MBaX4XxL
Preliminary User's Manual

MBaX4XxL UM 0001
27.05.2022

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REVISION HISTORY

Rev.	Date	Name	Pos.	Modification
0001	27.05.2022	M. Kreuzer	All	First issue

1. ABOUT THIS MANUAL

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1.5 Tips on safety

Improper or incorrect handling of the product can substantially reduce its life span.

1.6 Symbols and typographic conventions

Table 1: Terms and Conventions

Symbol	Meaning
	This symbol represents the handling of electrostatic-sensitive modules and / or components. These components are often damaged / destroyed by the transmission of a voltage higher than about 50 V. A human body usually only experiences electrostatic discharges above approximately 3,000 V.
	This symbol indicates the possible use of voltages higher than 24 V. Please note the relevant statutory regulations in this regard. Non-compliance with these regulations can lead to serious damage to your health and also cause damage / destruction of the component.
	This symbol indicates a possible source of danger. Acting against the procedure described can lead to possible damage to your health and / or cause damage / destruction of the material used.
	This symbol represents important details or aspects for working with TQ-products.
`Command`	A font with fixed-width is used to denote commands, file names, or menu items.

1.7 Handling and ESD tips

General handling of your TQ-products

	The TQ-product may only be used and serviced by certified personnel who have taken note of the information, the safety regulations in this document and all related rules and regulations. A general rule is: do not touch the TQ-product during operation. This is especially important when switching on, changing jumper settings or connecting other devices without ensuring beforehand that the power supply of the system has been switched off. Violation of this guideline may result in damage / destruction of the MBaX4XxL and be dangerous to your health. Improper handling of your TQ-product would render the guarantee invalid.

Proper ESD handling

	The electronic components of your TQ-product are sensitive to electrostatic discharge (ESD). Always wear antistatic clothing, use ESD-safe tools, packing materials etc., and operate your TQ-product in an ESD-safe environment. Especially when you switch modules on, change jumper settings, or connect other devices.

1.8 Naming of signals

A hash mark (#) at the end of the signal name indicates a low-active signal.
Example: RESET#

If a signal can switch between two functions and if this is noted in the name of the signal, the low-active function is marked with a hash mark and shown at the end.
Example: C / D#

If a signal has multiple functions, the individual functions are separated by slashes when they are important for the wiring.
The identification of the individual functions follows the above conventions.
Example: WE2# / OE#

1.9 Further applicable documents / presumed knowledge

- **Specifications and manual of the modules used:**
  These documents describe the service, functionality and special characteristics of the module used (incl. BIOS).
- **Specifications of the components used:**
  The manufacturer's specifications of the components used, for example CompactFlash cards, are to be taken note of. They contain, if applicable, additional information that must be taken note of for safe and reliable operation.
  These documents are stored at TQ-Systems GmbH.
- **Chip errata:**
  It is the user's responsibility to make sure all errata published by the manufacturer of each component are taken note of. The manufacturer's advice should be followed.
- **Software behaviour:**
  No warranty can be given, nor responsibility taken for any unexpected software behaviour due to deficient components.
- **General expertise:**
  Expertise in electrical engineering / computer engineering is required for the installation and the use of the device.

The following documents are required to fully comprehend the following contents:

- MBaX4XxL circuit diagram
- TQMaX4XxL Preliminary User's Manual
- Sitara AM64x / AM243x Data Sheets
- U-Boot documentation: www.denx.de/wiki/U-Boot/Documentation
- PTXdist documentation: www.ptxdist.de
- TQ-Support Wiki: support.tq-group.com/doku.php?id=en:arm:tqmaX4XxL

2. BRIEF DESCRIPTION

The MBaX4XxL is designed as a carrier board for the TQMaX4XxL.

All TQMaX4XxL interfaces are available on the MBaX4XxL. The AM64x/AM243x CPU/MCU characteristics can be evaluated, and therefore the software development for a TQMaX4XxL project can be started immediately.

The MBaX4XxL supports all TQMaX4XxL modules. It is suited for headless applications with extended real-time requirements. With its integrated PRU (Programmable Realtime Unit), the CPU offers up to four Gigabit Ethernet interfaces with TSN support for the realization of real-time applications.

3. TECHNICAL DATA

3.1 System architecture and functionality

3.1.1 Block diagram

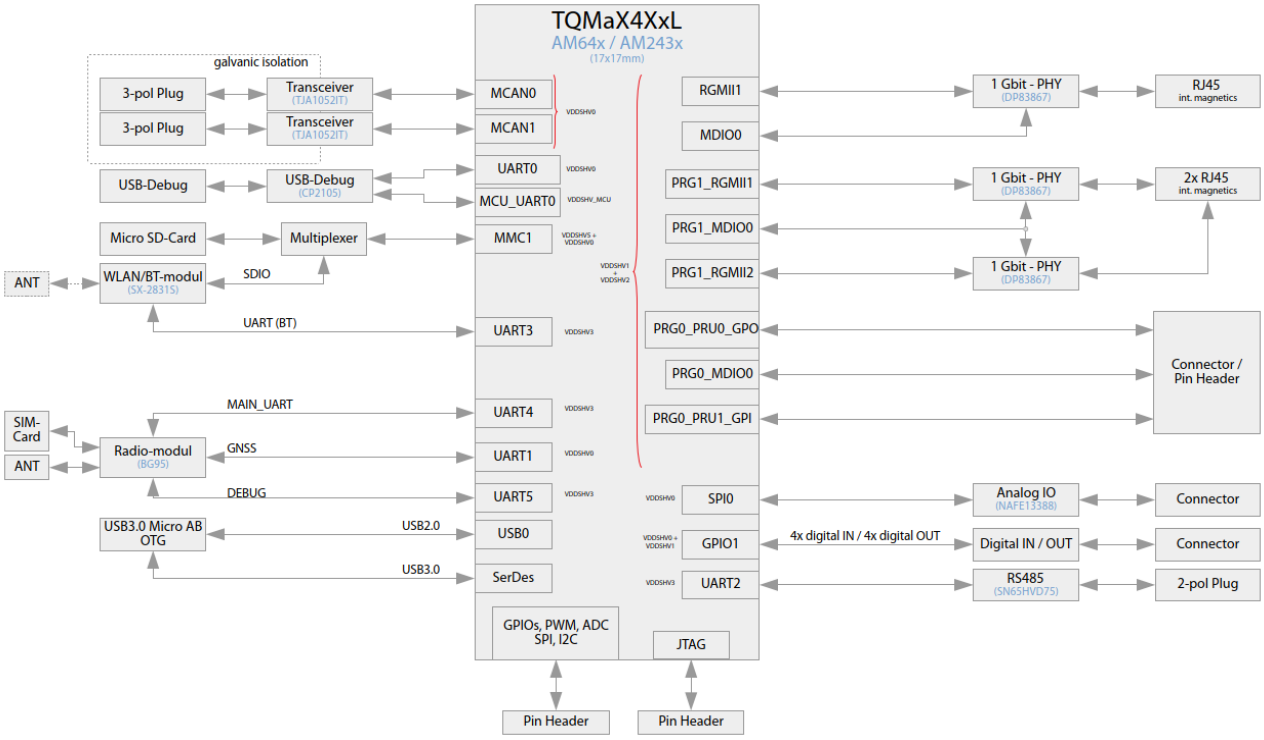

Figure 1: Block diagram MBaX4XxL

3.1.2 Functionality

The system core is the TQMaX4XxL processor module with Texas Instruments Sitara AM64x/AM243x CPU/MCU.
The TQMaX4XxL connects all peripheral components to each other.
In addition to the standard communication interfaces like USB, Ethernet, RS485 etc. all other available signals of the TQMaX4XxL are routed to standard headers.

The following interfaces / functions and user's interfaces are provided on the MBaX4XxL:

Table 2: Overview interfaces

Interface	Qty.	Type of connector	Remark
Ethernet 1000BASE-T	1	RJ45 receptacle	Receptacle with integrated magnetics
	1	RJ45 dual receptacle	
CAN	2	Phoenix basic housing	Straight version, gal. separated, 3-pole
USB3.0 OTG	1	USB receptacle Type B (Micro)	USB2.0 OTG and USB3.0 (SerDes)
Debug-USB	1	USB receptacle Type Micro B	2 x COM ports for Debug-UART
Analogue IN	1	Phoenix basic housing	Lay flat version, 8x ADC
Digital IOs	1	Phoenix basic housing	Lay flat version, 4x IN, 4x OUT and 2 x 24 V Input
WLAN / BT module	1	2 x u.FL	Module with 2 x u.FL receptacle
Radio module	1	2 x u.FL	SIM card holder, antenna for GNSS / Main
RS485	1	Phoenix basic housing	Straight version, 2-pole
SD card	1	Push-Push-Type (Micro)	SDR104 Speed-grade (UHS-I)
Headers	3	Header, 1.27 mm pitch	1 x PRG0 interface 1 x Factory tests connector Control signals 1 x SEC (Interface of module) 1 x MCU_UART1 1 x MCU_I2C0 1 x MCU_SPI0 5 x MCU_GPIO0 1 x ADC0 1 x PWM5
Battery holder	1	CR2032 holder	Backup battery RTC

Table 3: Overview diagnose and user's interfaces

Interface	Qty.	Component	Remark
Status-LEDs	1	LED blue	USB debug interface
	1	LED green	GPIO-LED
	1	LED yellow	GPIO-LED
	2	LED green / red	PGOOD (of module and mainboard)
	1	LED blue	Input supply 24 V
	3	LED green / yellow	Ethernet LEDs (activity / speed)
	1	LED green	IoT Net Status
Reset button	2	Push button	CPU / module reset (cold / warm)
User button	1	Push button	For GPIO
Boot-Mode configuration	4	DIP switch	4 x Boot mode configuration
CAN termination	2	DIP switch	–
RS485 termination	1	DIP switch	–
JTAG	1	10-pole header, 1.27 mm pitch	ARM 10-pin JTAG standard
Fan	1	Header X33, 2.54 mm pitch	4-pole header
Power In	1	Phoenix Contact, MC1,5/2-G-3,5	16 V to 26 V

4. ELECTRONICS

4.1 System components

4.1.1 TQMaX4XxL

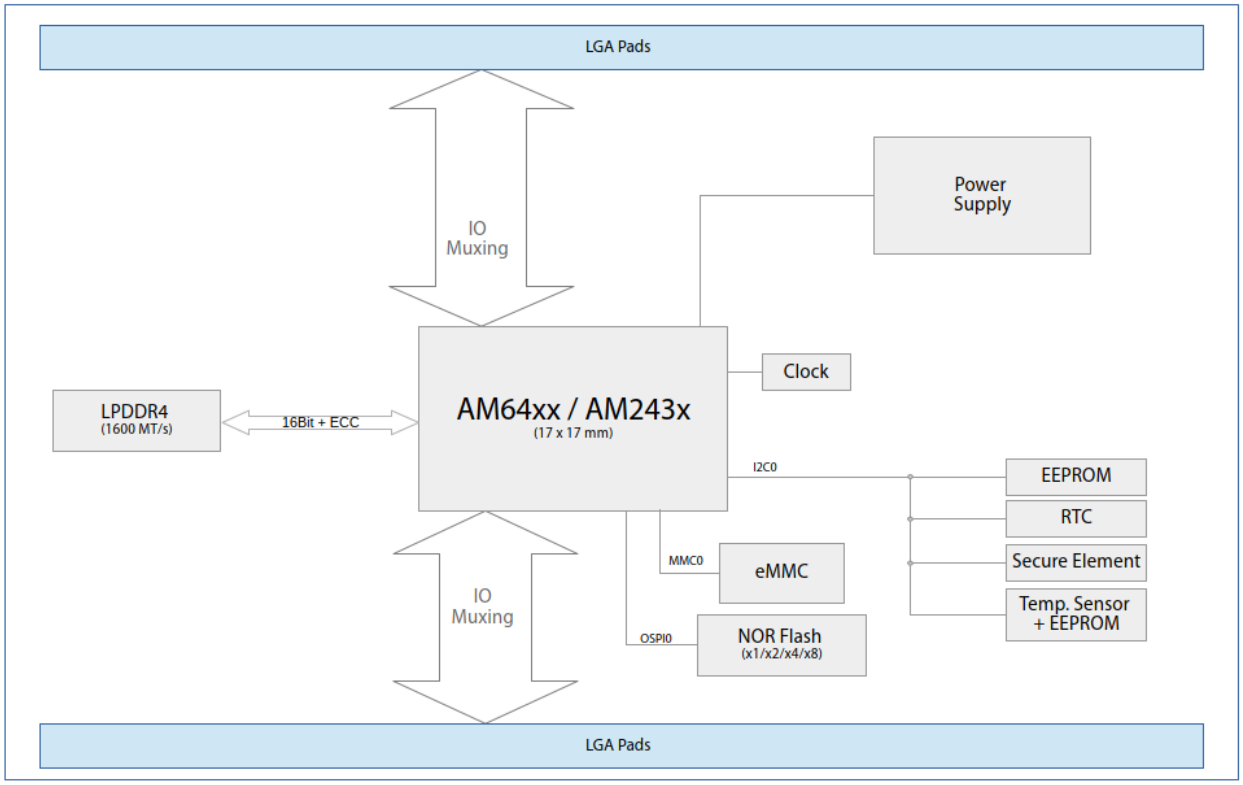

Figure 2: Block diagram TQMaX4XxL

The TQMaX4XxL with the AM64xx / AM243x CPU is the central system component. It provides LPDDR4 SDRAM, eMMC, NOR flash and EEPROM memory.

The available signals are routed to 366 LGA balls. When using the processor signals, it is essential to observe the multiple assignment of the pins by different processor-internal function units (multiplexing). More detailed information is to be taken from the accompanying TQMaX4XxL Preliminary User's Manual.

The TQMaX4XxL boot behaviour can be customised.

Attention: Available interfaces	
	Depending on the selected TQMaX4XxL, not all interfaces are available. Available interfaces are to be taken from the TQMaX4XxL pinout table.

4.1.2 I²C address mapping

The accessible I²C buses depend on the pin multiplexing. No I²C devices are provided on the MBaX4XxL. On the TQMaX4XxL the I2C0 bus is fixed for its I²C devices. The following devices are connected on the module:

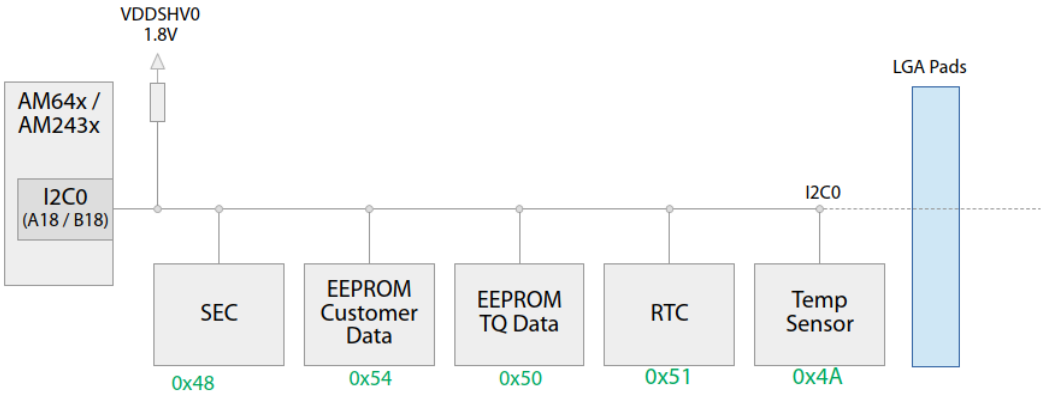

Figure 3: Block diagram I²C bus of the TQMaX4XxL module

The following table shows the used addresses of all I²C buses:

Table 4: I2C0 slave address mapping of the TQMaX4XxL module

Bus	Component	Address	Note
I2C0	Temperature sensor TMP1075	0x4A / 100 1010b	
	EEPROM M24C02	0x50 / 101 0000b	TQ-Data
	EEPROM M24C64	0x54 / 101 0100b	Customer EEPROM
	RTC PCF85063ATL	0x51 / 101 0001b	
	SEC	0x48 / 100 1000b	

4.1.3 RTC backup supply

For the backup supply of the RTC on the TQMaX4XxL a lithium battery (3 V coin cell type CR2032) with very low self-discharge is used on the MBaX4XxL. The TQMaX4XxL is supplied via pin V_RTC_IN.

