# Renesas G3-PLC
# Frequently Asked Questions

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## Introduction

The CPX3 PLC modem LSI, R9A06G037, is a high-performance NB-PLC (Narrow Band Power Line Communication) modem LSI. R9A06G037 integrates a high-performance DSP core and a MCU core (ARM® Cortex™-M3). The DSP core mainly handles PLC PHY layer protocol, and the ARM core handles the upper layer protocol.

The CPX3 PLC modem LSI, R9A06G037, can support a variety of PLC protocols such as G3-PLC (CENELEC A and B, ARIB and FCC), PRIME (1.4 and 1.3.6) and Meters and More and many others

This document is aimed as a guide to help users implement an application running the G3-PLC protocol on-top of the Renesas G3-PLC protocol stack running inside the CPX3 PLC modem LSI. The document is a series of frequently asked questions by users when implementing the application layer.

## Target Device

The CPX3 PLC modem LSI, R9A06G037.

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# 1. G3-PLC Related Questions

## 1.1 Does the CPX3 device store MAC PIB attributes and ADP IB attributes (G3-PLC and Renesas Original) to its internal memory?

No. The CPX3 device is a ROMless device. If the application layer, for any reason, needs to store the values of these attributes, the application layer itself is responsible for reading, storing and re-writing these values. Note that as these are not stored when re-initialising or resetting the CPX device, even in the case of two consecutive resets. The G3-PLC alliance prepared a clarification on G3-PLC based MAC layer security, please refer to the question on G3-PLC security options.

Renesas recommends that the application layer stores and re-stores both macFrameCounter and adpLoadSeqNumber for normal operation of a G3-PLC Network.

## 1.2 Which of the G3-PLC security options are supported by the CPX3 device?

The G3-PLC alliance prepared a clarification regarding the MAC layer security as the initialization vector used during ciphering/deciphering does not use the extended address, but the PanID and Short Address. The management of short address and address attribution must be made explicit to achieve the same security. In short this means that for a given GMK, [group key] the bundle of short address and PanID and macFrameCounter must never be repeated when sending a ciphered frame. This means a form of continuity has to be managed on the short address and the macFrameCounter. Two solutions are possible:

1. Stored frame counter, based on the principle that the frame used to cipher outgoing frames is stored in non-volatile memory by the modem. The storage of the frame-counter to non-volatile memory can be done every N values instead of every time the frame-counter is updated, to limit the number of write operations to the storage.

2. Volatile frame counter, based on the principle that the macFrameCounter is set to 0 at start up. It is not reset during re-keying. The PAN coordinator must allocate a different short address each time a device bootstraps so a device short address (and therefore corresponding IPv6 address) will change regularly. Due to the limited number of short address, re-keying is mandatory after 32766 bootstraps.

The CPX3 device supports both mechanisms, however it is up to the application layer to manage the security. For example, in option 1 above the storing and restoring of the frame counter should be done by the application layer. This could be done by regularly reading the frame counter and adding an offset and storing to non-volatile memory, or by setting the macFrameCounterIndicationInterval, in which case the CPX will issue a MLME-FRAMECOUNT.indication every interval.

## 1.3 During the initialization process, using G3-INIT.request command, for normal operation as a G3-PLC node which setting should be used?

For operation as a PAN Device then the CPX3 device should be initialised in ADP mode using the G3-INIT.request. For operation as a PAN Coordinator then the CPX3 device should be initialised in EAP mode. The CPX device also allows for operation at the MAC layer for other applications which do not require a full G3-PLC stack, in which case the CPX3 device should be initialised in MAC mode, note that full G3-PLC certification is not possible in MAC mode unless supported by the upper layers.

## 1.4 What is the maximum number of entries the CPX3 supports in the Neighbour, device and routing tables?

The CPX3 can support up to 1536 nodes in the neighbour and device tables and 2048 nodes in the routing table. Note that CPX3 can also support dual channel operation, meaning that there are two channels of operation which can be initialised in parallel, where the device can fully operate as both ADP in one channel and EAP in the other channel (or two ADP modes). When dual channel is used, then care should be taken over choosing appropriate table sizes, if EAP/ADP or ADP/ADP [ch0/ch1] mode is chosen then the above table sizes can be supported. However, if the initialisation fails then please consider reducing the sizes of the Client Information table, Routing table, Neighbour table combination.

## 1.5 The CPX3 serial command specification refers to recommended settings for G3-INIT in each of the modes, what does the number of network node mean?

The number of network node refers to the expected maximum number of nodes in the PAN, the local network. As each application may differ then the sizes set during the initialisation sequence may vary. If the maximum number of nodes in the network is not known then we recommend setting these values to the maximum.

## 1.6 What are the recommended values for the parameters neighbourTableSize, deviceTableSize panDescriptorNum, routeTableSize and adpdBuffNum within G3-INIT.request command?

For recommended settings of these parameters please refer to the G3-PLC serial command specification, section G3-INIT.request Recommended Setting. For example, if the number of the nodes in the network is expected to be 100, then it is recommended that the neighbourTableSize is min(N, 1536), which would be a minimum of 100.

## 1.7 What is recommended value of parameter “Duration” within ADPM-DISCOVERY.request command? Is this parameter application specific?

The parameter “duration” refers to how long the lower layers should wait collecting beacon frames after sending a beacon request on the network. After a beacon request, any (bootstrapped) device on the network which receives the frame will send a beacon, each device will randomise the sending of the beacon between 0 and macBeaconRandomizationWindowLength. It is up to the application layer to determine the duration, considering the longer the duration, the longer the total join time to a network will increase, the shorter the duration the less number of possible bootstrapping devices will be seen. Also note that the duration of the discovery should be set larger than the macBeaconRandomizationWindowLength, otherwise it may be possible that no beacons are received even though they are transmitted on the network.

Please also refer to the CPX3 Serial Command Timeout Specification.

## 1.8 What is the recommended manner for selecting an LBA following a successful ADPM-DISCOVERY.request?

After successfully issuing an ADPM-DISCOVERY.request, then a corresponding ADPM-DISCOVERY.confirm will be issued. The ADPM-DISCOVERY.confirm returns the number of entries in the PAN discovery list and the list itself. For every beacon received a new entry is created in the PAN list, the list contains the PanID, address, link quality (the quality of the received beacon) and the route cost to the coordinator. Please refer to the G3-PLC specification to understand how the route cost is calculated. It is up to the application layer to decide which of the entries to use as a bootstrapping agent. For example, the application could set a threshold for the joining link quality, scanning through the list and selecting all those entries above this threshold, determining if they have known route to the PAN coordinator (route cost < 0x7FFF), and if so selecting the LBA (or PAN list) with the best route cost. If no valid LBA’s are discovered, then the application could lower this threshold and wait (maybe randomizing the waiting time) before issuing a new discovery.

Please also refer to question 1.9

## 1.9 What is the recommended algorithm for selecting an LBA for use during bootstrapping?

The recommendation for the LBA would depend on the application that is using the G3-PLC stack. The choice of the LBA to be used for joining a network is application layer specific but can be based on the following criteria: minimum value of route cost to coordinator (RC_COORD), maximum value of beacon link quality.

Renesas has a network rack which can support up to 896 G3-PLC based nodes with attenuation and noise forcing a realistic (if ever a realistic network is possible to re-create) network for a metering type application. Using this setup then Renesas has selected the following algorithm, please note this is a sample guide only it has not been tested in a real environment or optimized beyond supporting some detailed evaluation of the stack itself, i.e. an algorithm allowing all devices to join the network was sufficient.

