Multiplexer
3GPP 27.010 Mux implementation in Wireless Modules
Application Note

Abstract

This document provides some basic multiplexer information and a short description of how to implement a multiplexer driver according to 3GPP TS 27.010. This document should help customers to develop their proprietary multiplexer driver for communication with u-blox wireless modules using several virtual channels simultaneously.

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Document Information

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Contents

1 Introduction

This document describes the implementation of the multiplexer protocol for wireless modules. The following symbols are used to highlight important information within the document:

☞   An index finger points out key information pertaining to integration and performance.

⚠️   **A warning symbol indicates actions that could negatively impact performance or damage the device.**

☞   This document applies to the following products:
- o   LEON-G100
- o   LEON-G200
- o   LISA-U1 series
- o   LISA-U2 series

u-blox wireless modules support the 3GPP 27.010 Multiplexer protocol. It is possible to emulate several virtual connection channels on a single physical interface to access the module concurrently (e.g. it is possible to read phonebook contacts while receiving GPRS data).

Each channel between the TE and UE is called a Data Link Connection (DLC) and is separately and sequentially established.

The multiplexer has three operating options:

- basic
- advanced without error recovery
- advanced with error recovery

Wireless modules support only the basic mode. The virtual channels are configured for the following functionalities:

- DLC1 – DLC5: AT commands / data connection
- DLC6: GPS tunneling

All LISA-U2 series modules versions except LISA-U200-00S provide an additional channel:

- DLC7: SIM Access Profile dedicated port

Moreover a control channel (DLC0) is defined for conveying information between the two multiplexers.

1.1 Features and limitations

- Multiplexer Basic Option compliant to 3GPP 27.010 Technical Specification [3] is supported. All the required features are supported, within the limits identified in this document. If not specified in the document, the optional features described in 3GPP specification are not supported
- Multiplexer can operate only at a fixed baud-rate. Once AT+CMUX is sent and autobauding is active (AT+IPR=0, where applicable), a switch to fixed rate is performed as soon as the multiplexer protocol is successfully activated. It is strongly recommended to enable the highest baud-rate supported by the UE
- Every instance has its own user profile. For additional information see chapter 4

- Every instance has its own independent flow control, implemented by means of FCON/FCOFF packets (3GPP 27.010 Technical Specification [3])

- Software Flow control (XOn/XOff) on the DLCs is not supported and should be disabled

- Multiplexer Power control and wake-up mechanism (as described in the 3GPP 27.010 Technical Specification [3]) is not supported. If power saving is enabled, power saving information towards the TE is indicated by the module CTS line (module output)

- It is recommended to use Hardware Flow Control (RTS/CTS) on the multiplexer physical port. If the ME power saving is enabled (e.g. AT+UPSV=1) and the UART interface is used this configuration is mandatory

- The (optional) Multiplexer Remote Port Negotiation Command is supported, but the DLCs priority is ignored

- Service Negotiation Command is not supported

- Multiplexer timers and retransmission (T1, T2, T3, and N2, see 3GPP 27.010 Technical Specification [3]) have limited support. See chapter 2 for details

- Multiplexer protocol can be activated over SPI interface (where available)

- No need to use multiplexer protocol with USB interface (where available). USB multiplexing capability based on multiple CDCs should be used

- Multiplexer is supported only on UART and SPI interfaces. Only one interface can be used at a time

2 System Parameters

Multiplexer operation is started by the +CMUX AT command. This command instructs the multiplexer to start up the multiplexer control channel. The TE multiplexer initiates this by sending an SABM frame on DLCI 0.

Once the multiplexer channel is established, other DLCs can be established. The multiplexer may negotiate the parameters associated with each DLC prior to its establishment, or use the default values.

System parameters T1, N1, N2 and k parameters can be configured by the multiplexer control channel or the default values given here can be used. System parameters T2 and T3 are set with the +CMUX AT command.

☞   For LISA modules, timers and retransmission mechanism are not implemented.

☞   For more details about the syntax command, please refer to u-blox AT Commands Manual [1] and AT Commands Examples Application Note [2].

2.1 Acknowledgement Timer (T1)

The acknowledgement timer governs the time that a station waits for an acknowledgement before resorting to other action (e.g. transmitting a frame). The two stations may operate with different T1 values.

☞   For LEON modules this value is fixed at 253.

☞   For LISA modules the T1 timer is not implemented and the requested T1 value is ignored.