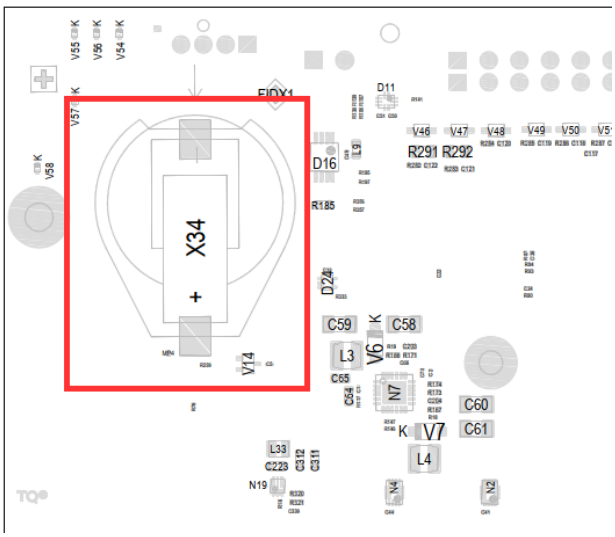

Figure 4: Placement battery holder X34

4.1.4 Reset structure

On the MBaX4XxL different possibilities are available for a complete or partial reset (periphery) of the module.
The following signals from the TQMaX4XxL are used on the MBaX4XxL:

Table 5: Reset signals

Signal	Type	Level	Description
TQMaX4XxL_HARD_RST#	I	5.0 V	• Activates power sequencing on module after approx. 200 ms delay (LOW -> HIGH) • Pull-up on module • Connect to GND to activate (e.g. push button)
MCU_PORz	I	1.8 V	• Control of a cold reset • Pull-up on module • Connect to GND to activate (e.g. push button)
MCU_RESETz	I	1.8 V	• Control of a warm reset of the MCU domain • Pull-up on module • Connect to GND to activate (e.g. push button)
RESET_REQz	I	1.8 V	• Control of a warm reset of the main domain • Pull-up on module • Connect to GND to activate (e.g. push button)
TRST#	I	1,8 V	• Connects directly to the TRST# of the module • Pull down on module
PORz_OUT	O	1.8 V	• Status signal for a cold reset of the main domain • Driver on module
MCU_RESETSTATz	O	1.8 V	• Status signal for a warm reset of the MCU domain • Pull-down on module
RESETSTATz	O	1.8 V	• Status signal for a warm reset of the main domain • Pull-down on module
TQMaX4XxL_PGOOD	O	1.8 V	• Status signal that is used to indicate the power sequencing on the module
GPIOx	O	1.8 V	• Activates RESET of various peripherals on the mainboard • Is controlled by software

Attention: Damage	
	The periphery on the base board should never be supplied before the module, otherwise the module may be damaged. This is ensured by the signal PGOOD.

4.1.5 Power supply

The following figure shows all voltage rails on the mainboard. In order to comply with the required power sequencing, the signal PGOOD is used to control the respective rails.

On the MBaX4XxL there is a two part supply:

- 5V supply
  - Permanently activated as soon as the MBaX4XxL is supplied
  - Module supply / Reset button / LED
- Remaining Power Supply
  - Supply of the periphery
  - Switched by PGOOD
  - Switched off if PGOOD is not present on the module

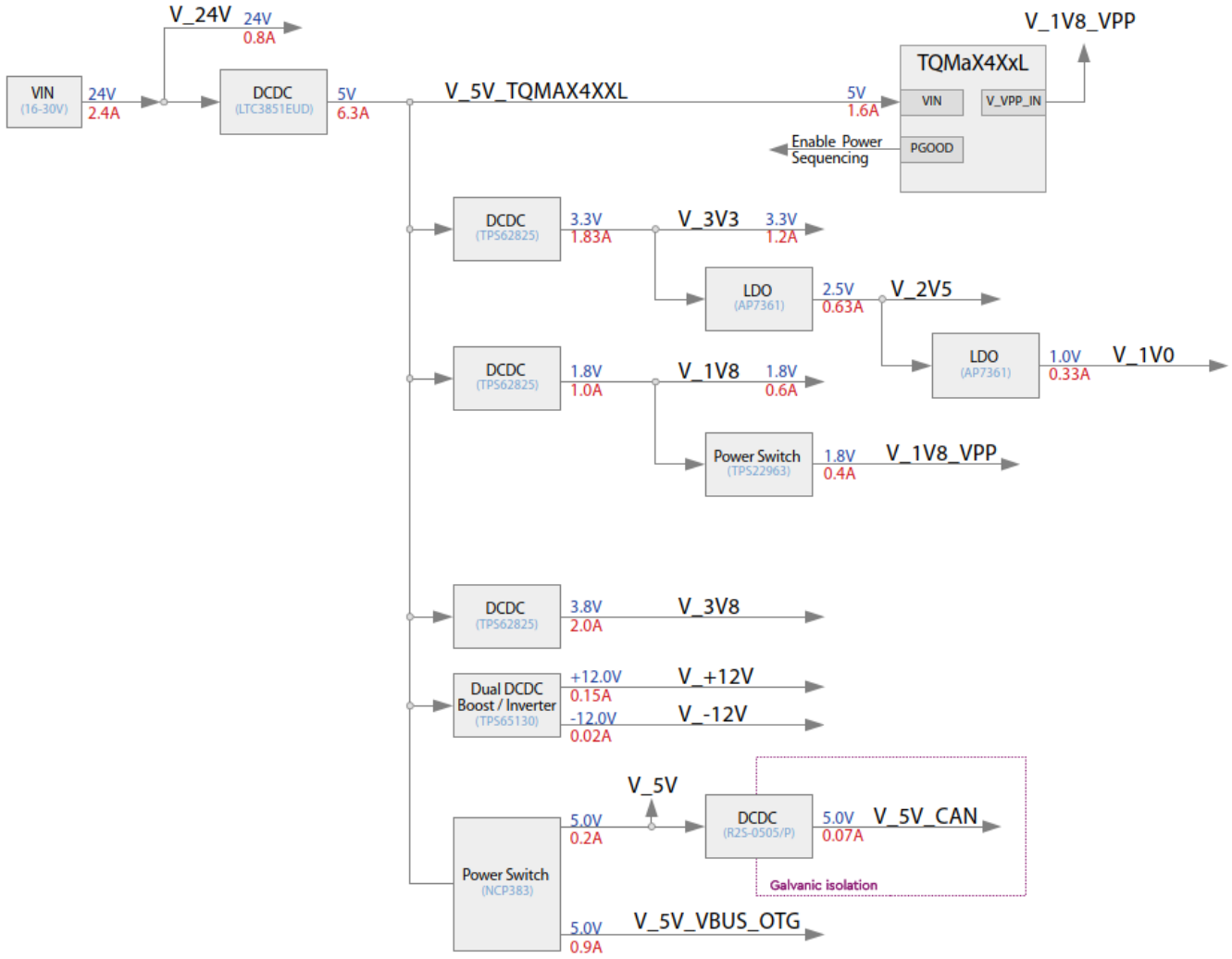

Figure 5: Block diagram power supply chain

On the MBaX4XxL the input voltage of 24 V (connector X40) has the following protective circuitry:

- Fuse 5A, slow blow
- Excess voltage protection diode
- PI filter
- Inverse-polarity protection
- Overvoltage limitation 26.7 V to 29.5 V
- Capacitors for voltage smoothing

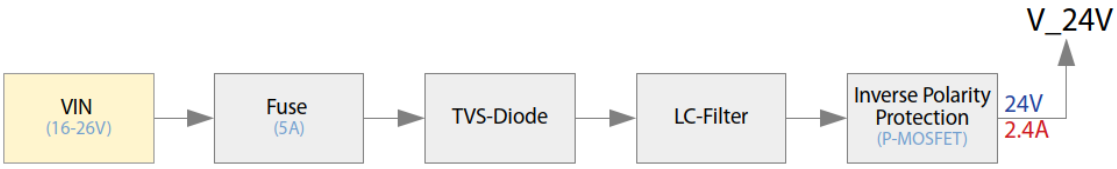

Figure 6: MBaX4XxL Input circuit

The mainboard MBaX4XxL, including TQMaX4XxL, consumes 58 W under full load (all supply voltages are loaded with maximum current, e.g. by connecting external modules to the pin headers). The power supply used must be selected accordingly. In most applications, however, the power consumption will be significantly lower.

Attention: Overload	
	The internal voltages (3.3 V, 1.8 V) provided at the starter kit pin headers are not additionally protected. Technically, an overload of the fuse is therefore possible. The resulting total current consumption of the MBaX4XxL should be observed.

Table 6: Electrical parameters of the supply voltages

Parameter	Min.	Typ.	Max.	Unit	Remark
V_5V0					
Output voltage	4.942	5	5.058	V	
Max. load current			6.5	A	
Current Limit			7.7	A	
V_3V8					
Output voltage	3.756	3.8	3.844	V	
Max. load current			2	A	
Current Limit			3.9	A	
V_3V3					
Output voltage	3.262	3.3	3.338	V	
Max. load current			2	A	
Current Limit			3.9	A	
V_1V8					
Output voltage	1.758	1.8	1.842	V	
Max. load current			2	A	
Current Limit			3.9	A	
V_2V5					
Output voltage	2.442	2.5	2.560	V	
Max. load current			1	A	
V_1V0					
Output voltage	0.986	1.0	1.014	V	
Max. load current			1	A	
V_+12V0					
Output voltage	11.664	11.995	12.335	V	
Max. load current			0.15	A	
V_-12V0					
Output voltage	-11.582	-12.054	-12.541	V	
Max. load current			0.02	A	
V_5V0_VBUS_OTG					
Output voltage		5.0		V	
Max. load current			0.9	A	
Current Limit		1.4		A	
V_5V0_SW					
Output voltage		5.0		V	
Max. load current			0.9	A	
Current Limit		1.4		A	
V_1V8_VPP					
Output voltage	1.758	1.8	1.842	V	
Max. load current			0.4	A	

The power sequencing of the mainboard MBaX4XxL is defined as following:

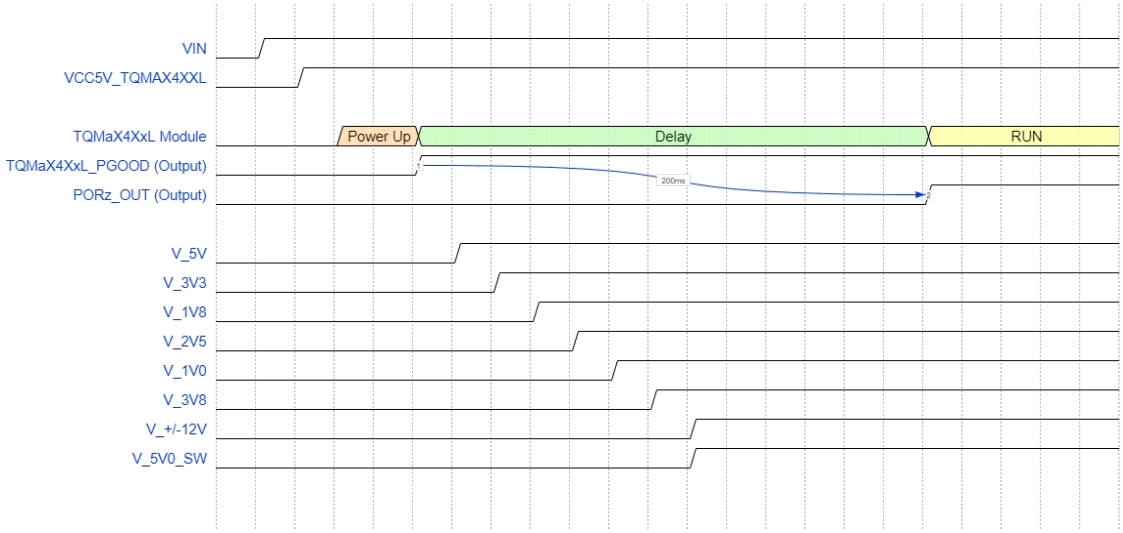

Figure 7: MBaX4XxL Power up sequenz

- The 5V for the module is permanently on - so "always" ON.
- The module executes the power sequencing independently and returns a PGOOD signal for the mainboard.
- As soon as the PGOOD signal is present, the mainboard performs the power sequencing independently. The used switching regulators / LDOs are controlled by EN and PGOOD signals.
- The time constant between PGOOD and reset of the CPU is approx. 200 ms.

4.2 Communication interfaces

4.2.1 UART- / Debug-interface

To get debug outputs of the CPU, the UART0 and MCU_UART0 interface of the CPU is used. The used UART of the CPU is connected to a Micro USB connector via a USB-to-UART bridge.

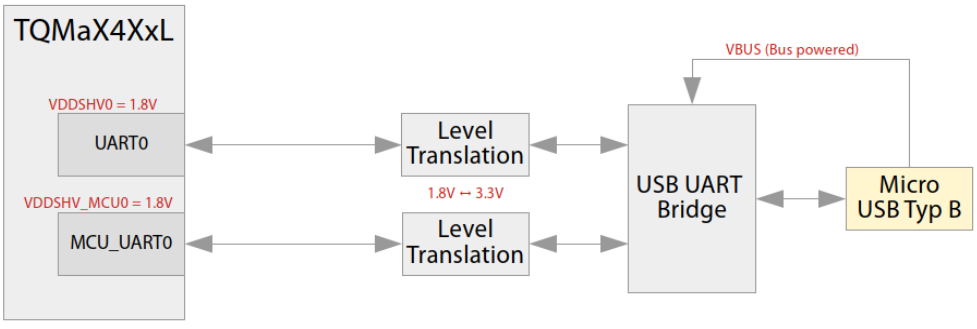

Figure 8: Block diagram UART- / Debug-interface

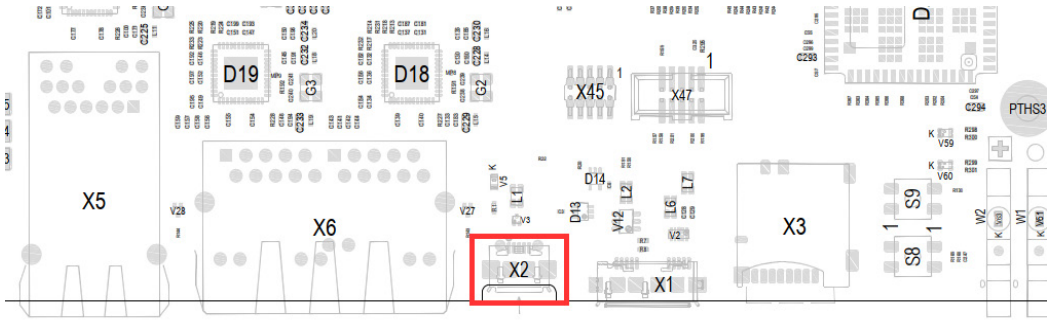

Figure 9: Position X2

4.2.2 USB interface

The MBaX4XxL provides a USB2.0 OTG as well as a USB3.0 interface via SerDes. The USB2.0 interface also serves as boot source (see also chapter 4.3.5).

- Protection circuit for USB0_DRVVBUS according to Reference Manual (1).
- 5V power switch depending on the USB ID pin.