The renesas algorithm is as follows, please also refer to the recommended PIBs for appropriate parameter values. Note this is also based on only a single PAN existing on the network.

1. Perform network discovery process: Invoke ADPM-DISCOVERY.request and wait for the confirm.
2. Browse through the complete pan descriptor list:
    a. If an entry exists which is above a minimum LQI setting and has a known route to the PAN coordinator:
        i. Calculate the route cost using the RC_COORD and the routing metric in Annex B of the G3-PLC specification.
        ii. Select the entry with the lowest overall route cost.
        iii. Perform a ADPM-NETWORK-JOIN.request with the selected LBA.
        iv. If ADPM-NETWORK-JOIN.request fails, then decrement the minimum LQI setting and restart the process (In the sample algorithm there is also a threshold where the minimum LQI setting is no longer reduced.
    b. Else, restart the process.

Each time the join process is started we recommend a random delay is introduced.

## 1.10 What is the recommended algorithm for selecting an LBA for use during bootstrapping if more than one PAN is discovered?

A single PAN descriptor list is returned in any case, regardless of whether there are multiple PAN ID's found.

If there are multiple PANs detected the application layer is responsible for deciding which PANID the device should join. The application layer should know if it is expecting to receive notification of more than one PAN.

For example, in a metering application, it is assumed that utility companies would know where the meters are installed and logically which data concentrator, PANC, they would join and the PANID of that device. If the meter joins to the wrong PAN, then we expect the application layer to have some mechanism to store a "Preferred PAN IB", this could then be set once the meter has joined to the network.

Then if the meter kicked from the network, it should be able to select the preferred PAN during the next bootstrapping processes.

Other applications may wish to follow a similar approach, if a device is unable to successfully join a network then the application may wish to store a list of PANID's which have been previously tried.

## 1.11 Who is responsible for setting the 'adpCoordShortAddress' attribute? When should it be set?

The 'adpCoordShortAddress' is an application specific attribute, meaning that the application layer should configure this to a different address if required. It is normally assumed that the adpCoordShortAddress is 0x0000.

When used:

- In G3-PLC it is also assumed that the LBS, the bootstrapping server is also the PANC (adpCoordShortAddress), so when devices are joining to the network the intermediate nodes relay frames to the adpCoordShortAddress address.
- If an ADPD-DATA.request is invoked with a destination IPv6 prefix unequal to the link local prefix or any prefix stored in adpPrefixTable, the frame will be directed to the adpCoordShortAddress as default gateway.

The application layer should take care of setting the address if it is different to the default value.

## 1.12 Who is responsible for setting the 'macShortAddress' and 'macPanID'?

On successful joining of a G3-PLC network, indicated by receiving an ADPM-NETWORK-JOIN.confirm primitive with the results 'success'. The values of networkAddress and panID parameters are automatically written into macShortAddress and macPanId by the stack itself.

## 1.13 How is ‘LinkQuality’ calculated (what affects this parameter)?

‘Link Quality’ is defined as the measured signal quality during reception of an incoming frame. According to the G3-PLC specification:

“The forward LQI shall be measured for each received packet and is a characterization of the quality of the underlying power line channel.

The LQI is an integer ranging from 0x00 to 0xFF and LQI values in-between shall be uniformly distributed between these two limits. The LQI value is derived from the average SNR (where averaging is done over all active tones and pilot tones, if present, in the bandplan and over all OFDM symbols in the received packet) where the SNR-to-LQI mapping is:

- SNR <= –10 dB maps to LQI 0x00
- SNR >= 53.75 dB maps to LQI 0xFF
- –10 < SNR < 53.75dB is linearly interpolated between 0x00 and 0xFF (the nominal step size is 0.25 dB).

Active tones are defined as tones which carry data (pilot tones and dummy bit tones are not included).”

Note that different implementations can estimate the LQI using different techniques, pure SNR of amplitude or EVM based. EVM based mechanisms are considered more accurate as the SNR considers phase on the signal not just amplitude.

Renesas implementation uses and EVM based calculation.

What affects this parameter? The LQI is calculated on received frame therefore there is nothing that can affect this parameter, however the LQI of a received frame can be influenced by a number of factors, such as but not limited to:

- Impedance at the transmitting station, injected signal level
- Distortion and or attenuation of the transmitted signal
- Noise level at the receiver, internally or externally generated noise.

## 1.14 Is the PhaseDifferential taken into account when calculating LinkQuality during the PAN discovery process?

No.

## 1.15 Is the Neighbour Table updated during the PAN Discovery process?

No, the nieghbourtable is only populated or updated on reception of a tonemap response frame.

## 1.16 Does the choice of LBA for the JOIN process have any impact on routing after a successful JOIN process?

It is the application layer who decides if the chosen LBA should be used as a default route after a successful join process. This is decided using the ‘adpDefaultCoordRouteEnabled’ attribute, “If TRUE, the adaptation layer adds a default route to the coordinator after successful completion of the bootstrapping procedure. If FALSE no default route will be created.” Please refer to the G3-PLC specification section 9.4.4.2.2.5, Authorization and initial configuration phase, “If ‘adpDefaultCoordRouteEnabled’ is set to TRUE and once the join procedure has been successfully completed, it is recommended to issue an ADPM-ROUTE-DISCOVERY towards the PAN coordinator with the ‘adpUnicastRREQGenEnabled’ ADP IB attribute set to TRUE to refresh the initial routing table entry and to announce the route to the PAN coordinator.

Renesas recommends that the ‘adpDefaultCoordRouteEnabled’ attribute is set to TRUE.

## 1.17 What is the MLME-BEACON-NOTIFY.indication primitive and what is it used for?

The MLME-BEACON-NOTIFY.indication primitive is a Renesas specific primitive. It is used to inform the application layer on receipt of each individual 'beacon' frame. This indication includes the phase differential information with may be useful to the application layer but is not information which is mandated in the G3-PLC specification. This notification is disabled by default but can be enabled by setting the 'adpBeaconIndEnable' attribute to TRUE. The MLME-BEACON-NOTIFY.indication primitive is only issued during an active 'scan duration'. The indication is issued upon every receipt of a beacon frame.

Using this primitive it is possible to discover information about PhaseDifference for every discovered LBA. This is outside the scope of the G3-PLC specification but useful in certain applications.

## 1.18 Is the phase difference information, together with LinkQuality and RC_COORD parameters, important for selecting LBA for the JOIN process?

The Phase difference information is not relevant for selecting and LBA, only the LinkQuality and RC_COORD parameters are important. The RC_COORD, route cost to the PANC, shall be based on the route cost calculation, as specified in clause 9.4.3. RC_COORD may be approximated by saving the lowest route cost extracted from the routing packets that originated from the PAN coordinator (for LOADng routing packets, see clause 9.4.3.2.7). Therefore the when evaluating the best LBA, the application layer has two variables to consider, the RC_COORD gives the application an estimate on the total link cost of that route, which is an estimate of all the hops along that link, and the LinkQuality gives an indication of the link quality between the LBD and the LBA. There are many different techniques for selecting the most appropriate LBA.

In the Renesas network environment of 448 nodes then a basic algorithm is used, first only consider LBA's with a LinkQuality above a given threshold, selecting the best RC_COORD with LinkQuality above that threshold. If none of these criteria is met a random delay is recommended, to allow more nodes to join the network, before repeating the scan process and reducing the threshold for the LinkQuality.