2.2 Maximum Frame Size (N1)

N1 defines the maximum number of octets that may be contained in an information field. It does not include octets added for transparency purposes.

The default value for the basic mode is 31 octets. The range is from 1 to 1509 octets.

2.3 Maximum number of retransmissions (N2)

N2 defines the maximum number of times that a station re-attempts a procedure requiring a response. The two stations may operate with a different value of N2.

☞   For LEON modules the range is 0-5, with the default value at 3.

☞   For LISA modules the retransmission mechanism is not implemented and the requested N2 value is ignored.

2.4 Window Size (k)

The window size parameter (k) defines the maximum number of I frames that a DLC can have outstanding. Since u-blox wireless modules support only the MUX basic mode (which doesn't implement the Error Recovery Option) this parameter is not supported.

2.5 Response Timer for multiplexer control channel (T2)

T2 timer is the amount of time that the multiplexer control channel waits before re-transmitting a command. T2 must be greater than T1.

☞   For LEON modules this value is fixed at 254.

☞   For LISA modules the T2 timer is not implemented; the requested T2 value is ignored.

2.6 Response Timer for wake-up procedure (T3)

T3 timer is the amount of time that the transmitting station of a power wake-up command waits before raising an alarm when no response is received. This parameter is not supported.

3 Multiplexer packet format for basic option

Frame structure in basic mode:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
1 octet	1 octet	1 octet	1 or 2 octets	Unspecified length but integral number of octets	1 octet	1 octet

Table 1: Frame Structure for Basic option

Opening and closing flags may appear in the information field of the frame. They cannot be used to determine the beginning and end of a frame. The Length Indicator for the frame must be used.

☞ In this document and in the 3GPP 27.010 Technical Specification [3] the bit fields are represented from the less significant bit (leftmost one) to more significant (rightmost one): B1(LSB) B2 B3 B4 B5 B6 B7 B8(MSB).

3.1 Flag

Flags (when included in the frame) have always value 0xF9.

3.2 Address

Address field contains the Data Link Connection Identifier (DLCI), the C/R bit and the address field extension bit (always 1). The C/R (command/response) bit identifies the frame as either a command or a response

Bit No.	1	2	3	4	5	6	7	8
	EA	C/R		D	L	C	I	

Table 2: Format of Address Field

DLCI identifies an individual user information stream as well as to identify connections between the TE and UE. Multiple DLCIs shall be supported but the number is implementation-specific. The DLCIs are dynamically assigned.

3.3 Control

The content of the control field defines the type of frame. The control fields of the frames are described in Table 3.

Frame Type	1	2	3	4	5	6	7	8	Notes
SABM (Set Asynchronous Balanced Mode)	1	1	1	1	P/F	1	0	0	
UA (Unnumbered Acknowledgement)	1	1	0	0	P/F	1	1	0	
DM (Disconnected Mode)	1	1	1	1	P/F	0	0	0	
DISC (Disconnect)	1	1	0	0	P/F	0	1	0	
UIH (Unnumbered Information with Header check)	1	1	1	1	P/F	1	1	1	
UI (Unnumbered Information)	1	1	0	0	P/F	0	0	0	Optional

Table 3: Coding of Control Field

In Table 3, P/F is the Poll/Final bit.

The poll (P) bit set to 1 shall be used by a station to solicit (poll) a response or sequence of responses from the other station.

The final (F) bit set to 1 shall be used by a station to indicate the response frame transmitted as the result of a soliciting (poll) command.

The poll/final (P/F) bit shall serve a function in both command frames and response frames (in command frames, the P/F bit is referred to as the P bit; in response frames, it is referred to as the F bit).

3.3.1 Set Asynchronous Balanced Mode (SABM) command

SABM command sets the addressed station to Asynchronous Balanced Mode (ABM) where all control fields shall be one octet in length. The station shall confirm acceptance of the SABM command by transmission of a UA response at the first opportunity. Upon acceptance of this command, the DLC sends and receives state variables that shall be set to zero.

3.3.2 Unnumbered Acknowledgement (UA) response

UA response is used by the station to acknowledge the receipt and acceptance of SABM and DISC commands.

3.3.3 Disconnected Mode (DM) response

DM response reports a status where the station is logically disconnected from the data link. When in disconnected mode no commands are accepted until the disconnected mode is terminated by the receipt of an SABM command. If a DISC command is received while in disconnected mode a DM response should be sent.

