semicolon* --> 1 byte

If addressed device properly receives the command, it will send back to source node confirmation of it.
This confirmation is given out of serial line with 0x38 --> ack received.

- **CMD:19:addr;**

Description: delivers to specified short address, via radio, the Integrated Circuit temperature value. This command should be preceded from CMD:16, as this last one reads the status of temperature.

Parameters	***Parameter Types***	***Command Outputs***
Addr --> 16bits address of note that will receive the command. *ffff* --> broadcast address	*Addr* --> 4 bytes, in ASCII characters, for hexadecimal address of destination node.	*termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> Parameters error ● 0x33 --> error in Parameters number ● 0x34 --> no response ● 0x38 –> ack received ● 0x40 --> system busy *semicolon* --> 1 byte

Example:

CMD:16;
reads the Ic temperature value and memorize into module internal buffer.

CMD:19:0001;
Sends Ic temperature status to device short address 0x0001.

Addressed node will output on serial line:

Remote Command Outputs	
For good data reception: *MsgType* --> 1 byte ● 0x03 --> Get Temp *Source Address* --> 2 bytes *Received Data* –> 2 bytes (to be converted using Formula Nr. 1) *semicolon* --> 1 byte	*For incorrect data reception:* *MsgType* --> 1 byte ● 0x48 --> data error *semicolon* --> 1 byte

If addressed device properly receives the command, it will send back to source node confirmation of it.
This confirmation is given out of serial line with 0x38 --> ack received.

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- **CMD:1A;**

Description: It start up the sampled cyclical data transmission, from the device to the coordinator. A similar command as CMD:06; but given by the serial port up to local node, rather that remotely by a coordinator.

Parameters	***Parameter Types***	***Command Outputs***
No parameters requested		*termination code* --> 1 byte ● 0x30 --> no_error ● 0x33 --> error in Parameters number ● 0x40 --> system busy ● 0x47 --> broadcast not available *semicolon* --> 1 byte

Further to the carried out command, cyclical transmission will activated by the device.
The Following data will be forwarded to the coordinator:

Coordinator Command Outputs	
For good data reception: *MsgType --> 1 byte* ● *0x08 --> send cycle* *Source Address--> 2 byte* *Battery Value (mV) --> 2 byte* *Temp. Value* (to be converted using Formula Nr. 1) --> *2 byte* *ADC1,res Value=max,ref=1,25 --> 2 byte* *ADC2,res Value =max,ref=1,25 --> 2 byte* *ADC3,res Values=max,ref=1,25 --> 2 byte* *ADC4,res Value=max,ref=1,25 --> 2 byte* *Digital I/O status --> 1 byte* *semicolon --> 1 byte*	*For incorrect data reception* put on queuing: *termination code* --> 1 byte ● *0x48 --> data error* *semicolon --> 1 byte*

In case of correct data reception, coordinator send to the device the rate value that should mantained for the transmission (default =10 sec).

- **CMD:1B;**

Description: It stop the sampled cyclical data transmission, from the device.

Parameters	*Parameter Types*	*Command Outputs*
No imput parameters requested		*termination code* --> 1 byte ● 0x30 --> no_error ● 0x33 --> error in Parameters number *semicolon* --> 1 byte

o ***Serial Comunication / Interfacing***

- **CMD:12;**

Description: Forwards the data placed into the module internal buffer (4 bytes), to the serial port.
This command must be used after one of the following commands: CMD:15; , CMD:16; , CMD:17;.
The above listed commands create a ADC conversion and storing the sampled data into the buffer.
In order to forward the sampling into the serial port, must be used subsequently the command CMD:12;

Parameters	*Parameter Types*	*Command Outputs*
No parameters requested		*termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> error in Parameters ● 0x33 --> error in Parameters number *semicolon* --> 1 byte *dati* --> 4 byte memorized into the buffer. *semicolon* --> 1 byte

NOTE: Used buffer is shared by other commands: For that reason, in case the intention will forward a conversion's result via serial port or radio transmission, after the comunication, is necessary perform the sending command immediatly.