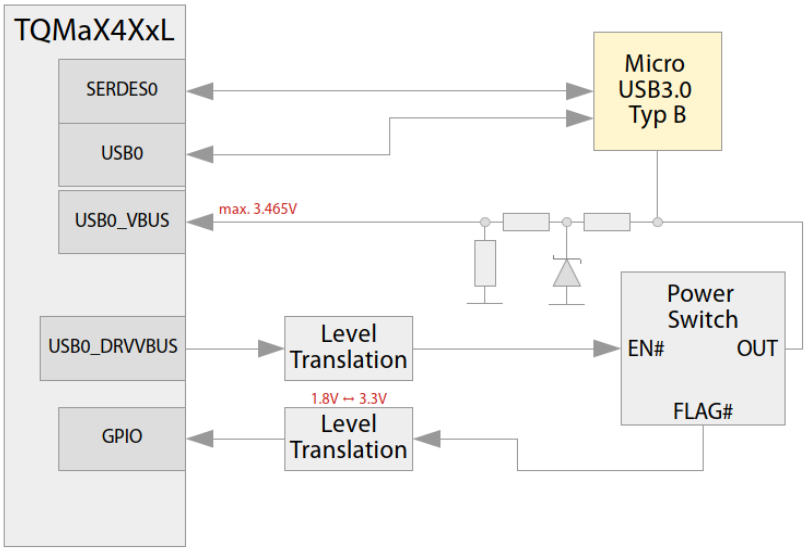

Figure 10: Block diagram USB interface

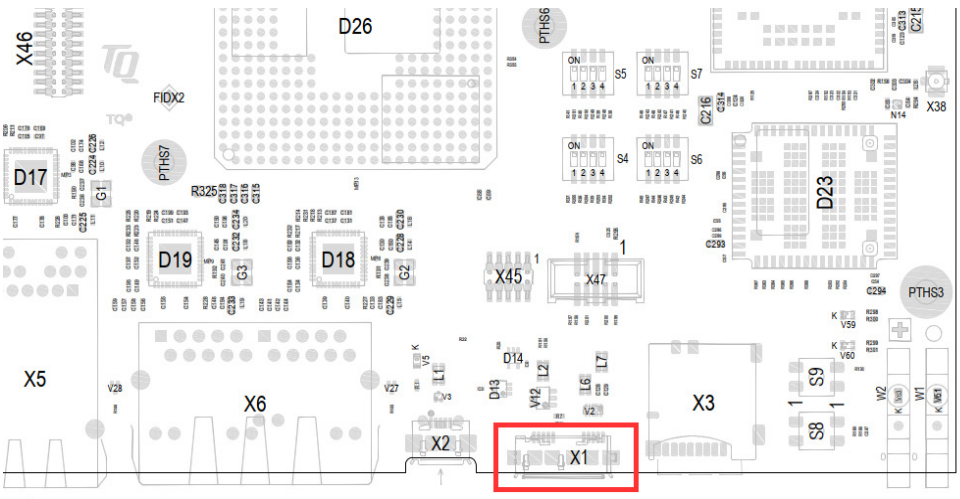

Figure 11: Position of USB interface

4.2.3 Ethernet interface

There are three Ethernet interfaces on the MBaX4XxL. The PHY DP83867ISRZGZ from TI is used for all interfaces. The PHY supports IEEE 802.3 10BASE-Te,100BASE-TX, and 1000BASE-T. The following interfaces are used:

- 1 x RGMII1 at connector X5
  - Multiplexer to use the interface PRG0_PRU0
- 2 x RGMII (PRG1_RGMII1/2) at connector X6
- 1 x PRU at Pinheader

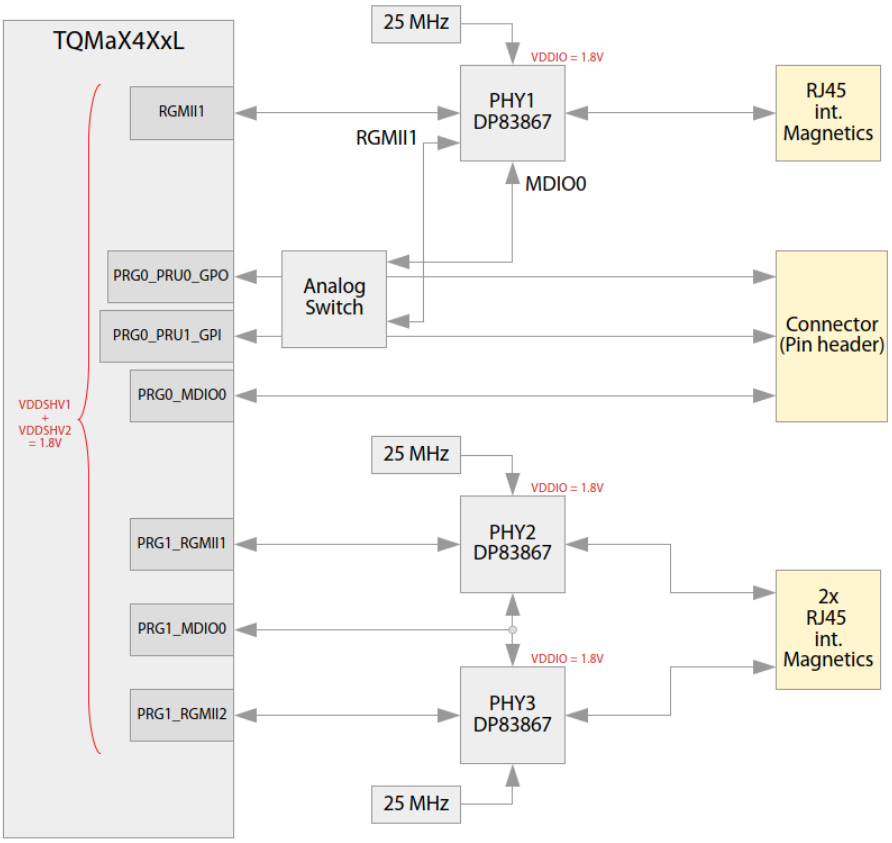

Figure 12: Block diagram Ethernet interface

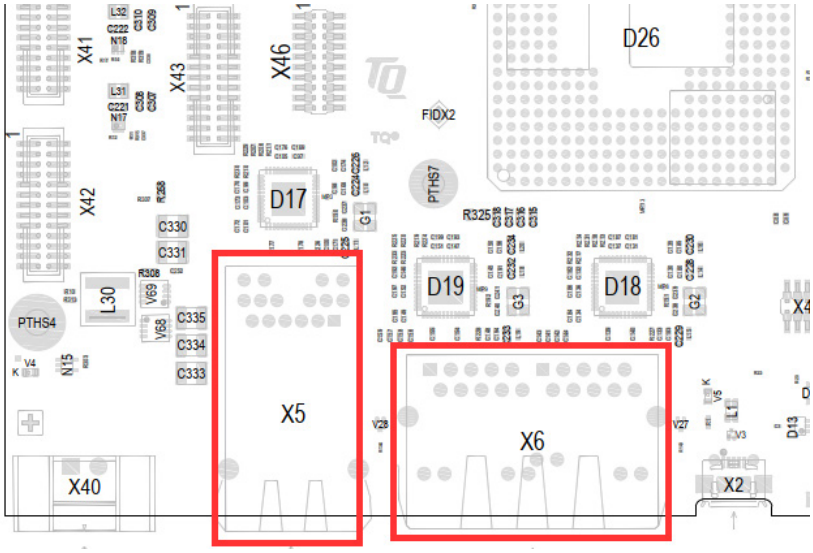

Figure 13: Position of X5 and X6

4.2.4 CAN

Two CAN interfaces are implemented on MBaX4XxL according to the ISO 11898 standard. The signals are each provided on a 3-pin socket X7 and X8.
Both interfaces are galvanically isolated with an isolation voltage of 1 kV, but not from each other.

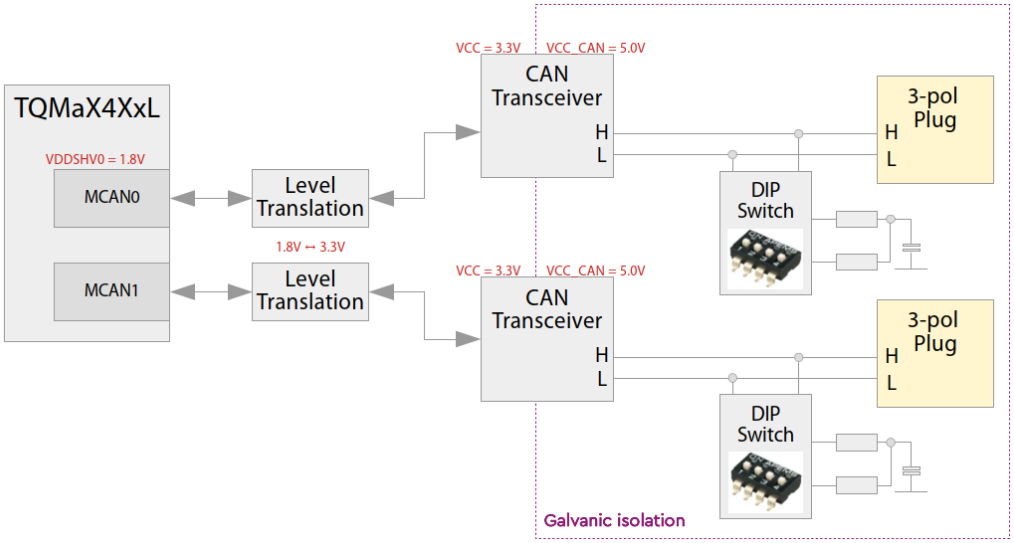

Figure 14: Block diagram CAN

The following tables show the pin assignment of the CAN connectors and the DIP switch for the 120 Ω CAN signal termination.

Table 7: CAN0 pinout (X7)

Pin	Pin name	Signal	I/O	Note
1	CAN_H	CAN1_H	I/O	galvanically isolated
2	CAN_L	CAN1_L	I/O	galvanically isolated
3	DGND	DGND_CAN	P	galvanically isolated

Table 8: CAN1 pinout (X8)

Pin	Pin name	Signal	I/O	Note
1	CAN_H	CAN2_H	I/O	galvanically isolated
2	CAN_L	CAN2_L	I/O	galvanically isolated
3	DGND	DGND_CAN	P	galvanically isolated

Table 9: CAN termination

DIP-Switch	Interface	ON	OFF
S1	CAN0	Termination CAN0 with 120 Ω	No termination CAN0
S2	CAN1	Termination CAN1 with 120 Ω	No termination CAN1

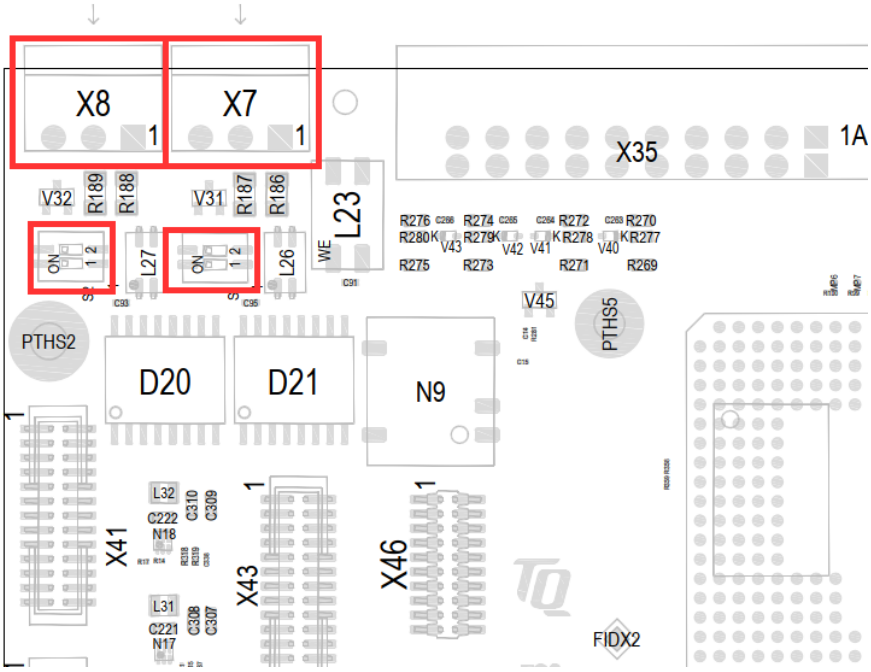

Figure 15: Position of CAN connectors and DIP switch

4.2.5 RS485

On the MBaX4XxL a RS485 interface (X4) with automatic direction switching is realized, which allows the use of Profibus. The direction switching is done via GPIO.

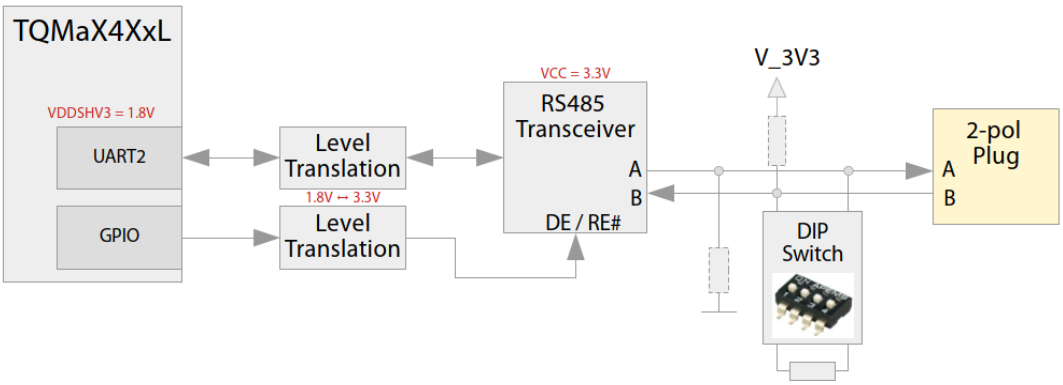

Figure 16: Block diagram RS485

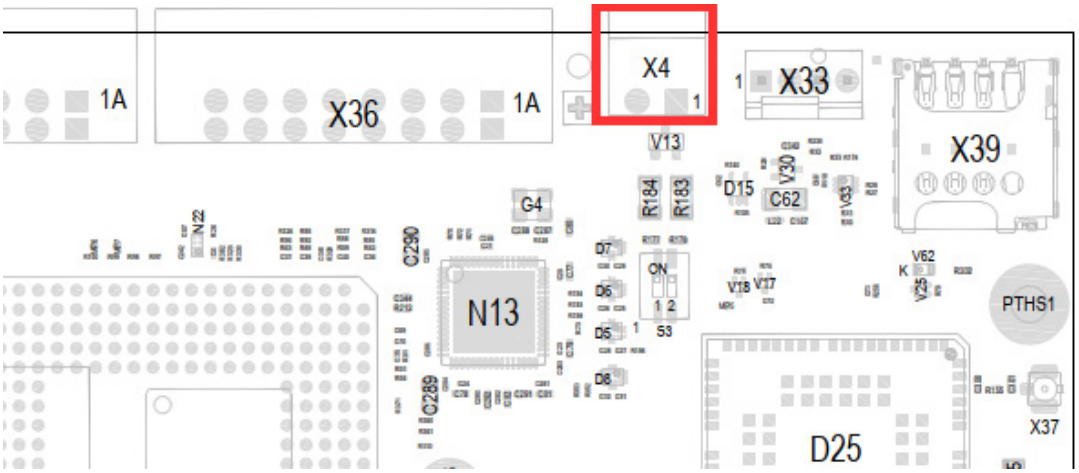

Figure 17: Position of RS485, X4

4.2.6 WLAN / Bluetooth module

A WiFi / Bluetooth module SX-SDMAC-2831S from Silex Technology is integrated on the MBaX4XxL:

- IEEE 802.11 a/b/g/n/ac (2.4 GHz, 5 GHz) - Dual band
  - 5 GHz: 20/40/80 MHz bandwidth (PHY data rate 433 Mbps)
  - 2.4 GHz: 20/40 MHz bandwidth (PHY data rate 150 Mbps, extended PHY data rate 200 Mbps)
  - 20/40 MHz Co-Existance is not supported
- Bluetooth 5.0 BR/EDR/LE (Class 2)
  - Backward compatible with Bluetooth 1.x, 2.x, 3.0, 4.0, 4.1
- Interfaces
  - WiFi: SDIO3.0 via MMC1
  - BT: UART via UART3
- The module has two antenna connectors (UFL sockets)

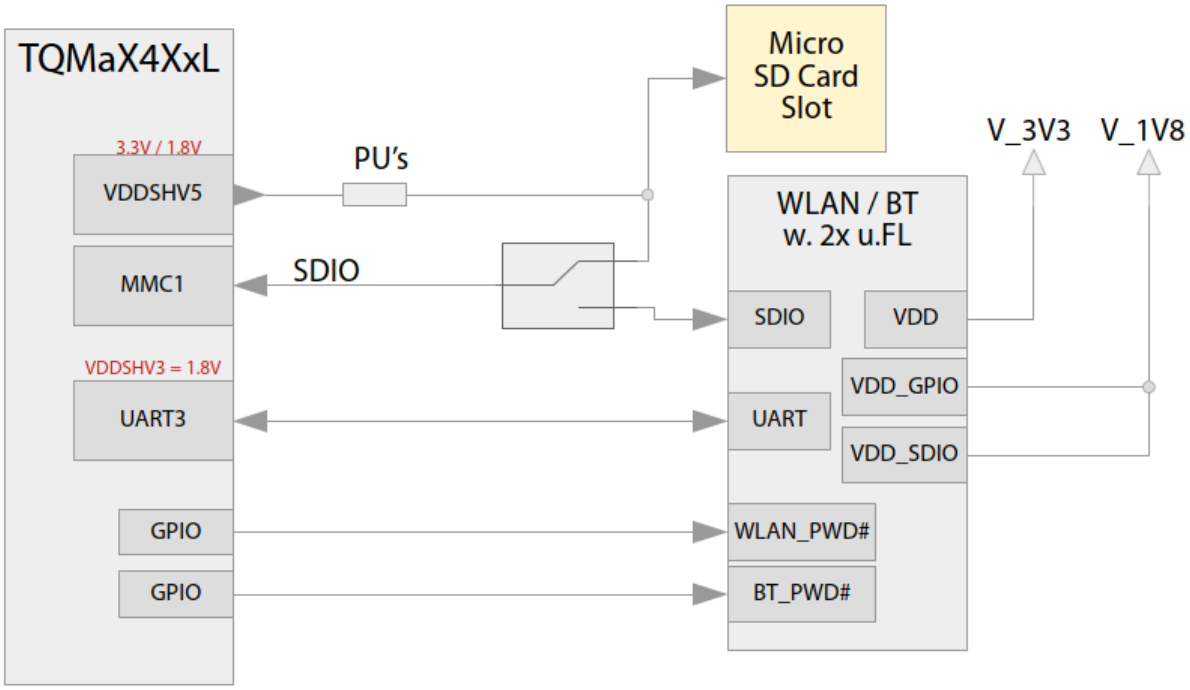

Figure 18: Block diagram WLAN /Bluetooth module

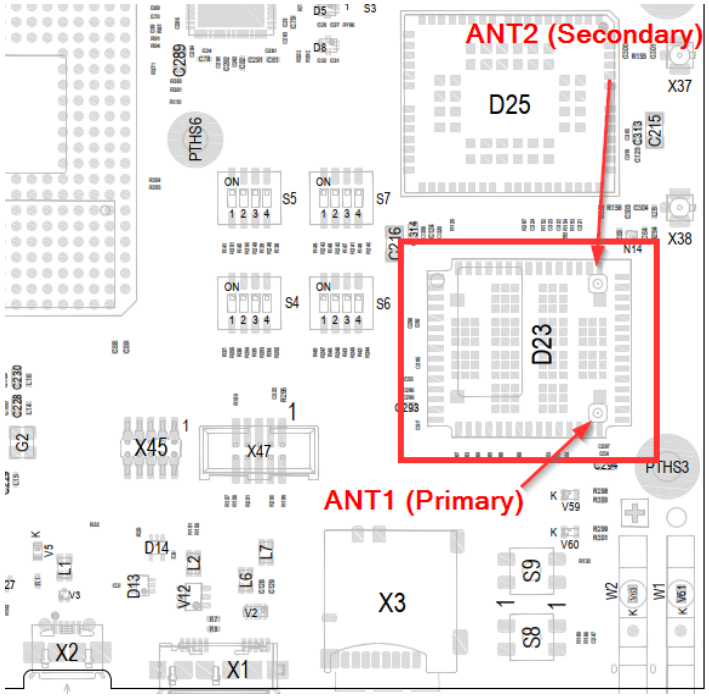

Figure 19: Position WLAN / Bluetooth module and antenna sockets ANT1 and ANT2

4.2.7 IoT radio module + SIM card

Quectel's BG95-M4 IoT radio module provides NB-IoT and GNSS functionality on the MBaX4XxL:

- LTE: CAT M1 (max. 588 DL / 1119 UL), CAT NB2 (max. 127 DL / 158.5 UL)
- VoLTE for CAT M1 (planned by Quectel)
- GNSS: GPS, GLONLASS, BeiDou, Galileo, QZSS
- 2 antenna ports
- 1 Micro-SIM connector:
  - 1.8V type
  - Card Detect available
- The MAIN_UART is connected to UART4.
- The GNSS_UART is connected to UART1.
- The DBG_UART is connected to UART5.
- The control signals can be controlled via GPIOs of the TQMaX4XxL.
- The USB port can optionally be used via placement options.
- NET_STATUS_LED:
  - Flicker slow (200 ms / 1800 ms) – Network searching
  - Flicker slow (1800 ms / 200 ms) – Idle
  - Flicker Quick (125 ms / 125 ms) – Data transfer
  - Alwayss High – Voice call
- BG95_STATUS: HIGH when module is on

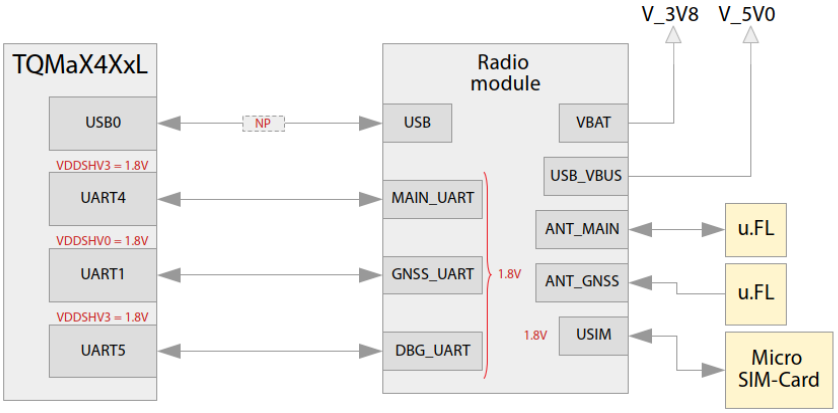

Figure 20: Block diagram IoT radio module

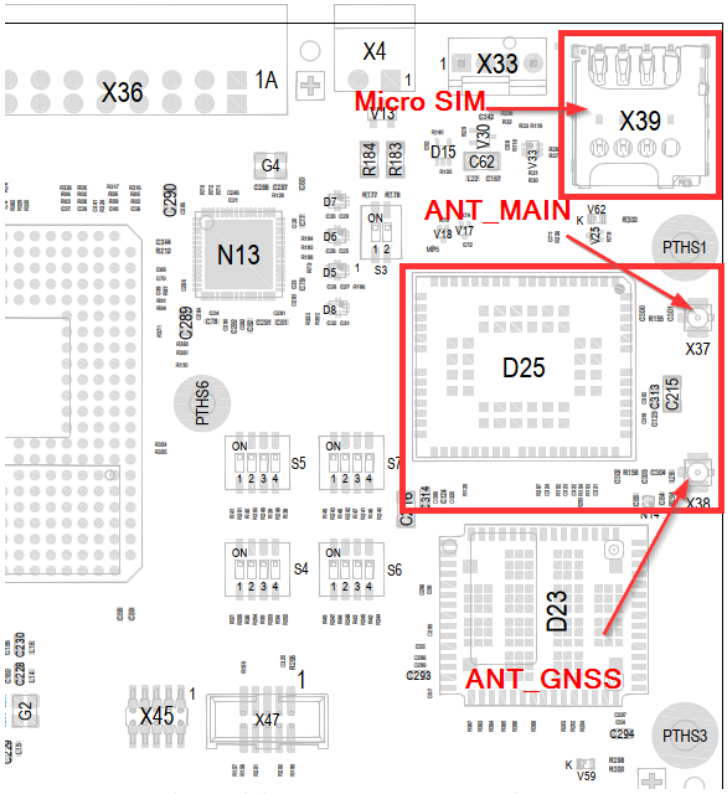

Figure 21: Position IoT radio module + u.FL + Micro-SIM card port

4.2.8 SD card

On the MBaX4XxL a SDIO (MMC1) interface of the CPU is implemented for a SD card connection (connector X3):

- MMC1 interface with 4 bit bus width
- Module provides an adapted supply voltage VDDSHV5 (1.8 V / 3.3 V) depending on the mode
- VDDSHV5 can be used for pullup supply
- Power switch (3.3 V) provided for SD card supply
    - Power Cycle at PORz_OUT and RESETSTATz

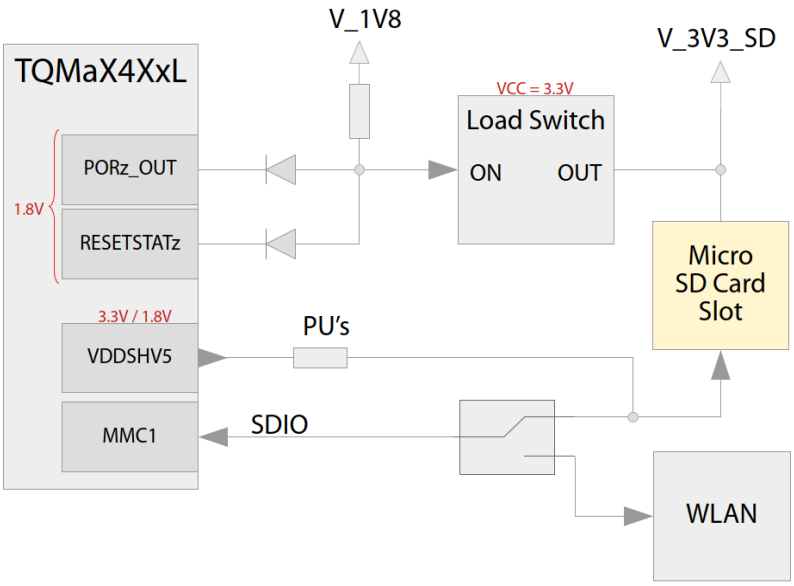

Figure 22: Block diagram SD card slot, X3

4.2.9 PRU

To operate the full range of functions of the TQMaX4XxL, the PRG0 (PRU) interface is made available by multiplexers on a pin header X41 and X42. This allows the full scope of the PRU interface to be tested. The IO logic of the interface is 1.8V.

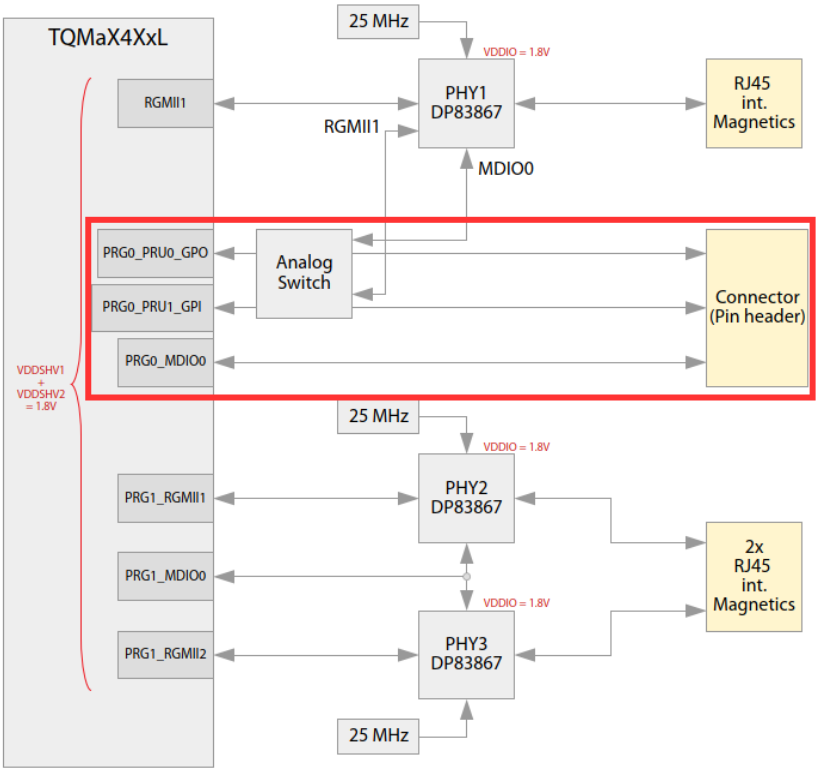

Figure 23: Block diagram PRU

Table 10: Pinout PRU (X41)

Pin	Signal	I/O	Note
1	V_3V3	P	
2	V_1V8	P	
3	DGND	P	
4	DGND	P	
5	PRG0_MDIO0_MDC	O	
6	PRG0_MDIO0_MDIO	I/O	
7	PRG0_PRU0_GPO0	I/O	
8	PRG0_PRU1_GPO0	I/O	
9	PRG0_PRU0_GPO1	I/O	
10	PRG0_PRU1_GPO1	I/O	
11	PRG0_PRU0_GPO2	I/O	
12	PRG0_PRU1_GPO2	I/O	
13	PRG0_PRU0_GPO3	I/O	
14	PRG0_PRU1_GPO3	I/O	
15	PRG0_PRU0_GPO4	I/O	
16	PRG0_PRU1_GPO4	I/O	
17	PRG0_PRU0_GPO5	I/O	
18	PRG0_PRU1_GPO5	I/O	
19	PRG0_PRU0_GPO6	I/O	
20	PRG0_PRU1_GPO6	I/O	
21	PRG0_PRU0_GPO7	I/O	
22	PRG0_PRU1_GPO7_SW	I/O	
23	DGND	P	
24	DGND	P	
25	PRG0_PRU0_GPO8	I/O	
26	PRG0_PRU1_GPO8	I/O	

Table 11: Pinout PRU (X42)

Pin	Signal	I/O	Note
1	PRG0_PRU0_GPO09_SW	I/O	
2	PRG0_PRU1_GPO09_SW	I/O	
3	PRG0_PRU0_GPO10_SW	I/O	
4	PRG0_PRU1_GPO10_SW	I/O	
5	PRG0_PRU0_GPO11	I/O	
6	PRG0_PRU1_GPO11	I/O	
7	DGND	P	
8	DGND	P	
9	PRG0_PRU0_GPO12	I/O	
10	PRG0_PRU1_GPO12	I/O	
11	PRG0_PRU0_GPO13	I/O	
12	PRG0_PRU1_GPO13	I/O	
13	PRG0_PRU0_GPO14	I/O	
14	PRG0_PRU1_GPO14	I/O	
15	PRG0_PRU0_GPO15	I/O	
16	PRG0_PRU1_GPO15	I/O	
17	DGND	P	
18	DGND	P	
19	PRG0_PRU0_GPO16	I/O	
20	PRG0_PRU1_GPO16	I/O	
21	PRG0_PRU0_GPO17	I/O	
22	PRG0_PRU1_GPO17_SW	I/O	
23	PRG0_PRU0_GPO18	I/O	
24	PRG0_PRU1_GPO18_SW	I/O	
25	PRG0_PRU0_GPO19	I/O	
26	PRG0_PRU1_GPO19_SW	I/O	

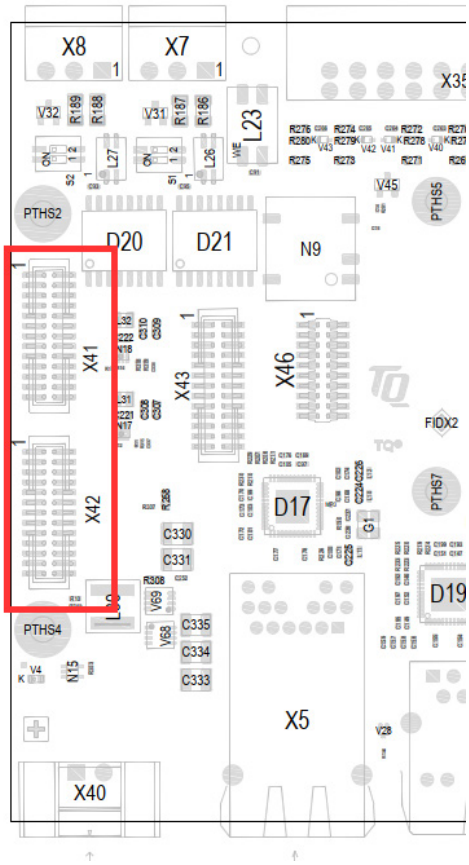

Figure 24: Position of X41, X42

4.2.10 JTAG & EMU

The JTAG signals of the CPU are provided on the 10-pin header X47.

