UPLM-M16
PLC MODEM MODULE

OPERATION GUIDE
(DRAFT V1.0)

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Abstract
This Operation Guide describes the usage and setup of the UPLM-M16 Modem Module. The UPLM-M16 is an evaluation board for PLC communication within the CENELEC band.

Introduction
Power line communication (PLC) is a method of communication using the existing electric power transmission and electricity distribution lines in and outside home. The carrier can communicate data by superimposing an analogue signal over the standard 50 or 60Hz main voltage frequency. Each room in a residence provides one, two, or more outlets. These nodes are already available throughout the household, which makes PLC to a low-cost solution, by offering this number of possible gateways. Any device requiring power is already attached to the power line network making PLC convenient and accessible for every user. The four major features for a successful communication solution are:

- Ease to use
- Ubiquitous node availability
- Reliable
- Cost effective

The UPLM-M16 solution delivers all four.

In Europe the CENELEC standard EN50065-1 defines frequency bands for the data transmittion on low-voltage electrical installations. These four bands are located in the frequency range from 3kHz to 148,5kHz.

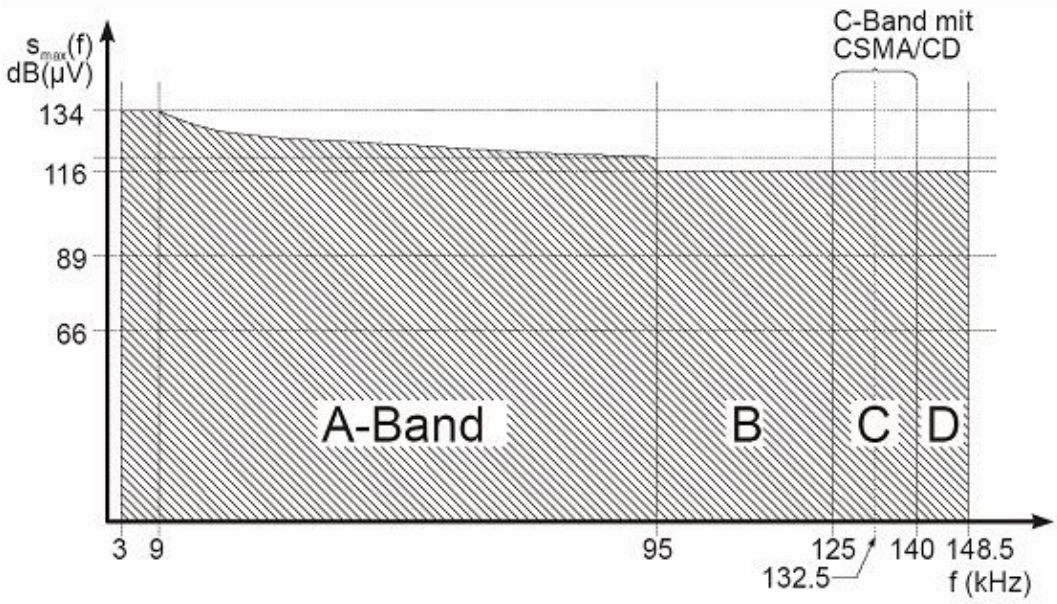


Figure 1: CENELEC band overview

Band	Frequency	Usage	Access protocol
A	3kHz – 95kHz	Outdoor, reserved for energy suppliers	No
B	95kHz – 125kHz	Indoor without Access protocol	No
C	125kHz – 140kHz	Indoor with Access protocol	CSMA/CD
D	140kHz – 148,5kHz	Indoor for alarm and security systems	No

Table 1: Usage of CENELEC band

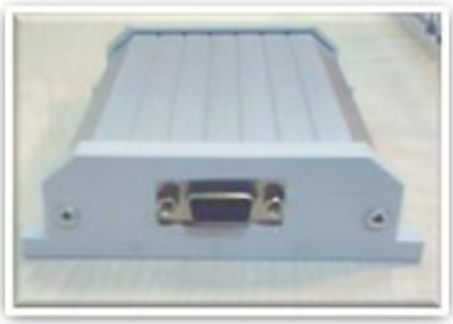
In America and Japan other requirements for the signaling in that lower frequency bands exist.