3.3.4 Disconnect (DISC) command

DISC command terminates an operational or initialization mode previously set by a command. It shall be used to inform one station that the other station is suspending operation and that the station should assume a logically disconnected mode. Prior to executing the command, the receiving station shall confirm the acceptance of the DISC command by the transmission of a UA response.

3.3.5 Unnumbered information with header check (UIH) command and response

UIH command/response sends information without affecting the V(S) or V(R) variables at either station. UIH is used where the integrity of the information being transferred is of lesser importance than its delivery to the correct DLCI. For the UIH frame, the FCS shall be calculated over only the address, control and length fields.

Reception of the UIH command/response is a non-sequential number verified by the data link procedures; therefore, the UIH frame can be lost if a data link exception occurs during transmission of the protected portion of the command, or duplicated if an exception condition occurs during any reply to the command. There is no specified response to the UIH command/response.

3.3.6 Unnumbered Information (UI) command and response

Support of UI frames is optional and the wireless modules do not implement it.

3.4 Length Indicator

It has the following format:

Bit	1	2	3	4	5	6	7	8
	E/A	L1	L2	L3	L4	L5	L6	L7

Table 4: Length field, first byte

L1 to L7 bits indicate the length of the following data field. The default length is 31 bytes.

When the EA bit is set to 1 in an octet, it signifies that this octet is the last octet of the length field. When the EA bit is set to 0, it signifies that a second octet of the length field follows. The total length of the length field is in that case 15 bits, L1-L15.

The second octet of the length field (only present when the EA field in the first byte is set to 0) format:

Bit	1	2	3	4	5	6	7	8
	L8	L9	L10	L11	L12	L13	L14	L15

Table 5: Length field, second byte

The length field shall always be present, even if the data field is empty.

3.5 Information Field

The information field is the payload of the frame and carries the user data and any convergence layer information. The field is octet structured. The information field is only present in UI frames and UIH frames.

3.6 Frame Checking Sequence Field (FCS)

The Frame Checking Sequence Field (FCS) is a checksum of the payload.

The FCS shall be the ones complement of the sum (modulo 2) of:

a)   the remainder of
$x^k (x^7 + x^6 + x^5 + x^4 + x^3 + x^2 + x^1 + 1)$
divided (modulo 2) by the generator polynomial
$x^8 + x^2 + x + 1,$

where k is the number of bits in the frame existing between, but not including, the final bit of the opening flag and the first bit of the FCS, excluding start and stop elements (start/stop transmission), and bits (synchronous transmission) and octets (start/stop transmission) inserted for transparency, and

b)   the   remainder   of   the   division   (modulo   2)   by   the   generator   polynomial
$x^8 + x^2 + x + 1$

of the product of x^8 by the content of the frame existing between, but not including, the final bit of the opening flag and the first bit of the FCS, excluding start and stop elements (start/stop transmission), and bits (synchronous transmission) and octets (start/stop transmission) inserted for transparency.

In the case of the UIH frame, the contents of the I-field shall not be included in the FCS calculation. FCS is calculated on the contents of the address, control and length fields only. This means that only the delivery to the correct DLCI is protected, but not the information. The FCS is calculated in the normal manner for all other frames in Table 3.

4 AT command / data interface

4.1 AT command profiles

When using the AT command interface over a Multiplexer channel the following notes should be considered:

* Every virtual channel has its own AT profile

* The +UPSV is the only profile field that is shared among all channels (both virtual and physical). A change of this parameter for any channel applies to all other channels

* The power saving configuration selected by means of the AT+UPSV command acts directly on the physical device and therefore it is effective even if it is issued on a virtual channel. Since the mode is shared among all the channels (virtual or not), each channel has the capability of modifying the power saving configuration

* AT&K and AT+IFC commands are applied to the Multiplexer virtual devices; this means that they configure the Multiplexer protocol to enable/disable the flow control via FCON/FCOFF packets on the selected DLC

* The commands AT+ICF and AT+IPR are ignored by the module if the multiplexer is active. It is possible to read/write value (OK is returned and profile updated) but they have no effect on the behavior of the module

* Using the Software Flow control (XOn/XOff) on virtual channels is not allowed. All the commands trying to set this mode are refused and a message error is returned

☞ AT channels are dynamically attached/detached in the multiplexer protocol. Each ATTACH operation results in a profile reload from the NVM. Therefore, a profile change (and in particular a change of the +UPSV parameter) in one open channel due to open/close operations of another channel is not to be unexpected. In the same way, when all the virtual channels are closed and the multiplexer protocol is uninstalled, the channel associated with the physical device is reattached; this also results in a profile reload.