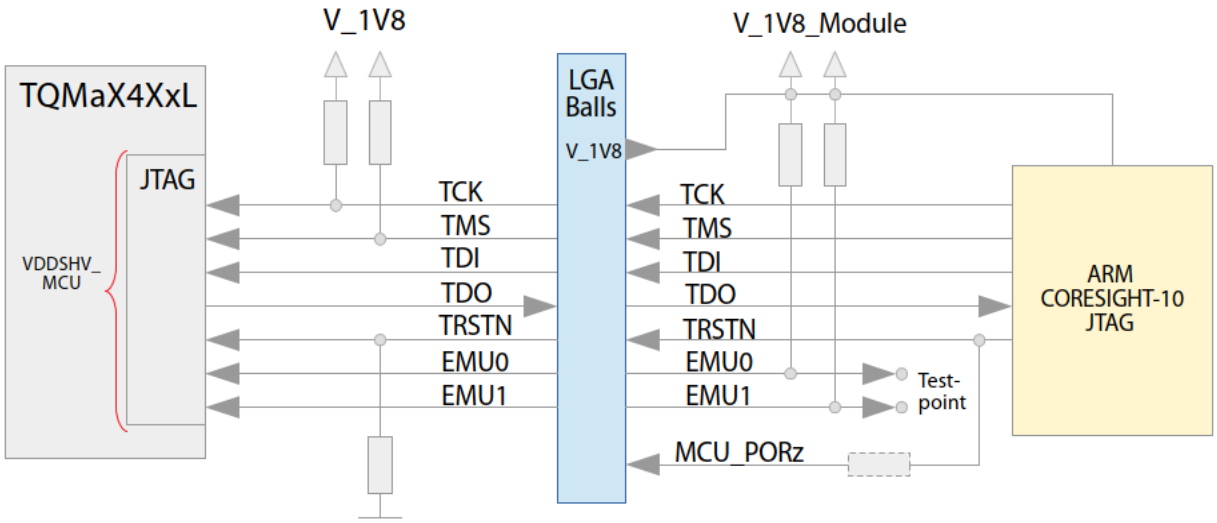

Figure 25: Block diagram JTAG

Table 12: JTAG signals

Signal / Multiplexing	I/O	Power group	Note
TCK	I	VDDSHV_MCU (1,8 V)	4.7 kΩ Pull-Up on module
TDI	I		
TDO	O		
TMS	I		4.7 kΩ Pull-Up on module
TRST#	I		4.7 kΩ Pull-Up on module
EMU[1:0]	IO		Optional signals, not required for JTAG

Table 13: ARM JTAG Interface Specification – CORESIGHT-10-JTAG

Signal	Pin	Pin	Signal
VREF DEBUG	1	2	TMS
GND	3	4	TCK
GND	5	6	TDO
KEY (GND)	7	8	TDI
GND	9	10	RESET-

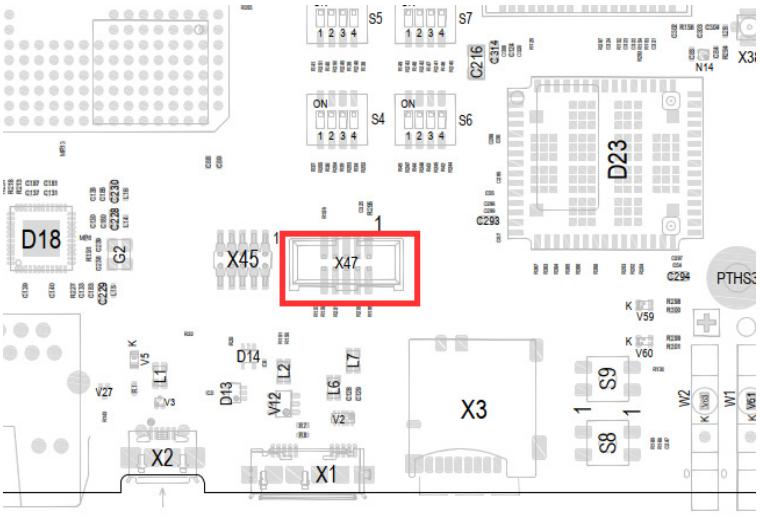

Figure 26: Position of JTAG, X47

4.2.11 Analog Frontend

For the processing of analog inputs, an 8-channel analog frontend is available on the MBaX4XxL at connector X36.

- 24 V Compatible
- Data rates: 7.5 SPS - 288 kSPS, Simultaneous 50 Hz / 60 Hz line rejection, ENOB: 17-bit at 72 kSPS
- High accuracy of data evaluation: ±0.01% (at room temperature)
- Temperature sensor
- Up to 30 MHz SPI interface
- Calibration and diagnostic capabilities
- Analog inputs
  - Input AI1P/N can be used for current measurement by changing the configuration.
  - Input AI3P/N and AI4P/N can be used as differential inputs by changing the components.
- GPIO0 and GPIO1 are used as analog inputs (V_1V8 and V_3V3).
- Communication via SPI0
- Voltage converter for all signals from / to TQMaX4XxL
- Analog inputs available at X36

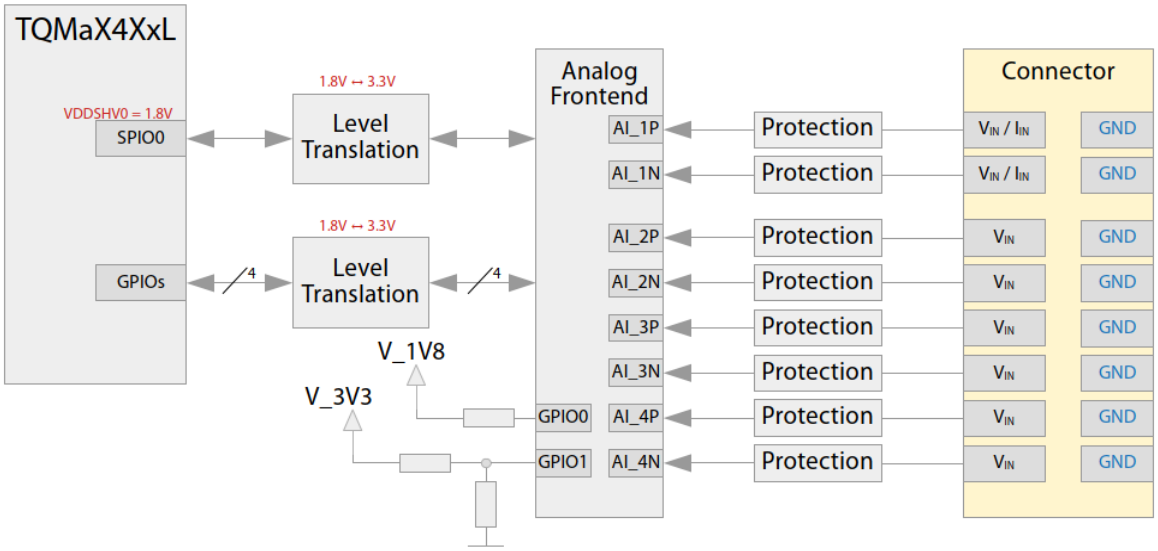

Figure 27: Block diagram Analog Frontend

The following tables show the pin assignment of the Analog Frontend at X36.

Table 14: Pinout X36

Pin	Signal	I/O	Note
1A	AI1P	I	Can be used for current measurement with AI1N by changing the assembly
1B	DGND	P	
2A	AI1N	I	Can be used for current measurement with AI1P by changing the assembly
2B	DGND	P	
3A	AI2P	I	
3B	DGND	P	
4A	AI2N	I	
4B	DGND	P	
5A	AI3P	I	Can be used as differential inputs with AI3N by changing the assembly
5B	DGND	P	
6A	AI3N	I	Can be used as differential inputs with AI3P by changing the assembly
6B	DGND	P	
7A	AI4P	I	Can be used as differential inputs with AI4N by changing the assembly
7B	DGND	P	
8A	AI4N	I	Can be used as differential inputs with AI4P by changing the assembly
8B	DGND	P	

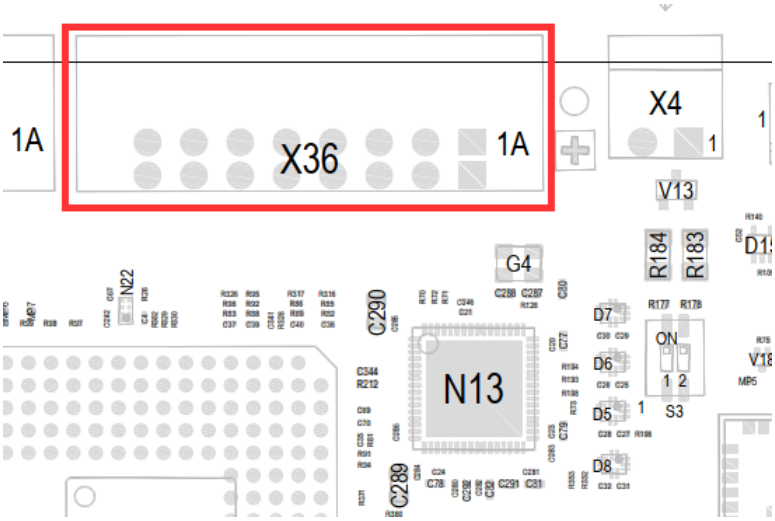

Figure 28: Position X36

Measurement options:

• Standard circuit for voltage and current measurement:

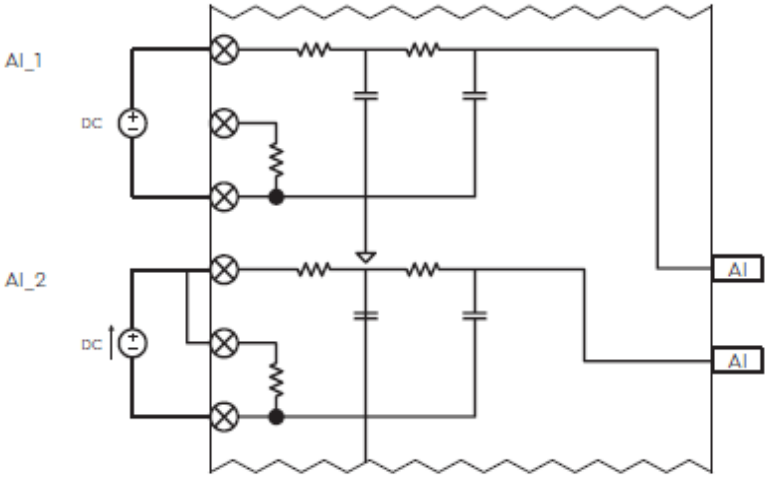

Figure 29: Analogue interface voltage-current measurement

• Standard voltage measurement:

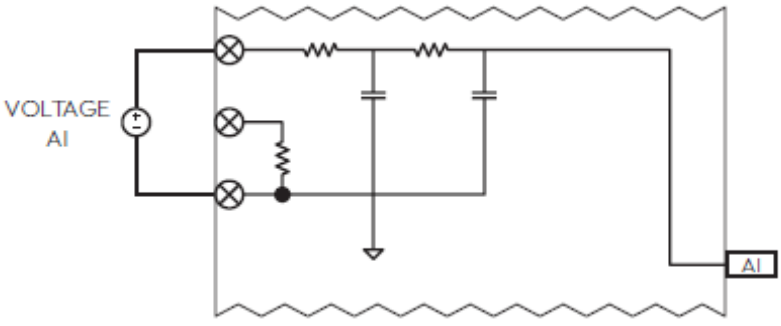

Figure 30: Analogue interface voltage

• RTD measurement (resistance thermometer). AFE can provide current source:

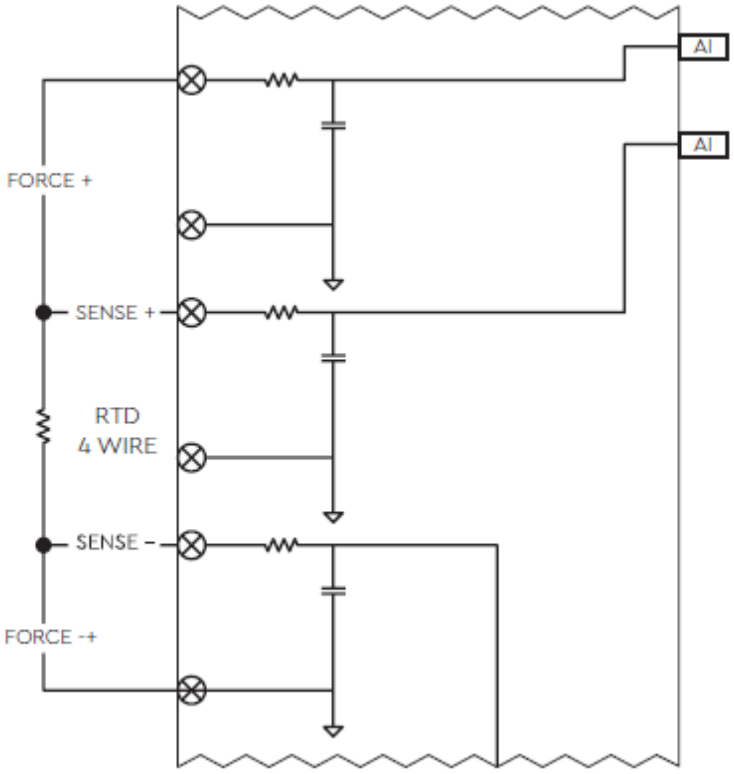

Figure 31: Analogue interface RTD measurement

• TC measurement (thermocouple) via differential measurement:

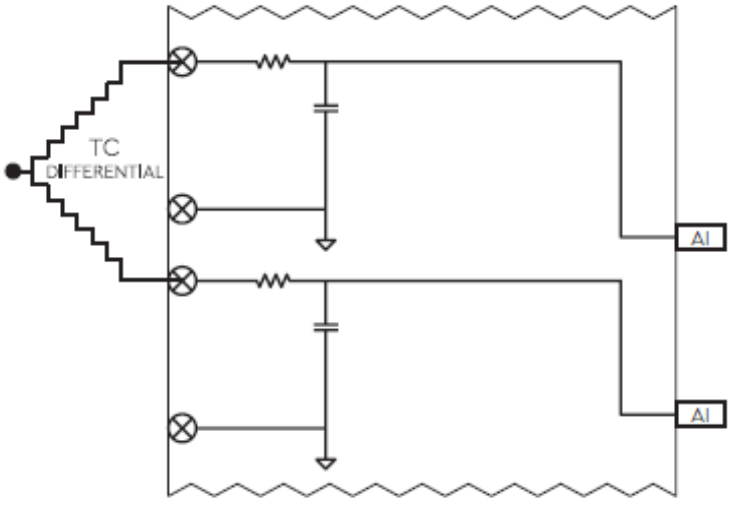

Figure 32: Analogue interface TC measurement

4.2.12 Digital IOs

The MBaX4XxL provides four digital inputs and outputs each, which are 24V compatible, at connector X35.