Please refer to question 1.9

## 1.19 When should the Peer device leave the PAN by itself (by invoking ADPM-NETWORK-LEAVE.request primitive), i.e. which event is the trigger for this?

Instigating the leave process from the PAN Device is application layer dependent. For example, in a metering application which would read metering data every day from a central station (PAN coordinator), it may be useful for the application layer of the central station to regularly ping each meter to check it is still existing on the network. If the metering information is read every day then maybe a ping each 5 hours would be useful. If the device doesn't receive a PING or any application data targeted to itself after 20 hours it may assume that it has lost connection and attempt to re-join the network. It is recommended to send a leave frame to update the routing tables of any intermediate nodes. However, sending PING frames on the network will cause additional network traffic possibly reducing the throughput of application data, so care should be taken when selecting the appropriate methods to detect losing connection.

## 1.20 After the PAN coordinator kicks a peer device from the PAN and peer device receives ADPM-NETWORK-LEAVE.indication primitive, what should be done next at the application level of the peer?

It is left to the application layer as to exactly what is performed when receiving the ADPM-NETWORK-LEAVE.indication, however Renesas would recommend following the procedure laid out in the G3-PLC specification for the ADPM-NETWORK-LEAVE.request which states:

- Acknowledge the frame if necessary
- Set its 16-bit short address to 0xFFFF;
- Generate an ADPM-NETWORK-LEAVE.indication
- Invoke an MLME-RESET.request primitive with the SetDefaultPIB parameter set to TRUE
- Invoke its ADPM-RESET.request primitive to reset itself.

The first three points are handled by the G3-PLC stack itself, it is therefore recommended that the application layer issues the ADPM-RESET.request, this will also reset all the adp and mac attributes to the default values.

In addition to this Renesas would recommend the following:

- If there are any PIB's that are different from the defaults, then these should be re-stored after the device has reset itself (ADPM-RESET.request), in which case they should be stored prior to the MLME-RESET.request.
- Application layer should consider if the context and prefixes should be re-stored, again this could be dependent on whether the device knows if it will simply rejoin the same network. [Joining a different network may render these settings as invalid], in which case they should be stored prior to the MLME-RESET.request.
- Depending on the security profile the macFrameCounter attribute should be restored [Assuming in this case that the application layer should be periodically storing the macFrameCounter attribute].
- It may also be worth restoring the adpLOADngSeqNum attribute.

It is assumed that after this the usual joining procedure will be followed. It is recommended to perform a discovery procedure as the devices in the existing PAN descriptor list may no longer be valid.

## 1.21 Once the PAN coordinator kicks the Peer from the PAN, Peer receives ADPM-NETWORK-LEAVE.indication primitive and the Peer is disconnected from the PAN. Should the discovery procedure and network joining procedure be repeated immediately?

The application layer is responsible for maintaining connection to the network. It is recommended that the PAND rejoins the network using the same mechanism as detailed in questions 1.8 and 1.9.

## 1.22 Who is responsible for invoking ADPM-NETWORK-LEAVE.request primitive in case of a peer device leaving a PAN?

The application layer is responsible for invoking the ADPM-NETWORK-LEAVE.request primitive when deciding to leave the network. The purpose of invoking this primitive is to inform all of the intermediate nodes that the route to the leaving device is no longer valid and this entry should be removed from the routing tables. It is left to the application layer to decide when to leave the network, an example might be a metering application whereby the meter data is read periodically, say once per day. The PAN coordinator may in that case decide to PING each device periodically. If the target nodes does not receive any PING within a given period it may assume it has lost connectivity to the network and in which case may re-join, avoiding days of uncollected application data.

## 1.23 In table 5-23 of the CPX3 G3-PLC Serial Command Specification the type of the MAC PIB attribute "macTMRTTL" is int32_t, however the G3-PLC specification defines uint8_t?

This is correct, for legacy reasons it is possible to configure the macTMRTTL attribute to higher than the defined range of 0 – 255'd in the G3-PLC specification. In this case we would recommend that the application layer conforms to the G3-PLC specification and only sets values which are within the range of the G3-PLC specification.

## 1.24 During the initialisation procedure, are all MAC PIB attributes and ADP IB attributes are set to default values by CPX3 itself?

Yes. Any time the CPX3 device is physically reset or reset by ADPM-RESET.Request then the IB are reset to the default values as specified. If the application layer, for any reason, needs to store the values of these attributes, the application layer itself is responsible for reading, storing and re-writing these values.

## 1.25 Is it necessary to go through the complete process of setup as peer, discovery process and network join process every time after the reset of Peer device?

Yes. After resetting the device, all of the IB are reset to the default values, this applies to the short address of the device, each device needs to complete the bootstrapping process (network join process) to reinstate itself within the network. If the application layer, for any reason, needs to store the values of these attributes, the application layer itself is responsible for reading, storing and re-writing these values.

## 1.26 What is the size of the internal buffer used for data transmission by the ADPD-DATA.request primitive?

The recommended setting for adpdBufNum (the number of elements to store ADPD-DATA.requests) is 2, the maximum setting is 4. This setting reserves sufficient internal memory for complete ADPD-DATA.request frames, the maximum size of an ADPD-DATA.request is 7 + nsdu bytes wide, where the maximum nsdu size is 1280 bytes.

## 1.27 Who is responsible for setting the Context table, should all devices on the network have the same context table contents?

The contents of the context table are outside the scope of the G3-PLC specification, the specification as such references the IETF RFC 6775 context option. The G3-PLC specification also references IETF RFC 6282 which describes the compression and compression format for IPv6 datagrams, this document also describes the neighbor discovery process in which the PAN coordinator shall generate router advertisement packets that carry the context information. The application layer is then responsible for setting the context table within the G3-PLC stack which then uses such information for compression. It is therefore implied that all devices within that PAN share the same context, otherwise the compression process fails.

## 1.28 What is the purpose of the attribute, adpDataType?

The default value for this attribute is “1”: Compression enabled, IPHC compression is used. Setting this attribute to “0” disables the IPHC defined by RFC6282 as required by G3-PLC specification and therefore is not compliant to the G3-PLC specification. Setting to “0” should only be done for testing purposes.

## 1.29 Who is responsible for compressing the IPv6 frame, are there other considerations from the host?

The compression and decompression of IPv6 frames is handled inside the G3-PLC stack, the host application does not need to take care or be aware of the compression. The upper layer is responsible for setting the information in the context table, please refer to question 1.27. The rules for header compression are detailed in RFC6282 and the IPv6 header, UDP and IPV6 extended header are compressed automatically, the compressed headers are also automatically uncompressed on receipt of a compressed IP frame and passed to the host uncompressed. The NSDU of the ADPD-DATA.request should be a valid IPv6 frame with relevant headers.

## 1.30 Who is responsible for filling the Prefix table, should all devices on the network have the same prefix table contents?

The contents of the prefix table are outside the scope of the G3-PLC specification, the specification as such references the IETF RFC 6775 prefix option (an update to the IETF RFC 4944). The G3-PLC specification also references IETF RFC 6282 which describes the prefix and prefix format for IPv6 datagrams, this document also describes the neighbor discovery process in which the PAN coordinator shall generate router advertisement packets that carry the prefix information. The application layer is then responsible for setting the prefix within the G3-PLC stack which then uses such information for routing. It is therefore implied that all devices within that PAN share the same prefix.