4.2 UART lines state during MUX protocol execution

As described in 3GPP 27.010 Technical Specification [3] the Multiplexer protocol implemented in u-blox wireless modules specifies that the notification of any change in the ITU-T V.24 lines is performed via a proper MSC packet.

☞ If the multiplexer protocol is activated on the UART interface, the handling of UART RING and DCD physical output (from the module) lines is implemented. The two lines are physically driven in the same way as without multiplexer protocol. For these lines both MSC packet sending and physical line switch are implemented.

This implementation ensures a high level of host responsiveness to module notified events such as incoming call or establishment of a data call (e.g. the host could be in power saving mode and be rapidly woken up by an event notification using a line toggling).

5 Linux reference driver

Below is a brief description of a Multiplexer host driver for Linux systems. This can be used as a reference for developing a proprietary Multiplexer driver since most parts of the code are machine independent.

5.1 Gsm0710.c
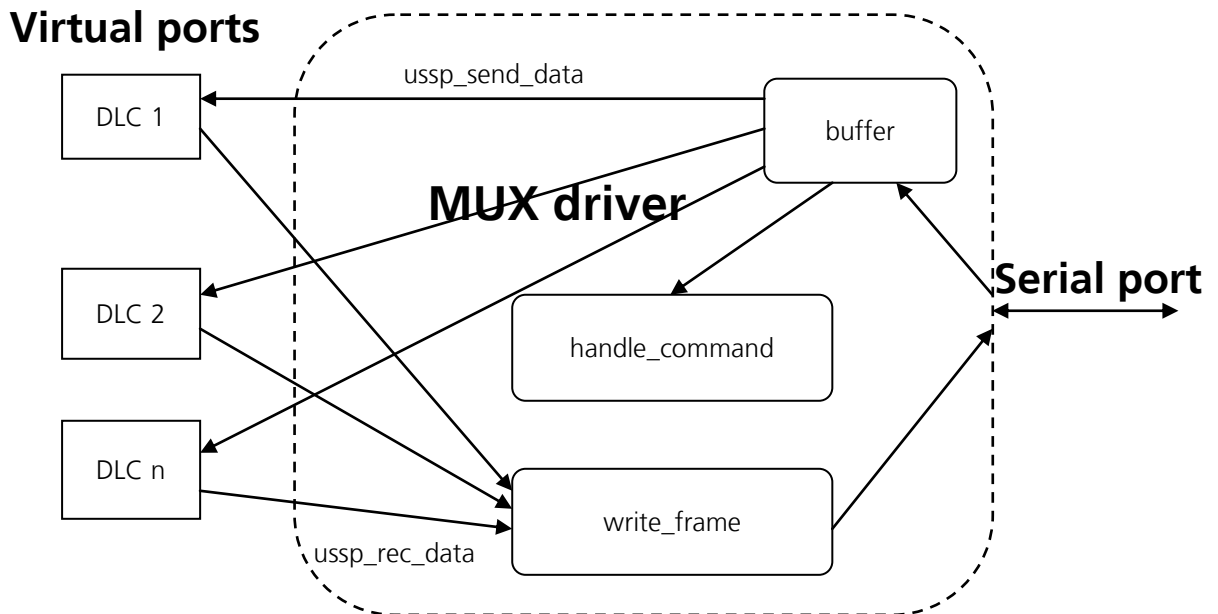
5.1.1 Main

The main program performs the following:

1. Parses the command line arguments: sets some global variable and perhaps calls "usage" function to show the help
2. It goes to background or not (in the daemonize() function) depending on command line parameters
3. Allocates memory for the structures used by the driver
4. Starts Mux protocol and initializes virtual ports: this part is handled by "openDevicesAndMuxMode" function (see chapter 5.1.2)
5. Continuously reads data from the TE serial port and writes it to the buffer (gsm0710_buffer_write), then extracts from it the single frames and forwards the payload (extract_frames) to the correct virtual channel (ussp_send_data) or performs a control action (handle_command). It also reads data from the virtual channels and writes it to the TE serial port (ussp_recv_data).
6. When terminated, it frees the allocated resources and closes the virtual ports and the Mux protocol

5.1.2 openDevicesAndMuxMode

This part is Linux dependent; it creates symbolic links for the virtual ports and configures their parameters ("open_pty" function).