- The digital outputs are switched via high-side switches. The input voltage V_24V_IN or an external voltage V_24V_HSS_IN (default) can be switched.
- The power switches are controlled via GPIOs of the CPU.
- The digital inputs are connected to the TQMaX4XxL via protection circuit and comparators.

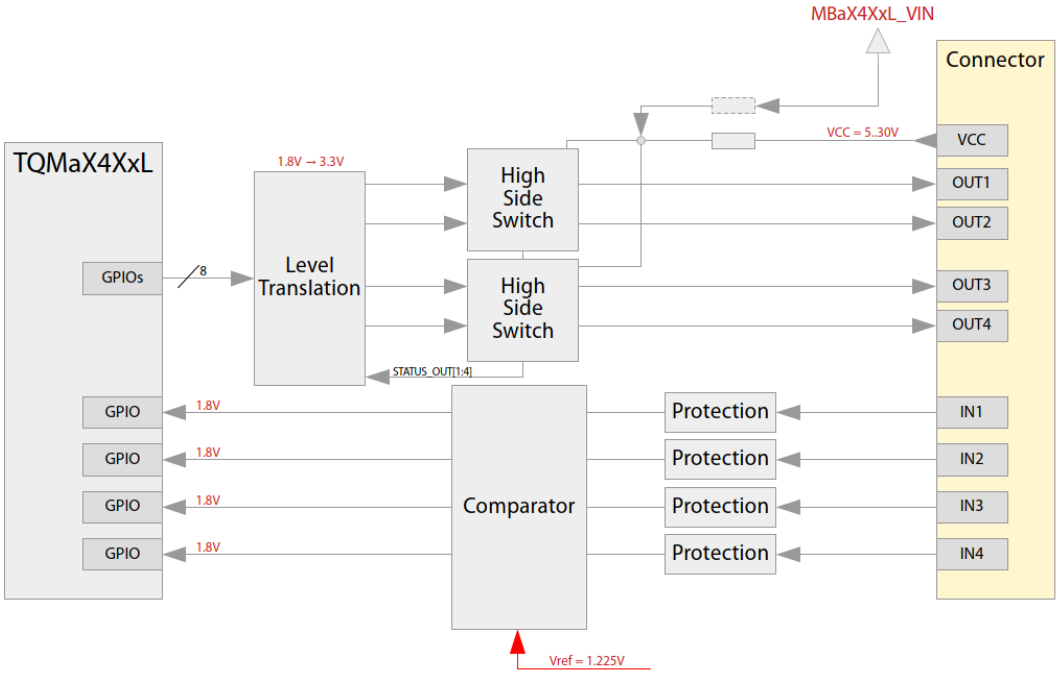

Figure 33: Block diagram Digital IOs

The following tables show the pin assignment of the digital IOs at X35:

Table 15: Pinout Digital IOs, X35

Pin	Signal	I/O	Note
1A	V_24_V_HSS_IN	I	Serves to supply the high-side switches. Alternatively, V_24V_IN can also be used by changing the assembly.
1B	DGND	P	
2A	V_24_V_HSS_IN	I	Serves to supply the high-side switches. Alternatively, V_24V_IN can also be used by changing the assembly.
2B	DGND	P	
3A	DIG_OUT_1	O	
3B	DGND	P	
4A	DIG_OUT_2	O	
4B	DGND	P	
5A	DIG_OUT_3	O	
5B	DGND	P	
6A	DIG_OUT_4	O	
6B	DGND	P	
7A	DIG_IN_1	I	
7B	DGND	P	
8A	DIG_IN_2	I	
8B	DGND	P	
9A	DIG_IN_3	I	
9B	DGND	P	
10A	DIG_IN_4	I	
10B	DGND	P	

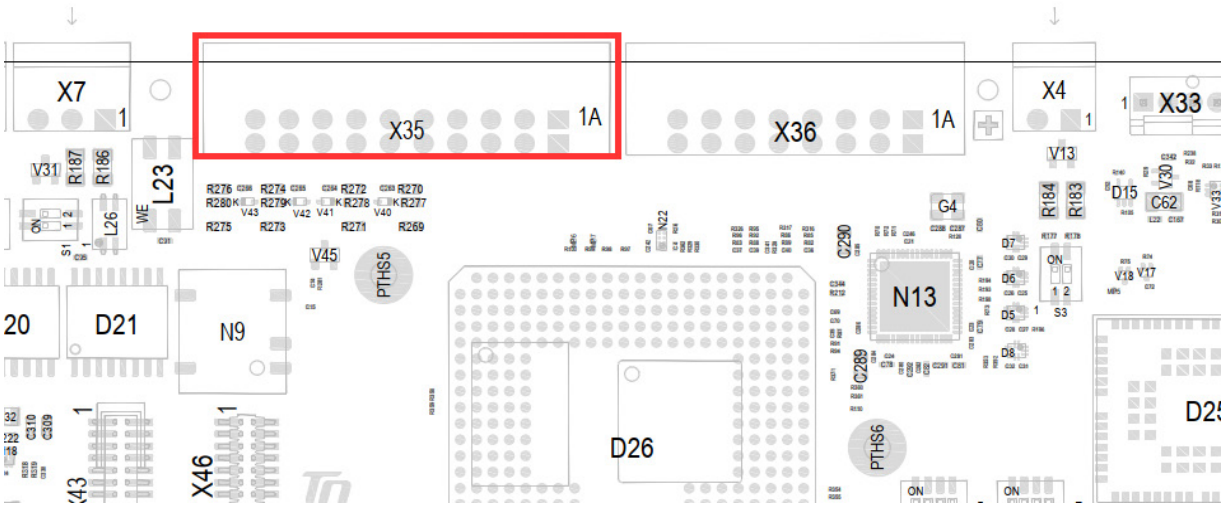

Figure 34: Position X35

4.2.13 Headers X43, X44, X45, X46

Control signals, GPIOs or factory test signals are routed to pin headers for test purposes as follows:

- GPIOs at X43
- SEC interface at X44
- Factory Tests header (not usable by the user) at X45
- Control signals at X46

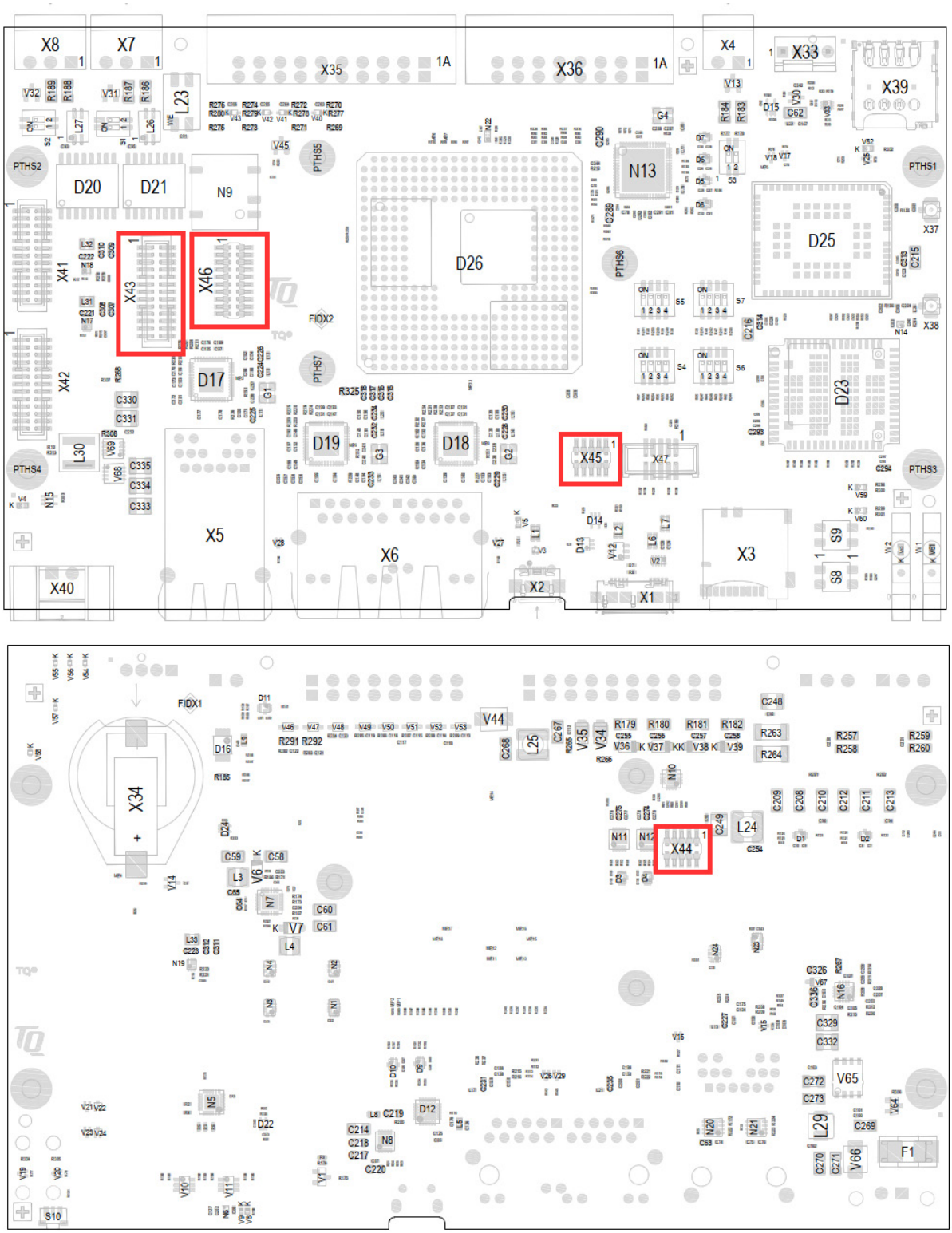

Figure 35: Position of headers X43, X44, X45, X46

Table 16: Pinout header X43

Pin	Signal	I/O	Note
1	V_3V3	P	
2	V_1V8	P	
3	DGND	P	
4	DGND	P	
5	MCU_UART1_RXD	I/O	GPIO
6	MCU_SPI0_CLK	I/O	GPIO
7	MCU_UART1_TXD	I/O	GPIO
8	MCU_SPI0_D0	I/O	GPIO
9	MCU_UART1_CTS#	I/O	GPIO
10	MCU_SPI0_D1	I/O	GPIO
11	MCU_UART1_RTS#	I/O	GPIO
12	MCU_SPI0_CS0	I/O	GPIO
13	MCU_I2C0_SCL	I/O	GPIO
14	MCU_SPI0_CS1	I/O	GPIO
15	MCU_I2C0_SDA	I/O	GPIO
16	MCU_GPIO0_1	I/O	GPIO
17	DGND	P	
18	MCU_GPIO0_0	I/O	GPIO
19	EHRPWM5_B	I/O	GPIO
20	MCU_GPIO0_20	I/O	GPIO
21	DGND	P	
22	MCU_GPIO0_21	I/O	GPIO
23	ADC0_AIN7_IN	I	0 V to 1.8V
24	MCU_GPIO0_6	I/O	GPIO
25	DGND	P	
26	DGND	P	

Table 17: Pinout header X44

Pin	Signal	I/O	Note
1	V_3V3	P	
2	V_1V8	P	
3	SE_7816_IO1	I/O	1.8 V IO logic
4	SE_14443_LA	I/O	
5	SE_7816_IO2	I/O	
6	SE_14443_LB	I/O	
7	SE_7816_CLK	I	
8	SE_ENA	I	
9	SE_7816_RST#	I	
10	DGND	P	

Table 18: Pinout header X45

Pin	Signal	I/O	Note
1	V_1V8_MOD	P	Test only, do not use
2	FACTORY_TEST_V_RTC	P	
3	V_3V3_MOD	P	
4	FACTORY_TEST_V_0V85	P	
5	FACTORY_TEST_V_1V1	P	
6	FACTORY_TEST_V_1V8_AUX	P	
7	FACTORY_TEST_V_VDD_CORE	P	
8	FACTORY_TEST_V_1V8A	P	
9	TQ_EEPROM_WC#	I	Data EEPROM
10	DGND	P	

Table 19: Pinout header X46

Pin	Signal	I/O	Note
1	V_3V3	P	
2	V_1V8	P	
3	TQMaX4XxL_HARD_RST#	I	
4	MCU_SAFETY_ERROR#	I/O	
5	MCU_PORz	I	
6	RTC_CLKOUT	O	
7	MCU_RESETz	I	
8	RTC_INT#	O	
9	RESET_REQz	I	
10	TEMP_ALERT	O	
11	PORz_OUT	O	
12	CUST_EEPROM_WC#	I	
13	MCU_RESETSTATz	O	
14	DGND	P	
15	RESETSTATz	O	
16	I2C0_SCL	O	
17	TQMaX4XxL_PGOOD	O	
18	I2C0_SDA	I/P	
19	DGND	P	
20	DGND	P	

4.3 Diagnosis- and user interfaces

4.3.1 Diagnosis LEDs

The MBaX4XxL provides the following status LEDs to indicate the system condition:

Table 20: Status LEDs

Reference	Note	Control signal	Colour
V59	TQMaX4XxL PGOOD	TQMaX4XxL_PGOOD	Green / Red
V60	MBaX4XxL PGOOD	V_5V0_SW_PGOOD	Green / Red
V4	Power X40	V_24V_IN	Blue
V61	User LED 1	USER_LED_1 (MCU_GPIO0_8)	Green
V63	User LED 2	USER_LED_2 (MCU_GPIO0_9)	Yellow
V62	Net status of IoT radio module	BG95_NET_STATUS	Green
X5 / X6	Activity / Link LED (Ethernet)	PHY LED signal	Green / Yellow
V5	USB Debug Self-Power (5V)	5 V Input of X2	Blue

4.3.2 Navigation button

A navigation button (user button) is available to the user on the MBaX4XxL.