## 1.31 Who is responsible filling the Routing table, Broadcast table, neighbor, POS table and Blacklisted table?

The G3-PLC stack itself, implemented and contained inside the CPX3 device is responsible for filling and maintaining the routing, broadcast, neighbour, POS table and blacklist tables. The information stored in these tables is accessible via the MLME-GET.request, ADPM-GET.request primitives, please refer to the G3-PLC Serial command specification section on MIB and PIB tables. Using the CPX3 implementation, it is also possible to configure the sizes of some of these tables. It is not necessary for the application layer to store any entries in these tables, however in some applications it may be useful to store or remember some values. Care should be taken as if the CPX3 device is reset by software or hardware then the values in these tables will be lost. Note that if the device is reset then one assumes that the bootstrapping and short address allocation process needs to be repeated and the device may not have seen necessary frames to maintain its tables, in which case best practice would be to clear these entries and not assume previous information is still valid.

## 1.32 Who is responsible for configuring the “macMaxFrameRetries” MIB attribute?

The setting of the macMaxFrameRetries is application layer dependent, meaning that the user is free to configure the network as required. It is recommended that the network settings are testing under realistic network conditions, meaning network size, topology, noise etc. It is also assumed that the MIB and AIB are network wide settings (all devices in the network have the same settings). Note that the G3-PLC specification also allows that the modulation is lowered on retransmissions such that the last transmission is done in Robust mode, the mechanism is implementation dependent. In the CPX3 implementation the parameters of the neighbor table are updated internally. Consider that if a transmission fails then the ADP layer may attempt to repair a route, this could trigger a flooding of route request on the network causing lower efficiency of data packets, in which case it may be more efficient to ensure success of each packet in the first instance.

## 1.33 Who is responsible for setting RC_COORD (Route cost to coordinator), or the route cost for the routing frames?

The G3-PLC specification specifies two different route cost metrics, the first adpMetricType type of 0x00 is a hop count based metric where a hop count is incremented on forwarding route request or route reply frames, implying the preferred route to a destination is the one with the least number of hops. The second metric is a composite metric based on a more complex set of values. The route cost to the coordinator (which is used in the beacon payload) is calculated using the formula described in annex B of the G3-PLC specification. The route cost, as described in the specification is the sum of all the link costs on the route, A device shall initialize RC_COORD to 0x7FFF on association of the network or if it is at adpMaxHops hops distance from the PAN coordinator. The PAN coordinator shall set its RC_COORD to 0x0000. As such the RC_COORD or the route cost to a neighboring node is computed within the G3-PLC stack and the application layer should leave this to the device (or stack). However, it is the application layers responsibility to select the preferred routing cost method and if the composite metric is chosen then it is the application layers responsibility to configure and select appropriate values for the routing parameters adpKr, adpKm, adpKc, adpKq, adpKh and adpKrt.

## 1.34 What are the attributes ‘adpLowLQIValue’ and adpHighLQIValue’?

These attributes are used to define unreliable links and reliable links, respectively. These would be measured by each product manufacturer, ‘adpLowLQIValue’ is seen as the lowest value of LQI which communication is considered acceptable (possible) in ROBO modulation. The ‘adpHighLQIValue’ is seen as the highest LQI that the product will see in good (best) communication conditions.

The attributes are used during the routing process as described in the G3-PLC specification Annex D.

## 1.35 What is the attribute ‘adpWeakLQIValue’ used for?

The adpWeakLQIValue is used to define a threshold of line quality information, below which a link is considered as possible but not preferred. The attribute is used during the routing process as described in the G3-PLC specification Annex D.

It is recommended that this value is configured by the application layer to be above the value defined by ‘adpLowLQIValue’. When performing a route discovery the route cost calculation is performed as described in Annex D and the selections related to Annex D.11.2, the idea is to find routes between peer’s which avoid weak links.

A weak link is considered as a frame where the received LQI is lower than the WEAK LINK THRESHOLD.

## 1.36 Who and when should configure attribute “macTMRTTL”?

The purpose of the Tone Map Response is to establish the best communication method between two devices. When attempting to send a data frame to a neighbor the macTMRTTL value should be checked, if it is ‘0’ or invalid then the device should request a tone map response and send the frame in ROBO modulation with all tones used. On receiving this frame the receiving device analyses the received packet and selects the tones and modulation it feels could have been used to send the packet, the choice of modulation and tone map is implementation specific. The receiving device then sends a response frame which contains information, such as tone map and modulation, which the transmitter keeps in the neighbor table. Any following frames are sent using this information and the macTMRTTL is recorded in the TMRValidTime field of the neighbor table. In such a case it is the application layer responsibility to select an appropriate value, as the channel characteristics vary then the channel should be analyzed on a regular basis to ensure the most optimum modulation etc. However, if the macTMRTTL is too low then the network will contain many more Tone Map Response frames, which reduces the efficiency/throughput of the network, conversely if the macTMRTTL is too high then any change in the channel characteristics will not be recognized be the nodes. It should also be noted that a recent modification to the G3-PLC specification was that on MAC layers retransmissions the last transmission is always done in ROBO modulation.

## 1.37 Who and when should set and decrement “TMRValidTime”?

It is assumed that the contents of the neighbor table are controlled or maintained by the G3-PLC stack itself and therefore not modified by the application layer as this may impact the behavior of the network. In the CPX3 G3-PLC stack implementation it is possible to modify the contents of the neighbor table. Care should be taken should the application wish to make modifications.

## 1.38 Is procedure for the adaptive tone mapping described in the G3-PLC specification implemented within the G3-PLC stack which resides in the CPX3 device?

Yes, the algorithm for selecting the tone mapping, txGain, tone map, modulation, etc is implementation specific and is contained within the stack itself.

## 1.39 Who should remove the entry from the Broadcast table once the valid time parameter reaches ‘0’?

The maintenance of the MAC and ADP tables is left to the G3-PLC stack, in this case this means that the CPX3 device maintains all the tables as required.

## 1.40 Who and when should initialize the valid time parameter in the Broadcast table with the value “adpBroadcastLogTableEntryTTL”?

The G3-PLC stack itself, implemented and contained inside the CPX3 device is responsible for filling and maintaining the routing, broadcast, neighbour, POS table and blacklist tables. The information stored in these tables is accessible via the MLME-GET.request, ADPM-GET.request primitives, please refer to the G3-PLC Serial command specification section on MIB and PIB tables. The setting of the adpBroadcastLogTableEntryTTL is application layer dependent, meaning that the user is free to configure the network as required. The purpose of the adpBroadcastLogTableEntryTTL attribute is to prevent attempting to install routes where the link is unidirectional only, meaning communication is only possible in one direction. Specifically, the blacklist table records neighbours from which an RREQ has been received (i.e., through which a forward route would be possible) but to which it has been determined that it is not possible to communicate (i.e., forwarding route replies via this neighbour fails, rendering installing the forward route impossible), however it may also use other frames, i.e. MCPS-DATA.confirm status triggers blacklisting for the following possible

values: TRANSACTION_EXPIRED, NO_ACK. When a neighour node is considered to have a unidirectional link then any received routing frames are not forwarded, thus preventing a route attempt through this neighbour.

When a neighbour node is blacklisted then a blacklisting entry is created and the adpBroadcastLogTableEntryTTL value is copied into the valid time parameter of the blacklist table. As mentioned the application layer is responsible for configuring an appropriate value for this parameter. To larger may stop routes being formed permanently, not adapting to any network variations. Too small and the blacklisting will have little effect as blacklisted neighbours will be cleared before an appropriate link is formed. It is recommended that the network settings are testing under realistic network conditions, meaning network size, topology, noise etc. It is also assumed that the MIB and AIB are network wide settings (all devices in the network have the same settings).