It opens and configures the physical serial port in "open_serialport" function.

Once the port is open it sends a simple "AT" command and waits for the OK answer, then it sends the Mux activation command (AT+CMUX=....), this part is handled by "initGeneric" function.

When the Mux protocol is established, it opens the virtual channels.

5.2 Buffer

This file contains general utility functions to manage data from/to the TE and to parse/from mux packets. These functions are platform independent. The functions that are mainly used are:

- gsm0710_buffer_init: Allocates memory for a new buffer and initializes it
- gsm0710_buffer_destroy: Frees allocated memory
- gsm0710_buffer_write: Writes data to the buffer
- gsm0710_buffer_get_frame: Gets a frame from buffer
- destroy_frame: Destroys a frame (free the memory allocated by gsm0710_buffer_get_frame)
- make_fcs: Calculates frame check sequence from given characters

6 Notes for developers

6.1 Enabling Multiplexer trace messages

For debugging purposes a special trace of the multiplexer protocol can be enabled.

LEON-G100 / LEON-G200 series	LISA-U1 / LISA-U2 series	Description
AT+XL1SET="muxtron"	AT+UMUX=1,11,255	Enable the trace
AT+XL1SET="muxtroff"	AT+UMUX=0	Disable the trace

AT+UMUX offers a higher granularity in the multiplexer trace activation. Please refer to Appendix C.1 for a complete command description.

This trace provides information (in form of ASCII output) about the multiplexer packets passing on the UART and on the DLCs.

☞ On LEON-G100-07 and subsequent versions, the "muxtron:<value>" command is available. Please refer to Appendix C.2 for the description.

6.2 Frame size

If the host driver sends packets bigger than the Maximum Frame Size (for more details please refer to chapter 2.2) the module ignores the packets without returning any error.

6.3 Flow Control on virtual channels

The flow control of the virtual channel is implemented in terms of MSC packets with the FC bit. If the application processor sets the FC bit to 1 for a particular DLC, the TE does not send data to the application processor for that DLC until FC returns to 0 for the same DLC. The TE has limited resources for buffering data, so if the DLC is involved in large data transfers (for example downloading data through a GPRS connection) a buffer overflow may occur if the time between FC=1 and FC=0 is too long; in this case data may be lost and there is no error indication.

The application processor should avoid (if possible) the use of this feature or keep the time interval with the FC=1 as small as possible.

Appendix

A List of Acronyms

Abbreviation / Term	Explanation / Definition
3GPP	3rd Generation Partnership Project
ASCII	American Standard Code for Information Interchange
AT	AT Command Interpreter Software Subsystem, or attention
ABM	Asynchronous Balanced Mode
C/R	Command/Response
CDC	Communications Device Class
CTS	Clear To Send
DISC	Disconnect
DLC	Data Link Connection
DLCI	Data Link Connection Identifier
DM	Disconnected Mode
EA	Extended Address
FCON	Flow Control ON
FCOFF	Flow Control OFF
FCS	Frame Check Sequence
GPS	Global Positioning System
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
LSB	Least significant bit
MSB	Most Significant Bit
MSC	Modem Status Command
NVM	Non Volatile Memory
P/F	Poll/Final
PC	Personal Computer
RAM	Random Access Memory
SABM	Set Asynchronous Balanced Mode
SMS	Short Message Service
TE	Terminal Equipment
UA	Unnumbered Acknowledgement
UART	Universal Asynchronous Receiver-Transmitter
UE	User Equipment
UI	Unnumbered Information
UIH	Unnumbered Information with header Check
USB	Universal Serial Bus

B Multiplexer transactions example

From host driver SABM frame on DLCI0:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	03	F3	01	-	1C	F9

From host driver UA frame on DLC0, modem status command:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	03	EF	0B	E3 07 07 8C 01	18	F9

From host driver SABM frame on DLCI1:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	07	3F	01	-	DE	F9

From host driver UA frame on DLCI1, modem status command:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	07	EF	0B	E3 07 07 8C 01	DA	F9

From modem UA (answer to SABM) on DLCI0

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	03	73	01	-	D7	F9

From modem UIH frame on DLC0, modem status command:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	01	EF	0B	E1 07 07 8C 01	79	F9