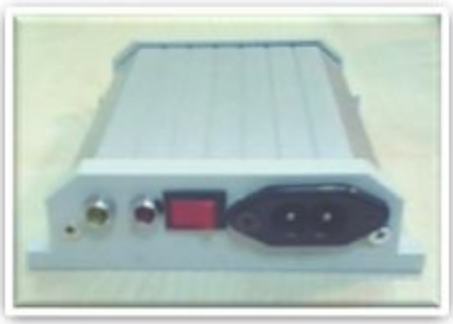
The UPLM-M16 does support the European CENELEC A or B band standard. Only external component have to be modified to adapt to the selected standard.

The UPLM-M16 comes in two versions:
- UPLM-M16-A for the CENELEC A band
- UPLM-M16-B for the CENELEC B band

1. TECHNICAL FEATURES

Modulation	: DCSK (Differential Code Shift Keying)
Frequency A	: 3 kHz – 95 kHz
Frequency B	: 95 kHz – 125 kHz
Data Rate PLC	: Max. 2.5 kbps – Min. 0.62 kbps
Network ID	: Max. 1023
Node ID	: Max. 2047
Communication Port	: RS232
Data Rate Communication Port	: 9.6 kbps
Protocol	: Proprietary udea
Supply	: 220 VAC
RX Led	: Red
TX Led	: Green





2. DATA LINK LAYER

The Data link layer includes the functions of below 2nd layer (Data Link Layer) in OSI reference model. The UPLM-M16 enables extremely robust communication over the existing electrical wiring. The Data Link Layer optimizes the performance of the modem.

Main Functions:

The DLL main functions are as follows:

Function	Description
Carrier sense	Supplies the CD (Carrier Detection) signal for triggering the media access algorithms as a function of the Physical Layer correlator output, which indicates the probability of the existence of transmission on the line.
Channel access prioritization	Determines the sequence and time of packet transmissions in a PLC node, in such manner that the nodes with the highest priority participate in the DLL contention for the media access.
Adaptive back-off	Spreads the time over which a PLC node contends for the channel using a uniform distribution of the transmissions number over a given period of time.
Acknowledgement Transmission Service	Serves for informing the transmitting node about the success or failure of a packet delivery to a target node by means of a traffic-free acknowledgement window
Repetitive un-acknowledgement	Serves for repetitive transmission of a packet in a pre-determined
Transmission Service	Number of times, for which acknowledgement is not expected or required and regardless of the reception status at the receiving node.
Multiple hop broadcast	Retransmits single-network broadcast packets and CNC messages to all the nodes connected to the same logical network using a common ID
Fragmentation and reassembly	Transfers packets longer than the maximum packet size allowed by the Physical Layer by means of fragmentation in the transmitting node and reassembly in the receiving node

3. MEDIA ACCESS CONTROL

3.1. Carrier Sense Mechanism

The carrier sense mechanism provides CD (Carrier Detection) indication for the media access algorithms. The output of the PHY correlator indicates the probability of transmission on the line.
The DLL supports the below mentioned carrier sense mechanisms, each triggered by a different CD indication, as follows:

Signal	Description
UPLM CD	This signal indicates an incoming data byte (rendering a higher probability for transmission start on the line).
X10 CD	This signal supports compatibility with the X10 technology. The X10 CD event indicates to the DLL that an X10 node on the power line has started transmission. In this case the DLL delays its pending transmission for a certain time.

3.2. Channel Access Priority

Prioritized channel access determines the sequence and time of packet transmissions and decreases the probability for exponential access delay, inherent to the standard back-off algorithms. The upper layer assigns priorities to its packets. The PLC nodes use the packet priority and signal the priority according to which they intend to transmit. That way only the highest priority packet nodes are allowed to participate in the DLL contention with other nodes for the media access. Each data packet assumes one of four priority levels before being transmitted over the network: high, normal, above low and low. (The “above low” priority is assigned to the fragmented packet by DLL automatically. The upper layer can not use the “above low” priority.)
On the transmitting side, the DLL protocol makes use of the packet priority to determine when a node, contending with other nodes for media access, can send the packet over the network. The upper layer explicitly defines the packet priority. In case of long packets, the packet priority is set by the DLL itself.

3.3. Adaptive Back-off Algorithm

The adaptive back-off algorithm is based on the back-off procedure of the standard CSMA/CA protocol with the required modifications for optimized performance over the power line. It is designed to manage the channel access using a uniform distribution of the number of transmissions over a given period of time for each network node.