## 1.41 When and how often should the ADPM-ROUTE-DISCOVERY.request primitive be invoked?

The current G3-PLC specification does not specify the usage of the primitives, this is left to the implementer on the application level. There are a number of methods to install a route between devices:

- Invoke the ADPM-ROUTE-DISCOVERY.request primitive.
- Use the default route used during bootstrapping.
- Invoke the ADPD-DATA.request with the discover route parameter set to true.

There are a few considerations, invoking the ADPM-ROUTE-DISCOVERY.request will flood the network with routing frames which will utilize bandwidth of the network, however it may also ensure that when data is required to be transmitted there is already an existing route which would speed up the overall transmission of the data packet. The application may which to decide which is more important, efficiency of the network or the speed of the data traffic, which conversely maybe impacted by the periodic route refreshing. Using the default route used during bootstrapping may not be the most efficient route either as there may have been limited routes to select during that time or may have been a lot of traffic due to many devices bootstrapping at the same time (power up of a network), similarly this could be the case in any of the above scenarios.

A further consideration may be that if the discover route parameter is used when invoking the ADPM-ROUTE-DISCOVERY.request and a route is not known (expired by intermediate nodes) then they would start the route discovery process to repair the route. This could lead to longer routes being established as routes are more likely to grow than shorten, in which case it may be wise to periodically refresh (or force new routes) from the coordinator, as these will then most likely be the more optimal routes.

There are also many other considerations such as route metrics and routing attribute values, AIB. Most importantly would be the routing table time to live attribute, a larger value meaning less time spent establishing routes at the cost of more efficient routes.

## 1.42 Who is responsible for supporting the LOADng protocol and modifying the Routing table?

The implementation of the LOADng protocol is contained with the ADP layer of the CPX3 (G3-PLC stack) device. As such the maintenance of the tables and handling of routing frames is done by the G3-PLC stack. As described above the application layer is responsible for maintaining network wide parameters, PIB, and choosing suitable values for each.

## 1.43 When should automatic route discovery be performed, i.e. when should the parameter “DiscoverRoute” be set to TRUE?

Please refer to the question 1.41. It is left to the application layer to understand the effect and consequence of setting this parameter.

## 1.44 Is the G3-PLC stack implemented inside the CPX3 device itself responsible for counting “adpRREQWait” seconds between two successive RREQ?

Yes. The implementation of the LOADng protocol is contained with the ADP layer of the CPX3 (G3-PLC stack) device.

## 1.45 When and how often should the ADPM-PATH-DISCOVERY.request primitive be invoked?

The ADPM-PATH-DISCOVERY.request primitive is used to build up a topology of the network itself. It is assumed that this primitive is only invoked on a device acting as a PAN coordinator. The path discovery will indicate all the intermediate nodes and their route cost on a route to and from a target node. This information can be used by the coordinator to manage the network or could be used by the application layer. The use cases are outside the scope of the G3-PLC specification itself.

## 1.46 Who is responsible for setting “adpDefaultCoordRouteEnabled” to TRUE?

The setting of the adpDefaultCoordRouteEnabled attribute is left to the application layer, it should also be considered what type of application is being developed. Renesas recommends setting this to TRUE for a metering application.

There are a few considerations, if the default route is used then it is not necessary to perform the first route discovery process, i.e. invoking the ADPM-ROUTE-DISCOVERY.request or ADPD-DATA.request with discover route set to true, which in turn will flood the network with routing frames which will utilize bandwidth of the network, it ensures that when data is required to be transmitted there is already an existing route which would speed up the overall transmission of the data packet (This route is presumably based on the best available route during bootstrapping). The application may wish to decide which is more important, efficiency of the network or the speed of the data traffic, which conversely maybe impacted by the periodic route refreshing. Using the default route used during bootstrapping may not be the most efficient route either as there may have been limited routes to select during that time or may have been a lot of traffic due to many devices bootstrapping at the same time (power up of a network), similarly this could be the case in any of the above scenarios.

A further consideration may be that if the discover route parameter is used when invoking the ADPM-ROUTE-DISCOVERY.request and a route is not known (expired by intermediate nodes) then they would start the route discovery process to repair the route. This could lead to longer routes being established as routes are more likely to grow than shorten, in which case it may be wise to periodically refresh (or force new routes) from the coordinator, as these will then most likely be the more optimal routes.

There are also many other considerations such as route metrics and routing attribute values, AIB. Most importantly would be the routing table time to live attribute, a larger value meaning less time spent establishing routes at the cost of more efficient routes.

## 1.47 Do the CPX3 devices come with the G3-PLC stack preloaded, or must the FW be downloaded by the HOST controller?

The CPX3 devices are ROMless devices so do not have any preloaded code (except the bootloader). The CPX3 firmware must be downloaded at start-up, this can be done using the host controller or the CPX3 can be connected to external SROM. In the case of the external SROM then the SROM must be loaded with the appropriate CPX3 firmware image. Please also refer to the Boot Operating Manual.

## 1.48 Who selects the EUI64 for use within a G3-PLC network?

This is referred to in the IEEE 802.15.4-2006 specification, known here as IEEE address. Each device should have its own unique IEEE address and a vendor can request a range of IEEE addresses from IEEE. This would mean that each vendor has a vendor ID and a unique range of EUIs that can be used.

## 1.49 Who selects the PSK for use within a G3-PLC network?

The PSK should be a unique key for each meter [device on the network]. This should be generated during production and stored in the device during programming, the matching PSK / EUI combination is then stored in the head system.

The idea is that during the initial bootstrapping the peer shares its EUI with the PANC. The PANC then requests the PSK from the HEAD system, for that EUI. [Idea being that the PANC is a more powerful device with much better encryption, so sharing the PSK is more secure]. The bootstrapping uses the PSK [it is never transferred on the PLC network] to authenticate both devices as both devices must know the PSK. The PSK is used as a cypher and as both devices know it then only they can decrypt the messages.

## 1.50 Can Renesas recommend some G3-PLC parameters which are different from the default values?

The following values are the G3-PLC PIB that Renesas use in their internal test network comprising of 448 network nodes. These are evaluated and are considered optimal for such a network, these are also defined based on a limited set of application requirements such as:

- Network convergence
- ICMPv6 echo request, pinging each device in turn.

| G3-PLC Layer | Attribute ID | Index | Attribute Value | Comment |
|---|---|---|---|---|
| ADP | 0x0005 | 0x0000 | 0x64 | adpHighLQIValue |
| ADP | 0x0004 | 0x0000 | 0x34 | adpLowLQIValue |
| ADP | 0x001A | 0x0000 | 0x42 | adpWeakLQIValue |
| ADP | 0x0012 | 0x0000 | 0x0168 | adpRoutingTableEntryTTL |
| ADP | 0x0020 | 0x0000 | 0x00B4 | adpMaxJoinWaitTime |
| ADP | 0x0016 | 0x0000 | 0x1E | adpKq |
| ADP | 0x001F | 0x0000 | 0x00B4 | adpBlacklistTableEntryTTL |
| ADP | 0x000F | 0x0000 | 0x0E | adpMaxHops |
| ADP | 0x0011 | 0x0000 | 0x0014 | adpNetTraversalTime |
| ADP | 0x0006 | 0x0000 | 0x14 | adpRREPWait |
| MAC | 0x0112 | 0x0000 | 0x03 | macA |
| MAC | 0x004F | 0x0000 | 0x03 | macMinBE |
| MAC | 0x0047 | 0x0000 | 0x09 | macMaxBE |
| MAC | 0x080A | 0x0000 | 0x1E | macUnicastDataTxTimeout |
| MAC | 0x0416 | 0x0000 | 0x1E | macBroadcastDataTxTimeout |
| MAC | 0x010D | 0x0000 | 0x0000001E | macTMRTTL |

## 1.51 What would be the maximum number of PLC nodes that can be installed within one network (slaves and masters)?

The ‘macShortAddress’ attribute is defined as a 16 bit attribute and is used as a unique identifier on the network. However the adaptation layer also supports the use of multicast addressing, which uses the broadcast address of 0xFFFF at the MAC level. The multicast addressing starts at 0x8000 as defined in RFC4944.