- **CMD:15:channel:resolution:reference;**

Description: performs the ADC conversion, according with the explained Parameters. On detail, with the following command, will be set all the parameters as the ADC conversion channel, resolution needed to conversion performing, and reading reference.
The ADC channel, resolution and reference will set during this command

Parameters	***Parameter Types***	***Command Outputs***
Channel : dedicated channel for conversion performing: 00 --> ADC 1 01 --> ADC 2 02 --> forbidden: UART Reserved 03 --> forbidden: UART Reserved 04 --> forbidden: UART Reserved 05 --> forbidden: UART Reserved 06 --> ADC 3 07 --> ADC 4 08 --> differential input ADC1 – ADC2 09 --> forbidden 0a --> forbidden 0b --> differential input ADC3 – ADC4 0c --> GND 0e --> Temperature Sensor 0f --> VDD/3 *Resolution* --> Conversion Resolution 0 --> resolution 8 bit 1 --> resolution 10 bit 2 --> resolution 12 bit 3 --> resolution 14 bit *Reference* --> Reference Voltage 0 --> reference voltage costant equates to 1.25V 1 --> ADC3 2 --> Power supply AVDD 3 --> differential reference voltage between pin ADC3 and pin ADC4	*channel* --> 2byte *resolution* --> 2byte *reference --> 2byte*	*termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> error in Parameters ● 0x33 --> error in Parameters number *MsgType --> 1 byte* ● *0x13 --> get adc value* *semicolon* --> 1 byte

Reading is given by two's-complement system.

In case of correct execution, sampled data is ready into the output buffer to be forwarded via serial port or radio transmission.
In any case every single data is evidenced by 2 bytes followed by semicolon, even in case of 8 bit sampling resolution.
N.B. First byte of the output buffer contain the *1 byte MsgType* so the total bytes to be transmitted are 4.

NOTE: Buffer on which is written the conversion result, is shared even for the result writing of others commands; For that reason, in case the result conversion via serial port or radio transmission is wanted, is necessary perform the sending command immediately after the conversion.

- **CMD:16;**

Description: performs the temperature reading, automatically setting the parameters required to the conversion of the value provided by the chip temperature sensor.

Parameters	***Parameter Types***	***Command Outputs***
No imput parameters requested		*termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> error in Parameters ● 0x33 --> error in Parameters number *MsgType --> 1 byte* ● *0x03 --> get temp* *semicolon* --> 1 byte

In case of correct execution, sampled data is ready into the output buffer to be forwarded via serial port or radio transmission.

N.B. First byte of the output buffer contain the *1 byte MsgType* so the total bytes to be transmitted are 4.

NOTA: Buffer on which is written the conversion result, is shared even for the result writing of others commands; For that reason, in case the result conversion via serial port or radio transmission is wanted, is necessary perform the sending command immediately after the conversion

- **CMD:17;**

Description: performs the battery reading, automatically setting the parameters required to the conversion of the power supply voltage value.

Parameters	***Parameter Types***	***Command Outputs***
No imput parameters requested		*termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> error in Parameters ● 0x33 --> error in Parameters number *MsgType --> 1 byte* ● *0x01 --> get battery* *semicolon* --> 1 byte

In case of correct execution, sampled data is ready into the output buffer to be forwarded via serial port or radio transmission.

N.B. First byte of the output buffer contain the *1 byte MsgType* so the total bytes to be transmitted are 4.

NOTA: Buffer on which is written the conversion result, is shared even for the result writing of others commands; For that reason, in case the result conversion via serial port or radio transmission is wanted, is necessary perform the sending command immediately after the conversion

• Commands common to all devices

o *Net functions*

• CMD:01;

Description: performs a device Full Reset.
If command is forwarded to coordinator, it erases all information relating to the previous network, running a scan on all channels and creating a new network on channel considered more free from RF interference.
If command is forwarded to a router or an end device, performs a Full Reset on the device (see section “interrupts management”).
If a coordinator reset will running, is necessary run it also to the others remote devices that are part of network. That because coordinator has certainly changed the 128 bit encryption key, and could also have chosen a different channel of the previous network.
If the keep alive is active on all the devices placed on the network, they performs an automatically reset subsequently to the coordinator reset. Otherwise will necessary running a manual reset on all the remote devices.