General Description

It is assumed that two or more nodes win the priority contention (have the highest priority) and they will start their transmission only after a random time period. If a node wins the contention then it starts counting a back-off time. The back-off time is intended to spread the time over which nodes contend for the channel. If during the back-off time a packet transmitted by another node is detected (by means of an active CD signal), the node defers transmission for the next contention period. The DLL randomly picks the back-off time from a range of values defined as the Contention Window (CW), specifically calculated by the adaptive back-off algorithm for each packet priority. The node that selects a shorter

back-off time starts transmission, where as the nodes that have randomly selected longer back-off times, wait for the completion of the winner node's transmission.

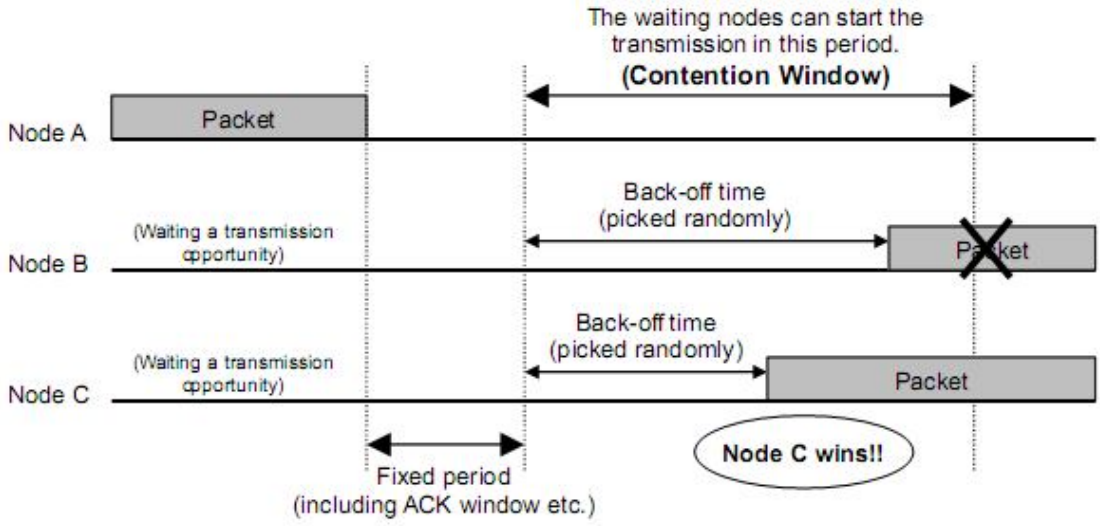


Figure 2: Channel Contention

Overhead Time Optimization

The overhead time for CSMA/CA access is a combination of the silent period, when all nodes defer transmission due to the back-off time and the collision time, when two or more nodes attempt to transmit simultaneously. When reducing the CW, the back-off time decreases, but the collision probability increases. Consequently, a certain CW value minimizes the channel access overhead ("wasted" time). The adaptive back-off algorithm always uses optimal CW value under any conditions.

4. PAKET DELIVERY SERVICE

4.1. Transmitter Queue

Queue Types

The DLL transmitter has two queues for outgoing packets: transmission queue and quarantine queue.The transmission queue contains packets to be transmitted immediately. The quarantine queue holds packets that had been transmitted and acknowledged by the receiving node, but with acknowledge that indicates that the packet was not delivered to the upper layer due to out-of-resources condition of the DLL at the receiving node.

Transmitter Queues Algorithm

If the target node receives a data packet from the channel, but has no free memory buffer for processing it, then it sends an out-of-resources acknowledgement to the source node (the node that transmitted the packet). An out-of-resources signal is sent only for unicast transmissions using the acknowledgement service. The transmitter node that received out-of-resources signal places the data packet to a quarantine queue for a certain quarantine period. During the period, the target node is expected to free its memory buffers for receiving the new packet. After the period expires, the DLL transmitter attempts re-sending the packet to the target node.

4.2. Acknowledgement Service

The DLL protocol makes use of the acknowledgement service to inform the transmitting node of a successful delivery or of a failure in delivery of a packet to a target node. If the packet has not been acknowledged, then the DLL re-contends for the channel in order to retransmit the packet.

A successful completion of the transmission service requires that:

- The PHY of the target node detects an error-free packet using CRC16 code.
- The destination address matches the target node address.

The target node returns an acknowledgement when the above-mentioned two conditions are met.

If no acknowledgement is received, then the DLL attempts retransmission until the number of attempts equals the value of the appropriate parameter. Each retransmission requires a new contention for the channel using the regular channel access protocol.