Range 2, 100xxxxxxxxxxxx: Bits 0, 1, and 2 SHALL follow this pattern if the 16-bit address is a multicast address (see Section 9). This leaves 13 bits for the actual multicast address.

As the devices are defined as having a single 16bit short address, shared across the ADP and MAC layer, then there are 13 bits allowed for the actual address.

## 1.52 Can the G3-PLC be addressed via TCP?

The G3-PLC specification itself mandates that the payload is a valid IPv6 frame, therefore it can support TCP/IPv6 packets.

## 1.53 Is it possible to make the Rand_P number generation used during bootstrapping it more random?

The G3-PLC stack inside CPX3 uses srand, rand of standard function. It is not a true hardware random generation. In the CPX3 implementation, rand uses a hardware free running counter (msec) as the seed of random generation, the hardware free running counter is started after the boot sequence (firmware download procedure). For more random operation of the Rand_P generation we recommend a randomised delay between the booting and the invoking of ADPM-NETWORK-JOIN.join.

## 1.54 If we have more than one PLC in the network, do all of them share the same bandwidth simultaneously by some form of coding? Or do they take turns in sending the data (time division duplexing)?

Devices on a G3-PLC network share the bandwidth of the network using a CSMA/CA (carrier sense multiple access with collision avoidance) channel access scheme, with a random back-off time. The random back-off mechanism spreads the time over which stations attempt to transmit, thereby reducing the probability of collision. Each time a device wishes to transmit data frames it shall wait for a contention period.

Please also refer to section 9.3.1 of the G3-PLC specification.

## 1.55 Does the G3-PLC solution support 3 phase networks?

The G3-PLC specification itself stipulates that all devices shall have an internal timer that is synchronized with the zero-crossing detector. The definition of the timer and associated calculations are detailed in the G3-PLC specification section 8.10, AC phase detection. Using the internal timer, an internal phase differential counter can be created, this counter value is included in the FCH field of each transmitted frame. It is therefore possible to compare the PDC of an incoming packet with a devices own PDC value. Comparing these gives a differential value of between 0 and 5 to indicate phase shifts in 60 degree intervals.

The phase differential information can be calculated between each neighbouring device and is stored in the Neighbourtable.

## 1.56 Does the CPX3 and Phase differential work with 50 and 60 Hz AC?

Yes. The G3-PLC stack implemented inside the CPX3 will automatically detect which system is being used.

## 1.57 What is an example frame, showing the format for a G3-PLC packet, expected at the serial input to the CPX3 device?

An example frame for MLME-SET.request, setting the attribute ‘plTxPower’, attribute ID ‘0x8340’ is given below. For information on decoding please refer to the G3-PLC Serial command specification.

7E 00 01 03 03 83 40 00 00 0F 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F 2E F1 F6 A0 D9 70 20 1B 5C 55 F9 7E

## 1.58 Is it possible to identify which version of G3-PLC stack is running inside the CPX3 device?

It is possible to identify which version of the G3-PLC stack is running in a number of different ways, the version information is split into separate parts, system version, ADP version, MAC version and DSP (LMAC and PHY) version.

The version information is given at the beginning of the CPX3 firmware file, for example, g3v2017_sampleapp_eap_g3both_cpx3_gcpx3_4band_RX631_v0400_28062019.h:

const uint8_t g_cpxprogversion[] = {…}

It is also possible to read these attributes using the 'adpSoftVersion' attributes using the ADPM-GET.request for ADP version, MAC version and DSP (LMAC and PHY) version and using SYSTEM-VERSION.request command for the system version.

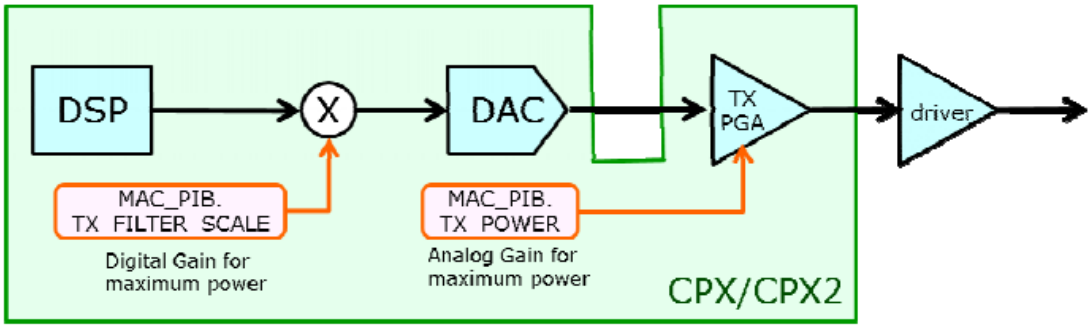
Information on the version information can be found in the G3-PLC Firmware for CPX3 Release Notes, section 3. Package Version Information

## 1.59 Is it possible to modify the PLC output signal in software?

It is possible to increase or decrease the signal level output by the CPX3 device in a number of ways. The intended operation is that the attributes 'plTxPower' and 'plTxFilterScale' are used to set the base power used by the modem, these should be adjusted so that the output signal complies with the spectrum regulations. It is expected that these powers will need to be optimized for each individual piece of hardware.

For this purpose:

- plTxPower: Analog gain parameter for the TXPGA, settable in 3dB steps.
- plTxFilterScale: Digital gain, 16 bit co-efficient for the DAC input




The table below shows the recommended method to adjust these parameters, where A describes the recommended 'plTxFilterScale' setting and B describes the recommended 'plTxPower' setting.

| Δgain | TX_FILTER_SCALE | TX_POWER |
|---|---|---|
| +4dB | round(A*10^(-2/20)) | B-6 |
| +3dB | A | B-3 |
| +2dB | round(A*10^(-1/20)) | B-3 |
| +1dB | round(A*10^(-2/20)) | B-3 |
| 0dB | A | B |
| -1dB | round(A*10^(-1/20)) | B |
| -2dB | round(A*10^(-2/20)) | B |
| -3dB | A | B+3 |
| -4dB | round(A*10^(-1/20)) | B+3 |

Care should be taken when choosing appropriate values and where possible the adjustment of plTxFilterScale' should be kept minimal, as close to the default value is recommended, increasing this value can introduce distortions in the generated PLC signal as the compression point of the DAC can be exceeded. Renesas recommends to check the signal for distortion after making the appropriate adjustments.

Once the maximum output level has been set and determined based on the regulations, the 'macTransmitAtten' attribute can be used by the application layer to reduces the output signal level between 0 and 25dB in 1 dB steps. The application layer is free to determine when this should be used, such as to lower power consumption or otherwise.