Parameters	***Parameter Types***	***Command Outputs***
No parameters requested		*termination code* --> 1 byte ● 0x30 --> no_error ● 0x33 --> error in Parameters number *semicolon --> 1 byte*

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o *Radio Section*

- **SNT:addr:#byte:data;**

Description: delivers to specified address, via radio, data queued to Parameters

Parameters	*Parameter Types*	*Command Outputs*
Addr --> 16bits address of node that will receive the packet.. *ffff* --> broadcast address *#byte --> bytes qt. to be transmitted (<u>limited to 80 bytes to the router transmission, and 46 bytes to ED transmission</u>)* *Data --> data to be transmitted*	*Addr* --> 4 bytes, in ASCII characters, for hexadecimal address of destination node. *#byte* -->2 bytes, in ASCII characters, for hexadecimal bytes to be transmitted *Dati --> data to be transmitted*	*termination code* --> 1 byte ● 0x30 --> no_error ● 0x32 --> errore nei Parameters ● 0x33 --> error in Parameters number ● 0x34 --> no response ● 0x38 –> ack received ● 0x40 --> system busy *semicolon* --> 1 byte

Example:

SNT:143E:14:0123456789abcdefghil;

Sents to the device short address 0x143E, 20bytes placed to the data field

The addressed device will write to serial:

Remote Command Outputs	
<u>*For good data reception*</u>: *MsgType* --> 1 byte ● 0x02 --> Generic Radio Msg *Source Address* --> 2 byte *Data lenght*--> 1 byte *Received data* –> #byte *semicolon* --> 1 byte	<u>*For incorrect data reception:*</u> <u>*MsgType* --> 1 byte</u> ● 0x02 --> Generic Radio Msg *Address sorgente*--> 2 byte *Data lenght* --> 1 byte *Dati ricevuti* –> #byte *Received data* --> 1 byte ● 0x48 --> data error *semicolon* --> 1 byte

If addressed device properly receives the command, it will send back to source node confirmation of it.
This confirmation is given out of serial line with 0x38 --> ack received

Interrupts Management

Through the interruptus will be handled the following input doors of the devices.

RESET: device reset
INTERRUPT: send alarm
PWD: enable/disable power saving on end device

- **RESET**

Interrupt on router manages two different kind of reset.
If line, normally HIGH, will forced LOW for a time less then 1 second, will performed an HALF RESET: Will be erased all the network parameters of the device, except PAN ID of the network that it was associated (in case of device were part of a network) and keep alive status. For that reason It'll try to turning back to the net which it belonged (same PAN ID)
If line, normally HIGH, will forced LOW for a time over then 3 seconds will performed a FULL RESET: Will be erased all the network device parameters and it'll try to turning back to any network as the first time.
Interrupt on end device the lower forcing will only activate the HALF RESET

- **INTERRUPT**

Low line forcing, created a sending an alarm signal from the device to the coordinator. The following message is transmitted to the coordinator:

Parameter Types	***Command Outputs su coordinatore***
P2IFG --> Gate P2 Status	*MsgType --> 1 byte* ● *0x20 --> Alarm* *16bits address remote node --> 2 byte* *I/0 digital Status --> 1 byte*

In case of correct execution process will be clear to the user. Otherwise if problems raising, two different situations exist:

Coordinator busy	Coordinator not achievable
termination code --> 1 byte ● 0x40 --> system busy *semicolon* --> 1 byte	*termination code* --> 1 byte ● 0x34 --> no response *semicolon* --> 1 byte

- **PWD**

enable/disable power saving on end device.
End Device usually are set in Power Down and wake up only after any Poll Rate.
In case is necessary to send packet from an ED toward another device through SNT command, is required wake up it, lowering the PWD line, and then send the command or run others operations required.
To bringing back ED in PWD, is required turning HIGH the PWD line.

NOTE: If the ED doesn’t take part of network, cause never has been associated before or because it is trying to reconnect itself to a new router, SNT command has no effect. For that reason before to wake up the device with the PWD line to forward the message, is necessary to ensure that the device is part of the network through the line OUT R. That line is low when the device is handling and take part of a network, High in reverse sense.

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