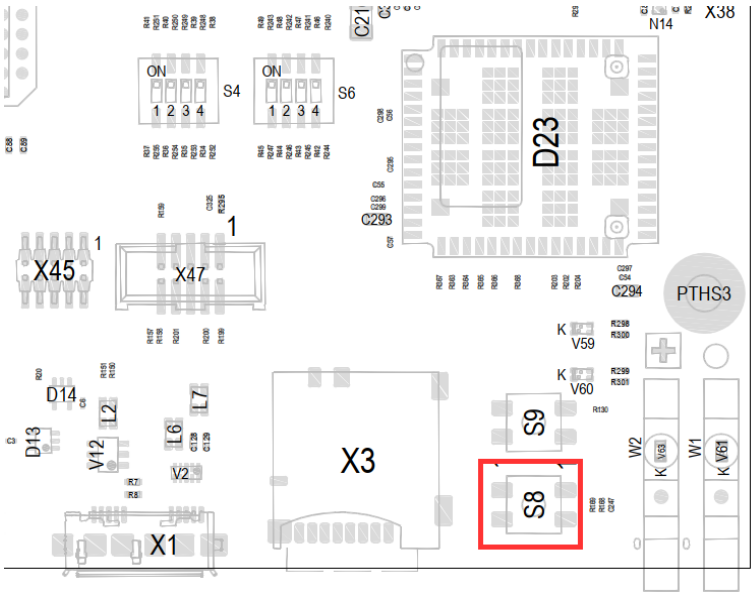

Figure 36: Position of navigation buttons S8

4.3.3 Reset buttons

Two reset buttons are available to the user on the MBaX4XxL.

Table 21: Reset buttons

Reference	Description	Control signal
S9	Control of a cold reset	MCU_PORz
S10	Activates the power sequencing on the module	TQMaX4XxL_HARD_RST#

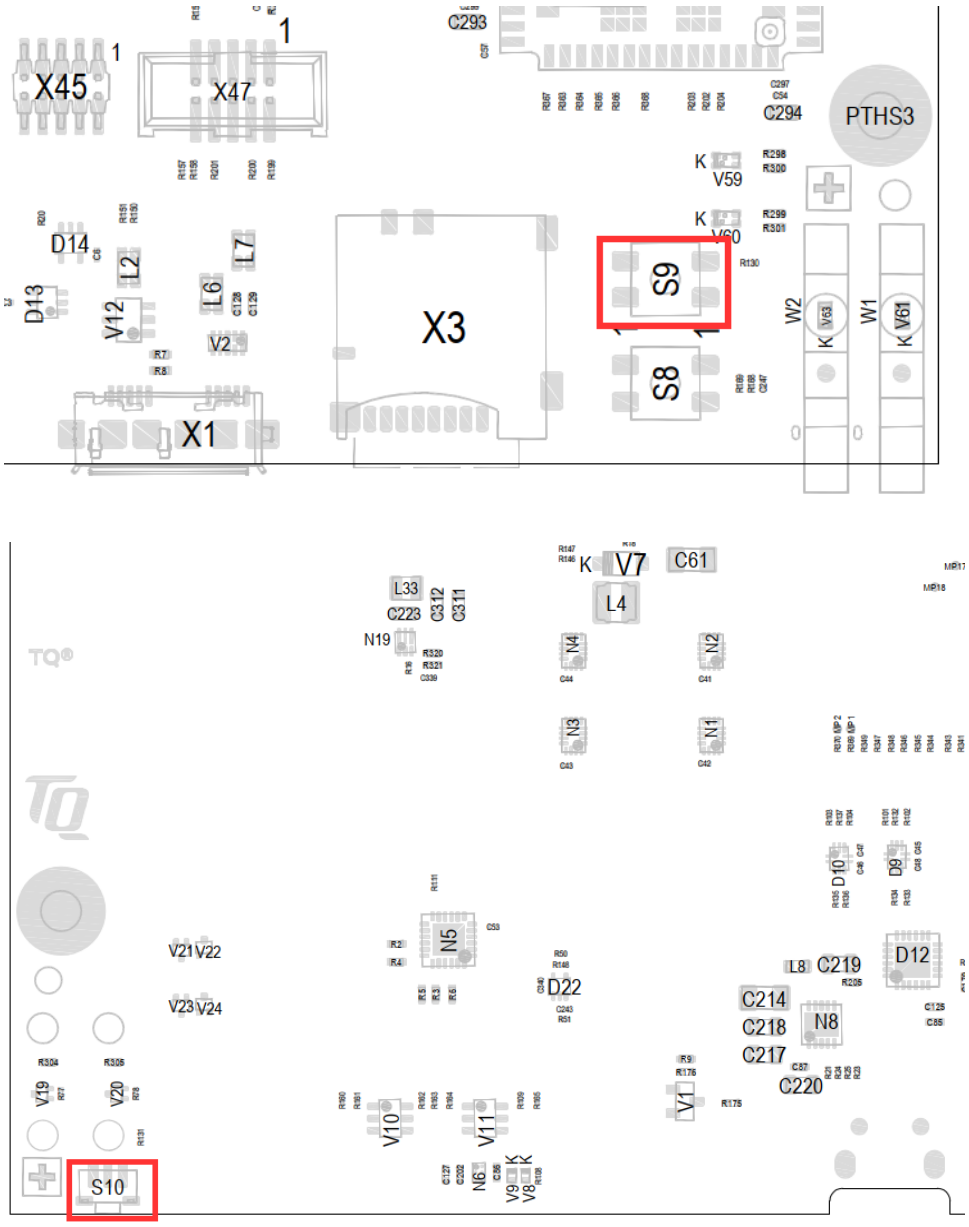

Figure 37: Positions of S9 and S10

4.3.4 Boot-Mode configuration

The MBaX4XxL supports the following boot sources of the TQMaX4XxL:

- eMMC Flash (internal to module)
- QSPI-NOR flash (internal to module)
- UART (external host) via Debug-USB (X2)
- USB slave (USB boot from external host) via USB-OTG (X1)

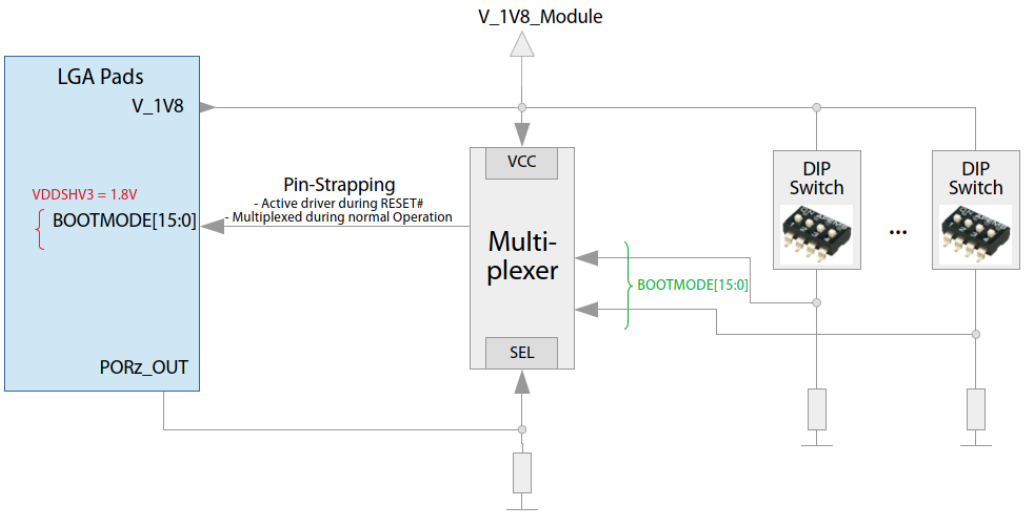

Figure 38: Block diagram boot source

The boot source is selected via the corresponding boot strap pins which can be set via DIP switches. The following table shows the settings of the DIP switch configuration.

Table 22: Boot mode configuration

DIP-Switch		Signal	eMMC	QSPI-NOR	UART	USB
S4	1	BOOTMODE00	ON	ON	ON	ON
	2	BOOTMODE01	ON	ON	ON	ON
	3	BOOTMODE02	OFF	OFF	OFF	OFF
	4	BOOTMODE03	ON	OFF	ON	OFF
S5	1	BOOTMODE04	OFF	ON	ON	ON
	2	BOOTMODE05	OFF	OFF	ON	OFF
	3	BOOTMODE06	ON	OFF	OFF	ON
	4	BOOTMODE07	Don't care	OFF	Don't care	OFF
S6	1	BOOTMODE08	Don't care	ON	Don't care	OFF
	2	BOOTMODE09	Don't care	Don't care	Don't care	AM64x = ON AM243x = OFF
	3	BOOTMODE10	Don't care	Don't care	Don't care	Don't care
	4	BOOTMODE11	Don't care	Don't care	Don't care	Don't care
S7	1	BOOTMODE12	Don't care	Don't care	Don't care	Don't care
	2	BOOTMODE13	Don't care	Don't care	Don't care	Don't care
	3	BOOTMODE14	OFF	OFF	OFF	OFF
	4	BOOTMODE15	OFF	OFF	OFF	OFF

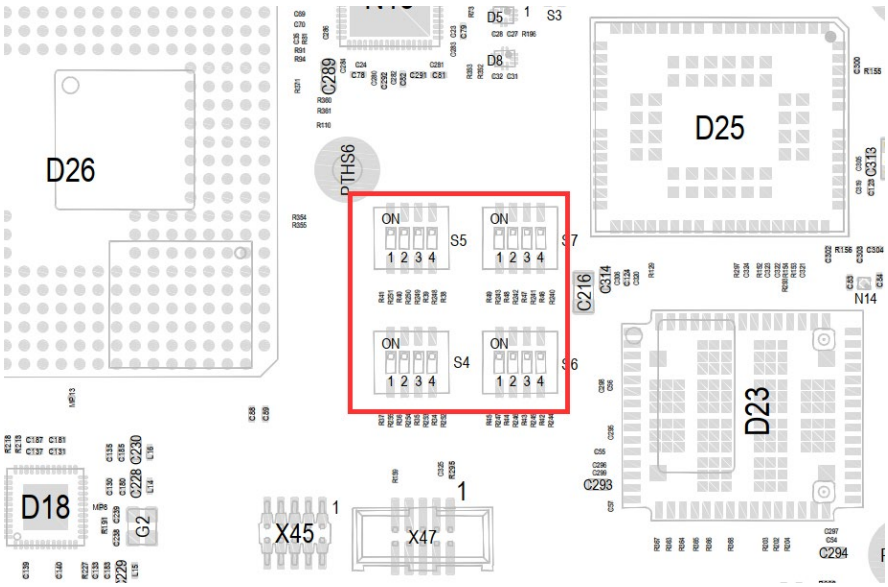

Figure 39: Placement DIP switches for boot source

5. SOFTWARE

No software is required for the MBaX4XxL.
Suitable software is only required on the module TQMaX4XxL and is not a part of this specification.
More information can be found in the Support Wiki for the TQMaX4XxL.

6. MECHANICS

6.1 Dimensions

The MBaX4XxL has overall dimensions (length × width) of 160 mm × 100 mm (Eurocard).

6.2 Thermal management

Depending on the application, the power consumption of the CPU makes it necessary to ensure a cooling of the CPU. For this a 4-pin connector X33 is provided on the MBaX4XxL for a standard fan. For more information, please refer to the TQMaX4XxL User's Manual.