## 1.60 What is the purpose of the attribute 'macKeepModRetryNum'?

Please refer to the CPX3 G3 Serial Command Specification section 11.2.

Unless there is a specific reason to change this then Renesas recommends the default value. In previous versions of the G3-PLC specification each retry at the MAC layer was done with the modulation selected during tone map negotiation.

However, it was also discovered that a link break (defined as previous communication between two nodes no longer being possible) leads to a route repair process which is a flooding of the network with RREQ messages. This flooding is considered inefficient; therefore the G3-PLC specification was updated to suggest that the modulation used for retries at the MAC layer could be reduced, or lowered, such that the last transmission would be sent in ROBO mode (mandatory). Therefore, each implementation could select different mechanisms to attempt to keep this link but must send the last attempt in ROBO mode.

This attribute is used such that the modulation, currently residing in the Neighbourtable, will be kept for 'macKeepModRetryNum' retries, if communication is not successful then a lower modulation is used for 'macKeepModRetryNum' transmissions, before eventually the last transmission being in ROBO. This is also kept consistent with macMaxFrameRetries.

## 1.61 What is the purpose of the attribute 'macNeiUpdateAfterRetransmit'?

Please refer to the CPX3 G3 Serial Command Specification section 11.2.

Unless there is a specific reason to change this then Renesas recommends the default value. When TRUE, if the modulation used to communicate with a neighbouring device was different than stored in the Neighbourtable, as described in question 1.55, the modulation actually used will be written to the Neighbourtable for future use (subsequent data exchanges until the re-negotiation of tone map).

## 1.62 What is the purpose of the attribute 'macRefRSSIdB'?

This is a Renesas specific internal attribute. Please do not modify.

## 1.63 What is LML-DATA.indication?

Renesas document System Block Serial Command Specification (r11um0043ej0107-cpx3.pdf) refers to LML-DATA.indication". From the logical point of view the G3-PLC specification is separated into layers and a management plane. There exists the PHY layer, MAC layer and Adaptation layer. In the Renesas solution it is possible to initialize the device into different modes depending on the required operation, EAP mode for G3-PLC compliant PAN Coordinator operation, ADP mode for G3-PLC compliant peer device, MAC mode for other operations, sniffer, optional IHD support etc. MCPS-DATA.indication, or LML-DATA.indication refer to the primitive defined to pass MAC layer data indication to the next upper layer.

## 1.64 What is the purpose of the attribute 'lmlLqiOffset'?

The LQI defined is a parameter associated with the MCPS-DATA.indication, or LML-DATA.indication primitives.

There are different methods for calculating the LQI of a received frame, for example vector based or absolute value based [Peak value]. In a basic concept then the received signal is the desired signal (attenuated and distorted slightly as it is injected and propagates) with some noise (both from the base noise of the receiving device and noise from other devices on the network). The signal can therefore be attenuated or distorted in phase, in an absolute method then we only consider the reduction in peak level, an EVM method considers the distortion in amplitude and phase, considered

as a more accurate method of calculating LQI. In low SNR conditions the effect of EVM is negligible, however when the LQI, or signal SNR, is high the effect of EVM is greater, so a signal with SNR = 20dB (strong signal level) is considered as ratio of amplitude of signal v amplitude of noise, but it doesn't consider the error in any phase shift so any error in phase shift is considered more pronounced.

Any G3-PLC device is likely to induce its own noise, for example from a power supply, called background noise but also likely to introduce some unwanted phase shift contributing to "EVM" noise.

The G3-PLC Alliance tests the performance of each device and one defined test is "2.9 PERF_PHY_009_LQI_COMPUTATION", "This test validates the correct computation of the LQI value by the DUT when receiving frames with a given SNR, following the formula defined in G3-PLC specification §7.17.1.3, which results in LQI = 40 + 4*SNR (valid for SNR between -10 and 53.75 dB)". This test does not compensate for any EVM error, therefore it might be necessary to add on offset to the LQI reported by the MAC layer, such that the tests conducted with high SNR have a return LQI within the expected range of this test case. Note that the offset is applied in all conditions and is applied continually to all LQI reported by the MAC layer, all LQI computations.

This is a hardware dependent attribute and needs adjusted on each design of hardware.

## 1.65 What are the following attributes, and what are they used for, 'plTxPower', 'plTxFilterScale', 'plTxDigitalPreambleGain', 'plTxDigitalGain', 'plTxWaitTime'?

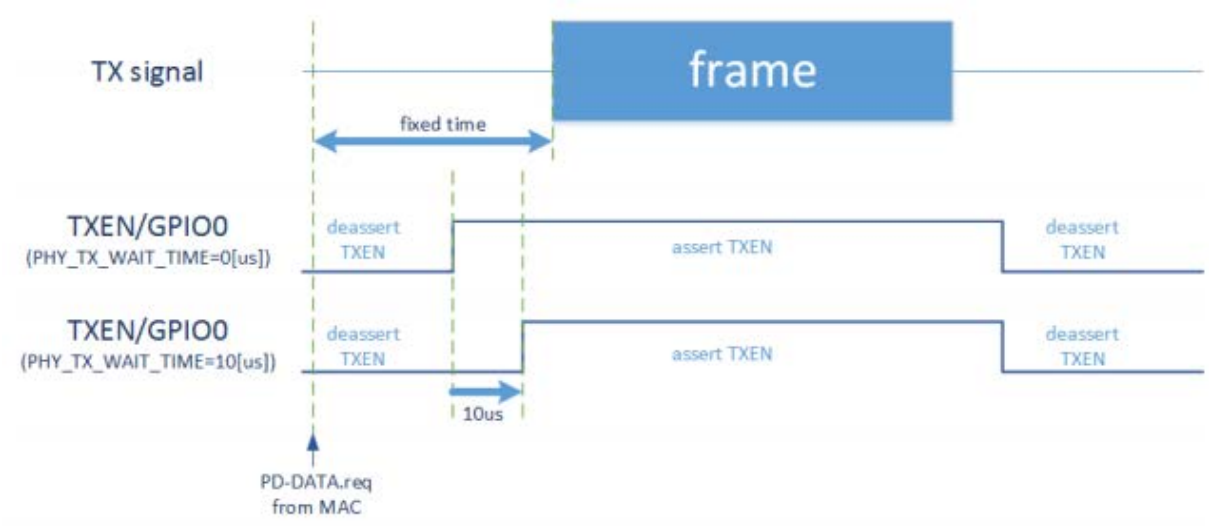
The digital gain and preamble gain, 'plTxDigitalPreambleGain', 'plTxDigitalGain' are settings which can be used to control the digital gain and the ratio of the preamble to payload, the ratio is fixed according to the G3-PLC specification. We do not recommend altering these default values.

The attributes 'plTxPower' and 'plTxFilterScale' are described in question 1.59.

Regarding 'plTXWaitTime', the transmit enable signal TXEN provided by the CPX can be controlled by the attribute '

'plTXWaitTime' as follows. The 'plTXWaitTime' is the delay time for asserting the TXEN. The time from PD-DTAT.request to the head of frame is fixed as long as 'plTXWaitTime' is within a valid range. The valid range is

- G3-CENELEC: 0-70 us
- G3-ARIB/FCC: 0-15 us




## 1.66 What are the following attributes, and what are they used for: 'plSATTCtrlDisable' and 'plSATTPolarity'?

It is possible to use many different power amplifiers with CPX3, such as the NJRC device and the ISL15102 device from Renesas. Please also refer to the NJRC datasheet and the reference schematic for using CPX3 with the ISL15102.