Although multiple copies of the packet may be received because of retransmissions, the packet sequence number ensures that only a single copy of the received packet is transferred to the upper layer.

Acknowledgement Packet Type

The acknowledgement protocol supports two types of packets as follows:

Packet Type	The target node DLL returns
Normal	A normal acknowledgement packet if the original packet was received correctly; it does not contend for media access like data packets.
Out-of-resources	An out-of-resources acknowledgement when it receives a data packet but has no memory buffers for processing it.

Discard Duplicate Packets

Since a packet may be transmitted to the same destination address several times, a DLL procedure for discarding received packet duplicates at the receiving node is implemented.

This procedure employs the sequence number and the source node ID for detecting a duplicate packet. All retransmitted packets from a certain node have the same sequence number (0 to 3) and source node ID.

The receiving node DLL makes use of these two parameters for rejecting all duplicate packets possible sent by the transmitting node as a result of packet retransmissions.

4.3. Repetitive Un-acknowledgement Service

The repetitive un-acknowledgement service is employed when an acknowledgement from the receiving node or nodes is not required.

Repetitive Un-acknowledgement Service Description

The service is used for sending broadcast or Unicast packets.

The service is useful for transmitting to a single node, to a group of nodes, or to the broadcast address (all network nodes). The number of times the DLL transmitter sends a packet is determined by the value of the appropriate parameter. On the transmitting side, the DLL protocol contends for the channel access on each transmission. On the reveiving side, the DLL protocol transfers only one copy of the packet to the upper layer.

4.4. Message Broadcast Service

Broadcast Packet Types

The node can retransmit single-network broadcast packets and Control Network Channel (CNC) messages. To prevent a node from repetitive retransmissions of the same packet, the DLL protocol registers each retransmitted packet.

A single network broadcast packet is sent to all the nodes in the same logical network.

A CNC message is a broadcast packet that is sent to all the nodes connected to the same physical network. This type of packet is used to broadcast messages to all the connected nodes regardless of their network ID.

Multiple Hop Broadcast Algorithm

Multiple hop broadcast transmission method allows for retransmission of broadcast messages by the receiving nodes. The number of hops is configured by the original transmitting node. Each node may transmit the packet once.

If the network ID in the packet header is not equal to the recipient node network ID, the node does not retransmit the packet.

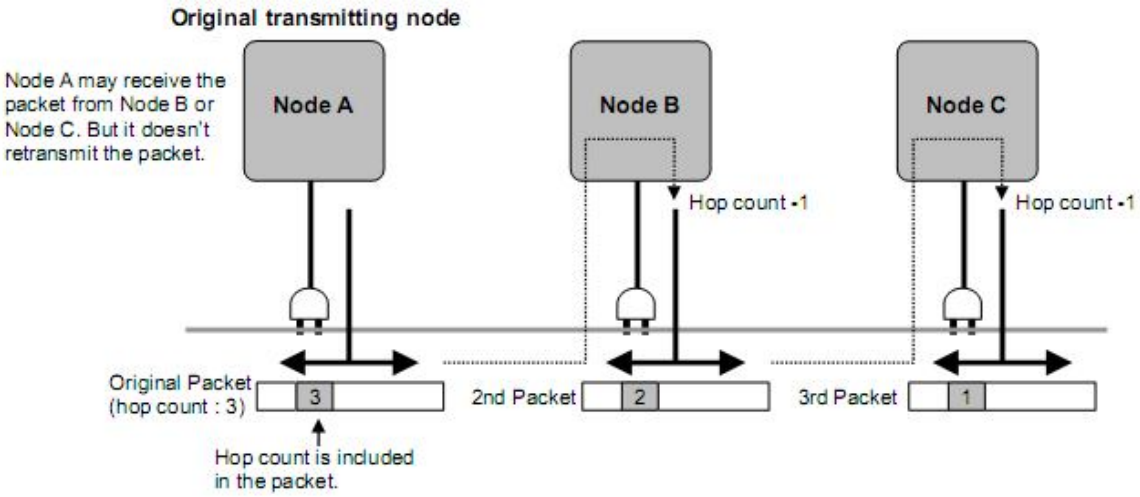


Figure 3: Multiple Hop Broadcast

CNC Service

A CNC (Control Network Channel) a cross-network broadcast, received by all nodes regardless of their network ID (or lack of network ID).

The CNC service is useful for introducing a new node to a network or transmitting a single-network broadcast message to all nodes connected to a physical network regardless of their network ID.