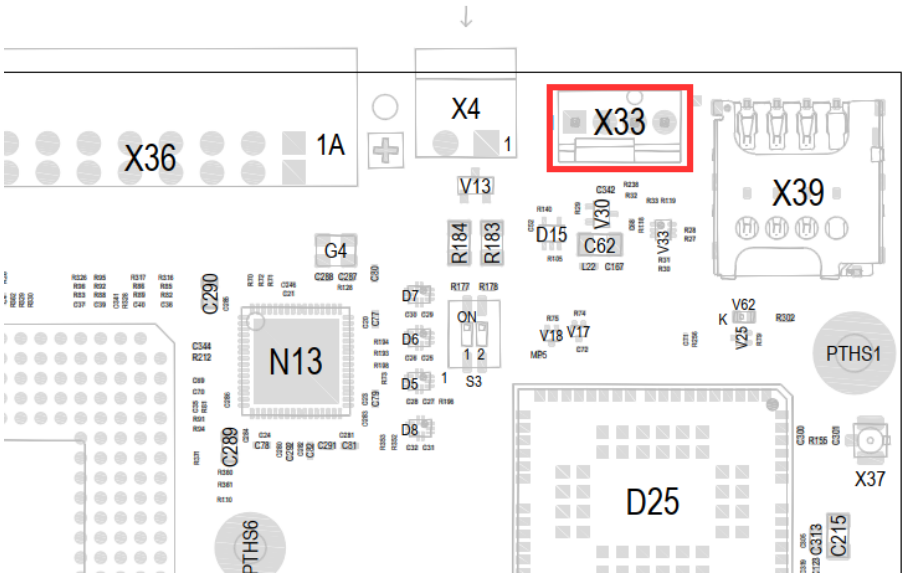

Figure 40: Position X33

Table 23: Pinout X33

Pin	Signal	Note
1	DGND	
2	V_FAN	Imax: 100 mA @ 12 V
3	FAN_RPM	
4	FAN_PWM	

6.3 MBaX4XxL, assembly

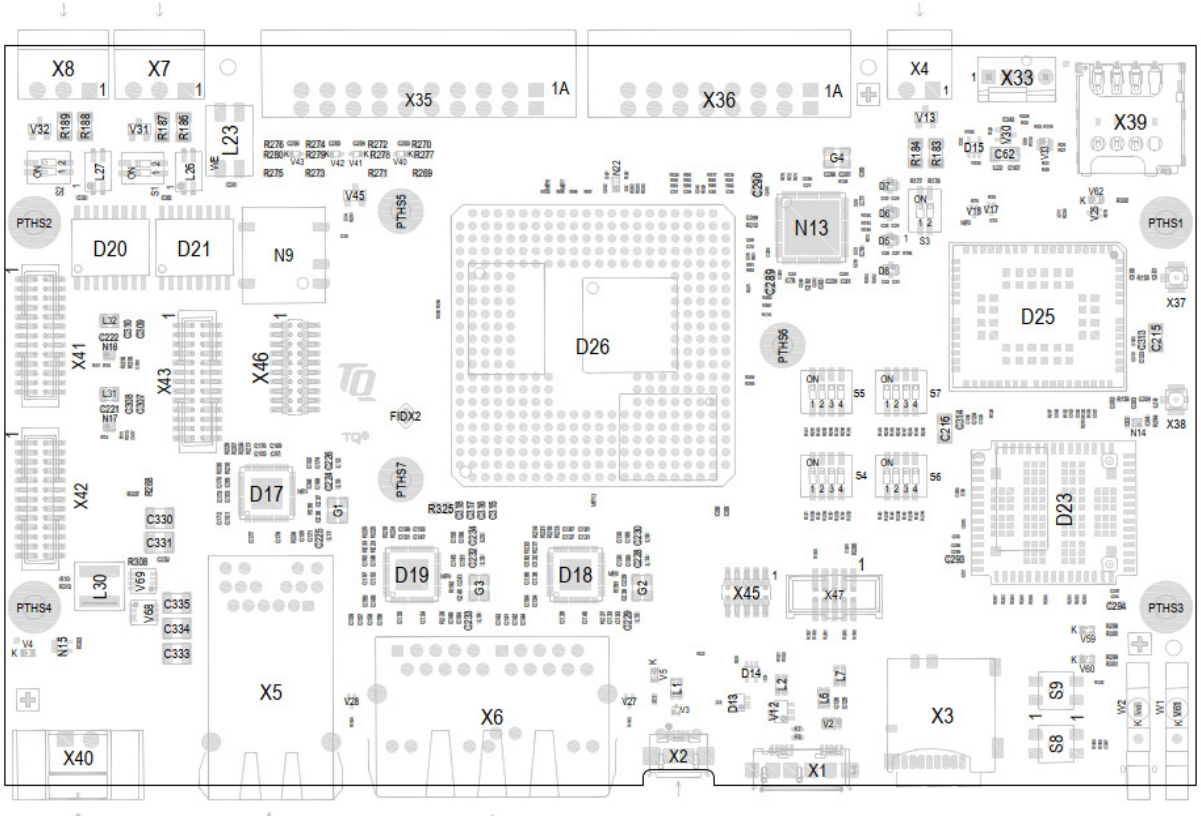

Figure 41: MBaX4XxL, component placement top

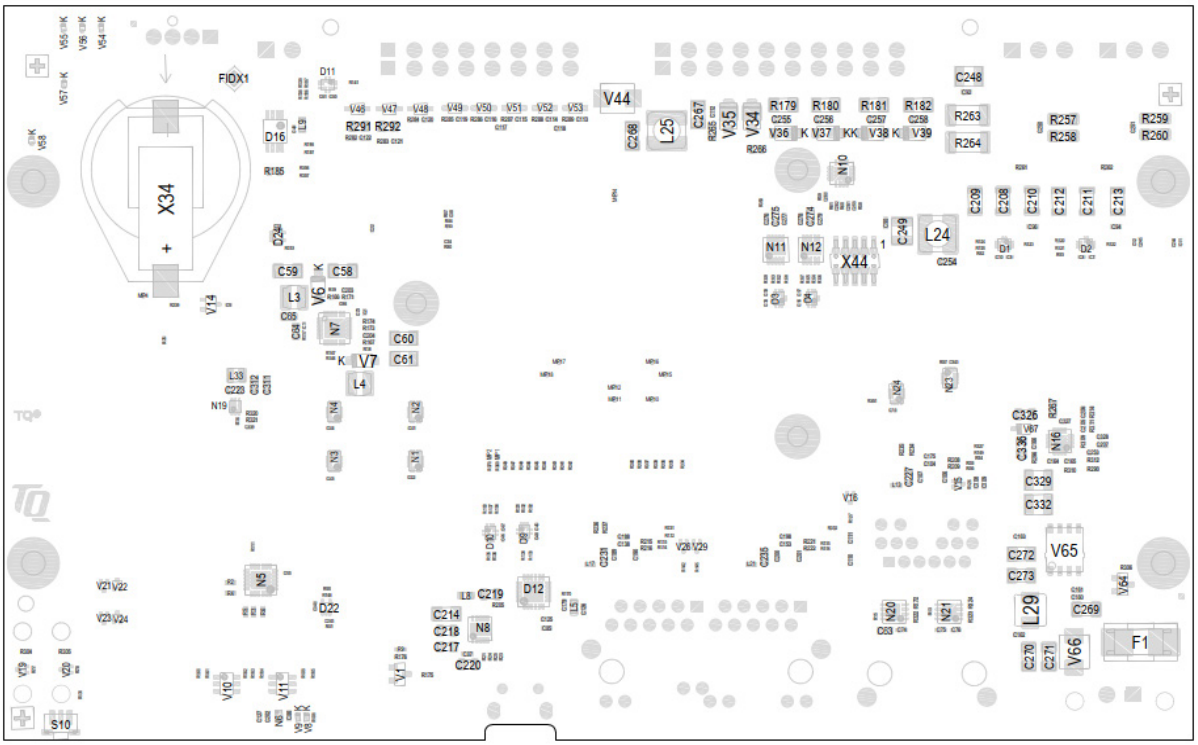

Figure 42: MBaX4XxL, component placement bottom

6.4 Label placement

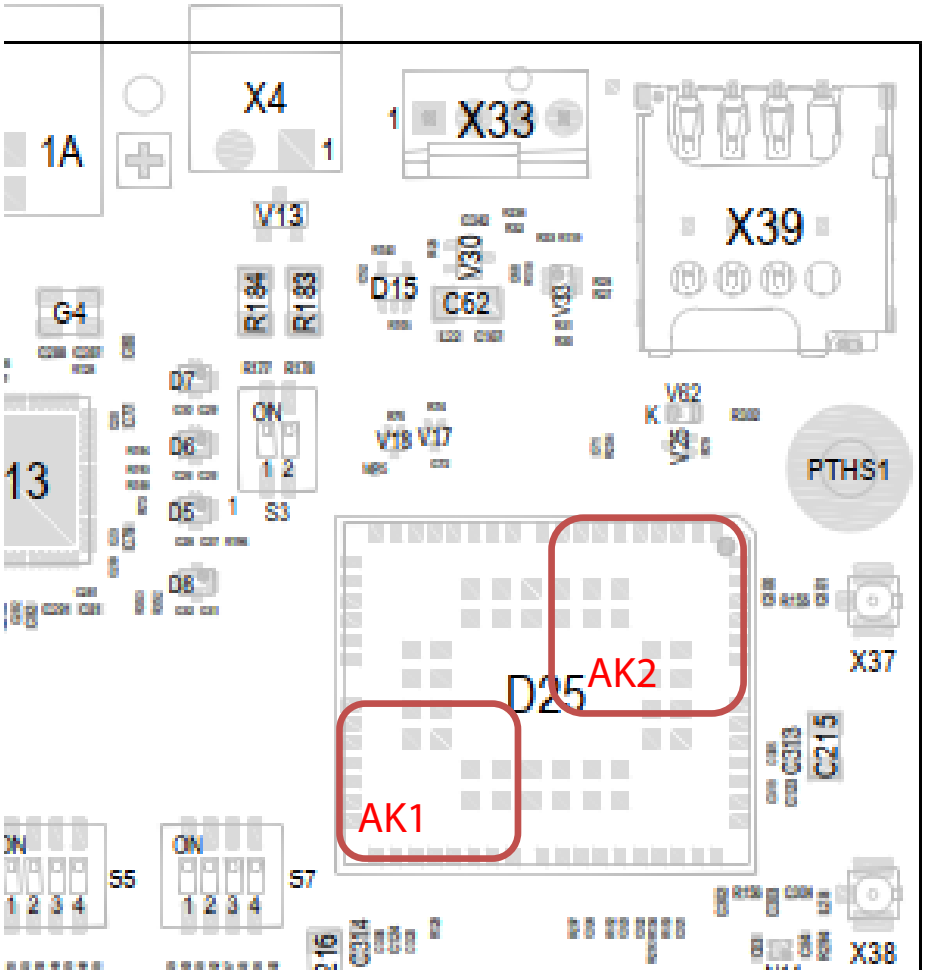

Figure 43: Label placement

Table 24: Labels

Name	Note
AK1	TQ Serial number
AK2	Article description / Test run

7. SAFETY REQUIREMENTS AND PROTECTIVE REGULATIONS

7.1 EMC

The MBaX4XxL was developed according to the requirements of electromagnetic compatibility (EMC). Depending on the target system, anti-interference measures may still be necessary to guarantee the adherence to the limits for the overall system.

Following measures are recommended:

- Robust ground planes (adequate ground planes) on the printed circuit board
- A sufficient number of blocking capacitors in all supply voltages
- Fast or permanently clocked lines (e.g., clock signals) should be kept short;
  avoid interference of other signals by distance and/or shielding,
  also pay attention to frequencies and signal rise times
- Filtering of all signals, which can be connected externally
  (also "slow signals" and DC can radiate RF indirectly)
- Direct signal routing without stubs for multi-pole interfaces (e.g. LC display)

7.2 ESD

In order to avoid interspersion on the signal path from the input to the protection circuit in the system, the protection against electrostatic discharge should be provided directly at the inputs of a system. As these measures always have to be implemented on the carrier board, no special protective measures were provided on the MBaX4XxL.

The following measures are recommended for a carrier board:

- Generally applicable: Shielding of inputs (shielding connected well to ground / housing on both ends)
- Supply voltages: Suppressor diodes
- Slow signals: RC filtering, Zener diodes
- Fast signals: Protection components, e.g., suppressor diode arrays

7.3 Operational safety and personal security

Due to the occurring voltages (≤30 V DC), tests with respect to the operational and personal safety haven't been carried out.

8. CLIMATIC AND OPERATIONAL CONDITIONS

The permissible temperature range of the module depends strongly on the installation situation (heat dissipation through heat conduction and convection) and the use. Therefore, no fixed value can be given for the entire module group. In general, reliable operation is ensured if the following conditions are met:

Table 25: Climatic and operational conditions MBaX4XxL

Parameter	Range	Remark
Environmental temperature	-40 °C to +85 °C	Without Lithium battery
Storage temperature	-40 °C to +100 °C	–
Relative air humidity (operation / storing)	10 % to 90 %	Not condensing

Attention:	
	The CPU belongs to a performance category in which a cooling system may be essential in certain applications. It is the user's responsibility to define a suitable cooling method depending on the specific mode of operation (e.g., dependence on clock frequency, stack height, airflow, and software). When connecting the heat sink, special attention must be paid to the tolerance chain (PCB thickness, PCB curvature, BGA balls, BGA package, thermopad, heat sink). The CPU is not the highest component in every case. A defective cooling connection can lead to overheating of the module and thus to malfunctions, premature aging or destruction.

8.1 Protection against external effects

Protection class IP00 was defined for the MBaX4XxL. There is no protection against foreign objects, touch or humidity.

8.2 Reliability and service life

No detailed MTBF calculation has been done for the MBaX4XxL.
The MBaX4XxL is designed to be insensitive to vibration and impact.
Service life limiting components such as electrolytic capacitors were not used.

9. ENVIRONMENT PROTECTION

9.1 RoHS

The MBaX4XxL is manufactured RoHS compliant.

- All components and assemblies are RoHS compliant
- The soldering processes are RoHS compliant

9.2 WEEE®

The final distributor is responsible for compliance with the WEEE® regulation.
Within the scope of the technical possibilities, the MBaX4XxL was designed to be recyclable and easy to repair.

9.3 REACH®

The EU-chemical regulation 1907/2006 (REACH® regulation) stands for registration, evaluation, certification and restriction of substances SVHC (Substances of very high concern, e.g., carcinogen, mutagen and/or persistent, bio accumulative and toxic). Within the scope of this juridical liability, TQ-Systems GmbH meets the information duty within the supply chain with regard to the SVHC substances, insofar as suppliers inform TQ-Systems GmbH accordingly.

9.4 EuP

The Ecodesign Directive, also Energy using Products (EuP), is applicable to products for the end user with an annual quantity >200,000. The MBaX4XxL must therefore always be seen in conjunction with the complete device.
The available standby and sleep modes of the components on the MBaX4XxL enable compliance with EuP requirements for the MBaX4XxL.

9.5 Packaging

By environmentally friendly processes, production equipment and products, we contribute to the protection of our environment. To be able to reuse the MBaX4XxL, it is produced in such a way (a modular construction) that it can be easily repaired and disassembled. The energy consumption of this subassembly is minimised by suitable measures. The MBaX4XxL is delivered in reusable packaging.

9.6 Batteries

9.6.1 General notes

Due to technical reasons a battery is necessary for the MBaX4XxL. Batteries containing mercury (Hg), cadmium (Cd) or lead (Pb) are not used.
If this is for technical reasons unavoidable, the device is marked with the corresponding hazard note.
To allow a separate disposal, batteries are generally only mounted in sockets.

9.6.2 Lithium batteries

The requirements concerning special provision 188 of the ADR (section 3.3) are complied with for Lithium batteries.
There is therefore no classification as dangerous goods:

- Basic lithium content per cell not more than 1 g
  (except for lithium ion and lithium polymer cells for which a lithium content of not more than 1.5 g per cell applies (equals 5 Ah)).
- Basic lithium content per battery not more than 2 g
  (except for lithium ion batteries for which a lithium content of not more than 8 g per cell applies (equals 26 Ah)).
- Lithium cells and batteries are examined according to UN document ST/SG/AC.10-1.

During transport a short circuit or discharging of the socketed lithium battery is prevented by extricable insulating foils or by other suitable insulating measures.

9.7 Other entries

By environmentally friendly processes, production equipment and products, we contribute to the protection of our environment. To be able to reuse the MBaX4XxL, it is produced in such a way, that it can be easily repaired and disassembled. The energy consumption of this subassembly is minimised by suitable measures. Due to the fact that at the moment there is still no technical equivalent alternative for printed circuit boards with bromine-containing flame protection (FR-4 material), such printed circuit boards are still used. No use of PCB containing capacitors and transformers (polychlorinated biphenyls). These points are an essential part of the following laws:

- The law to encourage the circular flow economy and assurance of the environmentally acceptable removal of waste as at 27.9.94
  (Source of information: BGBl I 1994, 2705)
- Regulation with respect to the utilization and proof of removal as at 1.9.96
  (Source of information: BGBl I 1996, 1382, (1997, 2860))
- Regulation with respect to the avoidance and utilization of packaging waste as at 21.8.98
  (Source of information: BGBl I 1998, 2379)
- Regulation with respect to the European Waste Directory as at 1.12.01
  (Source of information: BGBl I 2001, 3379)

This information is to be seen as notes. Tests or certifications were not carried out in this respect.

10. APPENDIX

10.1 Acronyms and definitions

The following acronyms and abbreviations are used in this document.

Table 26: Acronyms

Acronym	Meaning
ADC	Analog/Digital Converter
BIOS	Basic Input/Output System
BSP	Board Support Package
CAN	Controller Area Network
CPU	Central Processing Unit
DDR3L	DDR3 Low Voltage
DIN	German industry standard (Deutsche Industrie Norm)
DIP	Dual In-line Package
EEPROM	Electrically Erasable Programmable Read-Only Memory
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
eMMC	embedded Multimedia Card (Flash)
EN	European standard (Europäische Norm)
ESD	Electrostatic Discharge
EuP	Energy using Products
FET	Field Effect Transistor
FFC	Flat Flex Cable
FR-4	Flame Retardant 4
GPIO	General Purpose Input/Output
HP	Headphone
I/O	Input/Output
I^2C	Inter-Integrated Circuit
IEEE®	Institute of Electrical and Electronics Engineers
IP00	Ingress Protection 00
JTAG®	Joint Test Action Group
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LSB	Least Significant Bit
LVDS	Low Voltage Differential Signal
MCASP	Multichannel Audio Serial Port
MII	Media Independent Interface
MMC	Multimedia Card
MSB	Most Significant Bit
MTBF	Mean operating Time Between Failures

Table 26: Acronyms (continued)

Acronym	Meaning
n.c.	Not Connected
NOR	Not-Or
NP	Not Placed
OTG	On-The-Go
PCB	Printed Circuit Board
PCIe	Peripheral Component Interconnect express
PCMCIA	People Can't Memorize Computer Industry Acronyms
PD	Pull-Down
PHY	Physical (OSI model layer)
PMIC	Power Management Integrated Circuit
PRU	Programmable Real-Time Unit
PU	Pull-Up
REACH®	Registration, Evaluation, Authorisation (and restriction of) Chemicals
RGMII	Reduced Gigabit Media Independent Interface
RJ45	Registered Jack 45
RMS	Root Mean Square
RoHS	Restriction of (the use of certain) Hazardous Substances
RS-232, RS-485	Recommended Standard (serial interface)
RTC	Real-Time Clock
SD card	Secure Digital card
SD/MMC	Secure Digital Multimedia Card
SDRAM	Synchronous Dynamic Random Access Memory
SIM	Subscriber Identification Module
SMD	Surface-Mounted Device
SMT	Surface-Mount Technology
SPI	Serial Peripheral Interface
THD	Through-Hole Device
THT	Through-Hole Technology
UART	Universal Asynchronous Receiver/Transmitter
UIM	User Identity Module
USB	Universal Serial Bus
WEEE®	Waste Electrical and Electronic Equipment
WLAN	Wireless Local Area Network
WP	Write-Protection
WPAN	Wireless Personal Area Network
WWAN	Wireless Wide Area Network

10.2 References

Table 27: Further applicable documents

No.	Name	Rev. / Date	Company
(1)	AM64x / AM243x Processors Silicon Revision 1.0 Technical Reference Manual	B / June 2021	Texas Instruments
(2)	AM64x Sitara Processors Datasheet	A / June 2021	Texas Instruments
(3)	AM243x Sitara Microcontrollers Datasheet	A / June 2021	Texas Instruments
(4)	TQMaX4XxL Preliminary User's Manual	– current –	TQ-Systems
(5)	Support-Wiki for the TQMaX4XxL	– current –	TQ-Systems

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