The NJRC device has an internal SATT control integrated, whereas with the ISL15102 Renesas recommends an external discrete circuit.

In an ideal world the injected PLC signal is large, consider a case with PA at 12-15V supply then we would expect an output ~10Vpp, this output level is too large for the input stage of CPX3. Therefore, Renesas recommends some external SATT (attenuation) control (-18dB)

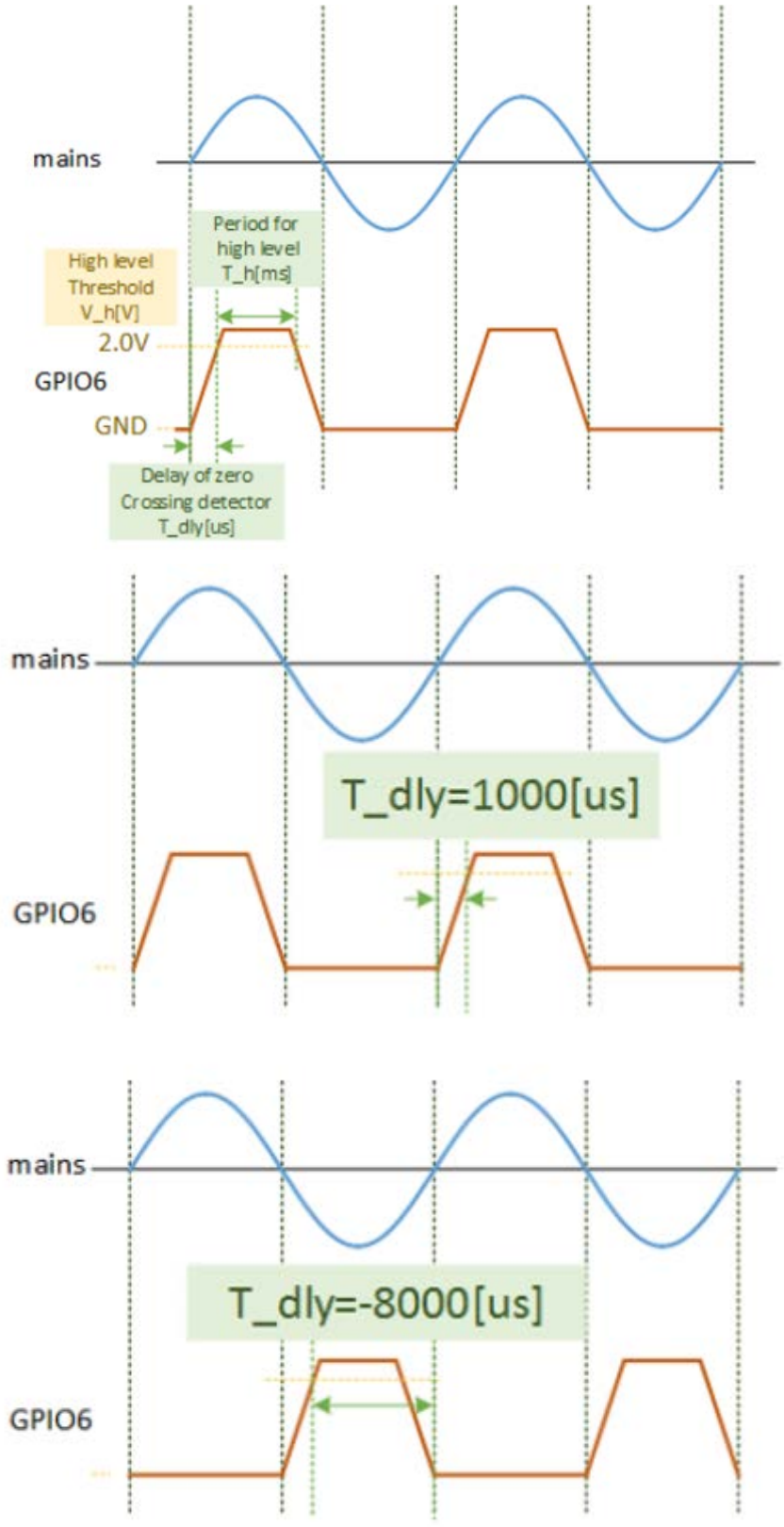
- plSATTCtrlDisable : Disable the SATT control if it is not used, doesn't exist in HW or PA.
- plSATTPolarity : Enables control of polarity for the SATT control, i.e. in the default setting of '1': positive logic [Low: SATT off / High: SATT on]

Some designers consider that the injected PLC signals are lower than the ideal, due to the very low impedance of a PLC network and the inherent attenuation of a PLC signal on a network. Therefore, to save cost remove this section at the risk of performance degradation and system dynamic range.

## 1.67 How can we calculate the proper value for 'plAcPhaseOffset' attribute?

The mismatch between the actual zero cross timing and the rising/falling edge of zero cross signal (GPIO2) produced by a zero cross detector should be measured on every modem board, the plAcPhaseOffset' attribute can then be used to compensate for any difference. The CPX device expects an input signal for the zero crossing detector at its input for zero crossing, it expects a signal with the following conditions:

- Input must be a signal which is converted to a digital level from half-wave rectified signal, see waveform.
- The period for high level T_h [ms] must be greater than 5 ms.
- The high-level threshold is 2.0V.
- The delay of zero crossing detector T_dly [us] which is from the rising zero crossing timing of mains to high level on CPX3 input pin needs to be measured to correct the delay in the DSP.
- The delay of the zero crossing detector T_dly is corrected in the DSP.
- T_dly needs to be set to 'plAcPhaseOffset' of MAC PIB in negative value to correct the delay
    - Example 1: measured T_dly = 1000 [us], plAcPhaseOffset' = -1000 = 0xfc18
    - Example 2: measured T_dly = -8000 [us], plAcPhaseOffset' = 8000 = 0x1f40




## 1.68 What is the ‘plTPgaCAj’ attribute used for?

The TPGACAJ register is used to adjust current of TX PGA inside CPX3. When a CPX3 is used without an external power amplifier, it is necessary to set the register. If using an external power amplifier, this attribute should be kept at the default state of ‘0’.

## Website and Support

Renesas Electronics Website

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Inquiries

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## Revision History

| | | Description | |
|---|---|---|---|
| **Rev.** | **Date** | **Section** | **Summary** |
| 1 | Feb 09, 2021 | All | First release |
| | | | |
| | | | |

## General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Handling of Unused Pins

   Handle unused pins in accordance with the directions given under Handling of Unused Pins in the manual.

   — The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible. Unused pins should be handled as described under Handling of Unused Pins in the manual.

2. Processing at Power-on

   The state of the product is undefined at the moment when power is supplied.

   — The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the moment when power is supplied.
   In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the moment when power is supplied until the reset process is completed.
   In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the moment when power is supplied until the power reaches the level at which resetting has been specified.

3. Prohibition of Access to Reserved Addresses

   Access to reserved addresses is prohibited.

   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

4. Clock Signals

   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has stabilized.

   — When the clock signal is generated with an external resonator (or from an external oscillator) during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Moreover, when switching to a clock signal produced with an external resonator (or by an external oscillator) while program execution is in progress, wait until the target clock signal is stable.

5. Differences between Products

   Before changing from one product to another, i.e. to a product with a different part number, confirm that the change will not lead to problems.

   — The characteristics of Microprocessing unit or Microcontroller unit products in the same group but having a different part number may differ in terms of the internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.