A new node has no assigned address, thus it is unable to receive Unicast and single-network broadcast packets.

However it can communicate with the nodes connected to the same physical medium using CNC cross-network broadcast packets.

A node filters out duplicate CNC packets.

4.5. Fragmentation and Reassembly Mechanism

General Data

The DLL protocol implements a mechanism of fragmentation in the transmitting node and reassembly in the receiving node in order to transfer packets longer than the maximum packet size allowed by the Physical Layer.

The maximal length of the Physical Layer packet payload is 127 bytes. The DLL uses this space for its header and payload. The size of the DLL header depends on the packet type. The maximum length of the DLL packet payload is restricted to 110 bytes. The DLL protocol supports 16 fragments of 110 bytes for a message length of 1760 bytes maximum per long packet.

Fragmentation and Reassembly Algorithm

When broadcasting a fragment, the repetitive un-acknowledgement service is used. If the transmitting side is unable to deliver one of the fragments to the receiving side, the whole packet is abandoned. The remaining fragments are not transmitted and the upper layer is informed about the unsuccessful transmission.

On the receiving side, a reassembly buffer is implemented for reassembling the long packet before transferring it to the Upper Layer.

Receiving a non-sequential fragment occurs if one or more fragments are missing during the assembly process. In this case, the receiver side ignores all other incoming fragments belonging to the same long packet, drops the assembly process and frees the reassembly buffer. All next fragments of the long packet are acknowledged and discarded immediately after reception by the DLL. The transmitter is not notified about the reassembly failure on the receiver side.

If the transmitting side does not receive an acknowledgement for a transmitted fragment, it attempts re-transmission of the fragment a few times as defined by ackRetry. If all attempts fail, the transmitter abandons transmission of the long packet. On the receiving side, the DLL protocol waits for reassembly completion for a certain period of time before freeing the reassembly buffer.