From modem UA (answer to SABM) on DLCI1

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	07	73	01	-	15	F9

From modem UIH frame on DLC1, modem status command:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	05	EF	0B	E3 07 07 8C 01	BB	F9

From host driver UIH frame on DLCI1, "AT+CPIN?":

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	07	EF	13	61 74 2B 63 70 69 6E 3F 0D	C8	F9

From modem UIH frame on DLC1, "+CPIN: READY":

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	05	EF	21	0D 0A 2B 43 50 49 4E 3A 20 52 45 41 44 59 0D	6E	F9

C Multiplexer debug command

These icons are used to indicate applicability to the related products:

- **LEON** : LEON-G100 / LEON-G200 series

- **LISA** : LISA-U1 / LISA-U2 series

C.1 Multiplexing mode +UMUX

LISA

Allows setting the multiplexer protocol's trace (debug) capabilities. For each DLC both a global and a local trace level can be set.

☞   The command is used only for testing / debugging purpose.

Type	Syntax	Response	Example
Set	AT+UMUX=[<action>[,<p1>][,<p2>][,<p3>][,<p4>][,<p5>][,<p6>][,<p7>][,<p8>][,<p9>][,<p10>]]	OK	AT+UMUX=1,4,255 OK
Read	AT+UMUX?	+UMUX: <action>,<p1>,<p2>,<p3>,<p4>,<p5>,<p6>,<p7>,<p8>,<p9>,<p10> OK	+UMUX: 1,5,255,0,0,0,0,0,0,0,0 OK
Test	AT+UMUX=?	+UMUX: (list of supported <actions>), (list of supported <p1's>), (list of supported <p2's>), (list of supported <p3's>), (list of supported <p4's>), (list of supported <p5's>), (list of supported <p6's>), (list of supported <p7's>), (list of supported <p8's>), (list of supported <p9's>), (list of supported <p10's>) OK	+UMUX: (0,1),(0-4,11),(0-65535),,,,,,,, OK

C.1.1 Defined Values

Parameter	Type	Description
<action>	Number	Operation to be performed • 0: disable MUX trace (default value) • 1: enable MUX trace

Parameter	Type	Description
<p1>	Number	Global trace level • 0: no global trace • 1-2: low trace load • 3: auxiliary trace (data dump) • 4: statistics trace • 5: power saving trace • 11: error detection trace All the trace capabilities for a p1 value are included in case higher values are selected
<p2>	Number	Mask for selective activation of the local trace capabilities over the supported DLCs • 0 : no local traces • >0: set p1 local trace for the DLCs for which (p2 & (1<<DLC_x==1)) The local trace is only generated in case of p1>1
<p3>-<p10>	Number	Extended trace options (not supported) The read command always returns 0 for these parameters.

C.2 "muxtron:<value>" description

LEON

☞ Not supported by LEON-G100-06 / LEON-G200-06 and previous version.

Allows setting the multiplexer protocol's trace (debug) capabilities, with a configurable trace level.

☞ The command is used only for testing / debugging purpose.

☞ The multiplexer protocol debug information requires that trace capability is activated on the module; trace data must be collected on the serial interface configured as debug interface. If the trace data is filtered, keep the ASCII trace and the "mux" process traces active.

Type	Syntax	Response	Example
Set	AT+XL1SET="muxtron:<value>"	OK	AT+XL1SET="muxtron:1" OK

C.2.1 Defined Values

Parameter	Type	Description
<value>	Number	Level of trace • 1: enables base MUX trace (equivalent to the "muxtron" command) • 2: enables extended MUX trace (enables the MUX frames dump)

Related documents

[1]   u-blox AT Commands Manual, Docu No WLS-SW-11000

[2]   u-blox AT Commands Examples, Application Note, Docu No WLS-CS-11003

[3]   3GPP TS 27.010 3rd Generation Partnership Project; Technical Specification Group Terminals; Terminal Equipment to User Equipment (TE – UE) multiplexer protocol (Release 1999)

Documents [1] and [2] are available on our homepage (http://www.u-blox.com).

☞   For regular updates to u-blox documentation and to receive product change notifications please register on our homepage.

Revision history

Revision	Date	Name	Status / Comments
-	22/04/2011	lpah	Initial release
1	25/11/2011	lpah	Extended to include LISA-U2 series. Added section 4.2.
2	28/03/2012	mben	Extended "muxtron" command description Added SAP channel for LISA-U200-01x / LISA-U230-01x and further versions

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