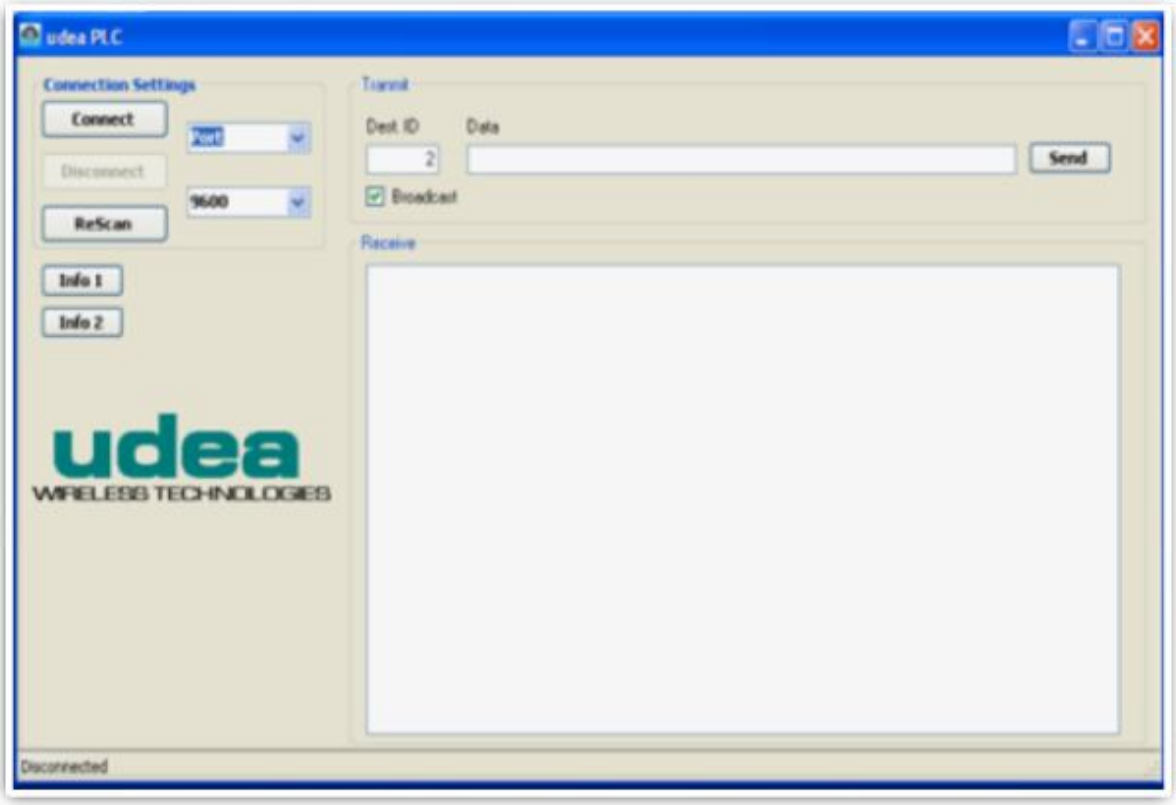
5. MAC COMMAND FRAME

COMMAND	COMMAND FRAME	FUNCTION
ID command	<C> <NIDXXXX> <$0D>	C: command header NIDXXXX: network ID (XXXX = 1 – 1023) $0D : enter code
	<C> <SIDXXXX> <$0D>	C: command header SIDXXXX: source node ID (XXXX = 1 – 2047) $0D : enter code
Transmission commands	<C> <TXR1><$0D>	C: command header TXR1 : auto transmission rate $0D : enter code
	<C> <TXR2><$0D>	C: command header TXR2 : rate is robust 2.5kbps $0D : enter code
	<C> <TXR3><$0D>	C: command header TXR2 : rate is exterme robust 0.625kbps $0D : enter code

Transmission mode command	<C> <EACK><$0D>	C: command header EACK : Enable ACK Mode $0D : enter code
	<C> <DACK><$0D>	C: command header DACK : Enable NACK Mode $0D : enter code
Send data commands	<D> <DID> <SEND DATA STREAM><$0D>	D: Unicast transmit for command header DID : destination node ID (0001 – 2047) SEND DATA STREAM : send data max 120 char $0D : enter code
	<B> <DID> <SEND DATA STREAM> <$0D>	B: Broadcast transmit for command header DID : destination node ID (0001 – 2047) SEND DATA STREAM : send data max 120 char $0D : enter code
	<C><EACK><$0D>	EACK: Enable ACK mode
	<C><DACK><$0D>	DACK: Enable NACK mode
User command	<C><k><$0D>	NID, SID and DID show
	<C><h><$0D>	All parameters is show

Using the minimal Test Software

The minimal test Software enables you to setup two nodes within your power line network. Depending on your selection in a menu, one node will be the sender of information and the other one will be the receiver. The transmitting node is sending a given number of data packets at a specific transfer speed and the receiving node is counting the received number of packets.



PRECAUTIONS FOR SAFETY

Naturally, if you talk of power line communication you talk also about high voltages. Therefore you should be aware about the risk of accidentally touching high voltages. Please handle this evaluation product with care.

Warning

If the requirements shown in the "WARNING" sentences are ignored, the equipment may cause serious personal injury or death.

Caution

If the requirements shown in the "CAUTION" sentences are ignored, the equipment may malfunction.

Important

It means important information on using this product.

In addition to the three above, the following are also used as appropriate.

means WARNING or CAUTION.

CAUTION AGAINST AN ELECTRIC SHOCK

means PROHIBITION

DISASSEMBLY PROHIBITED

means A FORCIBLE ACTION

UNPLUG THE POWER CABLE FROM THE RECEPTACLE.

Warnings for AC Power Supply:

• If the attached AC power cable does not fit the receptacle, do not alter the AC power cable and do not plug it forcibly. Failure to comply may cause electric shock and/or fire.

• When using outside Europe, use AC power cable which complies with the safety standard of the country.

• When it is not possible to prepare for the AC power cable, contact your local distributor.

• Do not touch the plug of the AC power cable when your hands are wet. This may cause electric shock.

• This product is connected signal ground with frame ground. If your developing product is transform less (not having isolation transformer of AC power), this may cause electric shock. Also, this may give an unrepairable damage to this product and your developing one. While developing, connect AC power of the product to commercial power through isolation transformer in order to avoid these dangers.

• When installing this equipment, insure that a reliable ground connection is maintained.

• If you smell a strange odor, hear an unusual sound, or see smoke coming from this product, then disconnect power immediately by unplugging the AC power cable from the outlet. Do not use this as it is because of the danger of electric shock and/or fire.

Warnings to Be Taken for This Product:

• Do not disassemble or modify this product. Personal injury due to electric shock may occur if this product is disassembled and modified.

• Make sure nothing falls onto the product, especially liquids, metal objects, or anything combustible.

Revision Record

Rev.	Date	Description		
		Section	Changed by	Summery
Rev.V.1.0A	01.06.2008	all	IU	First edition issued