Zoox TCU User Manual Version 0.0

05.09.2023
Harman International Corp
nasserullah.khan@harman.com

ZOOX

Change History

Version	Date	Change from Previous	Name	Status
0.0	09.05.2023	Frist Draft	Nasserullah Khan	Draft

1.1 Contents

1.2 List of Figures:

1.3   List of Tables.

2   Technical Description

2.1   Disclaimer

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2.2 Regulatory Notices

FCC

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

(1) This device may not cause harmful interference, and

(2) The device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

EMC

Class B

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

—Reorient or relocate the receiving antenna.

—Increase the separation between the equipment and receiver.

—Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.

—Consult the dealer or an experienced radio/TV technician for help.

RF exposure safety

This device complies with the FCC RF exposure limits and has been evaluated in compliance with portable/mobile exposure conditions.

The equipment must be installed and operated and was evaluated with minimum distance of **32 cm** of the human body. This distance or greater is maintained by vehicle design and ensures compliance by normal use of the vehicle.

This TCU is not intended for operation by end consumers, and it intended to be used only in the Zoox L5 Robot Taxi vehicle, where it will be controlled and operated by the Head unit in the vehicle.

2.3 Introduction

Development of a new generation telematics control unit with:

State-of-the-Art mobile communication technology (4G, 5G, 3GPP Release 15)

Novel customer functions and technologies (1 Gbps Ethernet)

Modular Architecture supporting future updates of the mobile communication technology

Scalable HW-/SW-Platform for different Variants

…while accomplishing the following premises:

Fulfillment of the Development/Quality/Cost objectives

Complete support of legal requirements

Timely compliance with the development deadlines

Ensuring the industrialization milestone (D-Sample)

Ensuring the start of the Series Production with SOP 07/2021

2.4 Intended Usage

This TCU device is a Communication and Data Interface for the Vehicle and contains the following features:

GSM, UMTS, LTE and Optionally 5G.

GSM and 5G are disabled in the TCU by the device Software.

It provides different telematics services and is the interface between different ECUs of Zoox vehicles and the public Cellular network.

The Zoox vehicle is fully Autonomous and the intended use of the vehicle is as a ride share or fully Autonomous Taxi. So, the vehicle uses 3 TCUs for redundancy.

3   System Description

3.1 TCU System Features

- The Zoox TCU (Telematics Control Unit) is a robust stand-alone ECU which provides external connectivity through mobile communication networks for the vehicle. This allows the vehicle to enable voice calls, emergency call services as well as data services from and to the Zoox backend and the internet.

- The TCU serves as an IP router for other vehicle ECUs. In addition to the router functionality, the main features are various emergency call services, Remote Vehicle Services, Status Uploader, Vehicle Video upload and Remote Software Update to the vehicle (over-the-air), among others.

- The TCU provides state-of-the-art mobile communication technologies such as GSM, UMTS, LTE and 5G with 2x2 MIMO and carrier aggregation capabilities. Moreover, it supports FDD and TDD modes. It also integrates a modular architecture that allows for future updates of the mobile communication technology (i.e. future 3GPP Releases) with no impact on the software and hardware components with the exception of software communication interfaces, software device drivers and the NAD (i.e. mobile communication modem).

- Zoox TCU has only one mechanical variant. This is the Roof variant, where the ECU is mounted on the roof. External antennas are connected to the TCU by means of coaxial cables and automotive grade coaxial connectors.

- The Functional variant offered to Zoox is the 4G variant with an option to upgrade to the High variant, with 5G state of the art, mobile communication technology. The TCU NAD supports 2x2 MIMO. The TCU supports CAT 16 LTE with up to 1 Gbps data rate in DL with 5 CC CA. The 5G option supports 1.9 Gbps DL. For UL, the TCU supports CAT 13 with 150 Mbps data rate 2UL CA. The 5G option can support uplink data rates of >2Gbps depending on Network conditions. The final Throughput from the TCU is limited by the Ethernet connection to the vehicle.

- The TCU is connected to the head unit via an automotive Ethernet interface based on the 1000Base-T1 specification. The TCU has a network access device, with a eUICC/SIM with subscription management (that allows for managing the SIM subscription of different mobile network operators). It also has an application processor running the diagnostics as well as the application and system software and a Wake up controller to reduce the sleep current requirements.

- The TCU also supports WiFi access with 801.11 a/b/g/n/ac/ax capability. 11ax data throughput is limited by the Ethernet data rate and the processing required at the SOC to convert between WiFi packets and Ethernet packets. Please refer to section 4.4 for more details of WLAN.

- The main Audio interface to the Vehicle is through the A2B audio bus interface. The A2B bus is a daisy chain configuration, which can connect to many different audio devices. In the Zoox Vehicle, the A2B bus connects all the 3 TCUs to the head unit. The head unit is the main node and all the TCUs are subordinate nodes. The TCU also has a mic and a speaker (driven by an audio amp) which are used only for emergency phone calls when the head unit is not functional.

3.2   Power supplies

The TCU is powered directly from the 12V nominal Vehicle battery. A PMIC, Switching regulators and LDOs are used to generate all the internal voltages required by the TCU circuits. Please refer to **Error! Reference source not found.** for the details.

4   Detailed Description

4.1   Application Processor

The Zoox TCU currently uses the MT2712X derivate.

Part # per 2-phase	big Cores A72	Little Cores A35	Peak DMIPS	DRAM LPDDR4	GPU- ARM Mali T880	VIDEO Codec	DISPLAY OUTPUT
MT2712N	1x 1.2GHz	3x 1.2GHz	12.0K	4ch x 16b	MP2	FHD	x3
MT2712T	1x 1.0GHz	3x 0.8GHz	8.9K	4ch x 16b	MP2	FHD	x3
MT2712X	1x 1.0GHz	3x 0.8GHz	8.9K	4ch x 16b	NA	NA	NA

Figure 1: -- Application Processor Version Table

4.2   NAD Module – Network Access Device

The NAD module has been designed with the Samsung S5123 chipset and supports 3GPP release 15 features. It contains all the components to realize these features including the RF front end, RF ICs, and Base band processor. It has high speed interfaces to the host processor and other interfaces to the TCU circuits. It has internal 512 MB LPDDR memory which is loaded from the external flash memory at startup. It is powered from a single 4.2V power supply. It interfaces to a SIM card and also an eSIM IC. SW can select which SIM will be configured and used. For Zoox, the NAD module supports 2x2 MIMO and has two coaxial connectors connected to two external antennas.

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4.2.1 Supported Bands

Products	Bands
NA	**LTE FDD:** B2,B4,B5,B7,B10,B12,B13,B17,B25,B26,B29(Rx),B30(Rx),B66,B71 **LTE TDD:** B41 **WCDMA/HSPA+:** B2,B4,B5 **GSM/GPRS/EDGE:** 850MHz,1900MHz **5G:** n2,n5,n7,n25,n41,n66,n71

Table 1. NAD supported Bands

4.2.2 Physical Properties

Feature	Description
Physical Dimensions	Dimensions (L $\times$ W $\times$ H): 43 mm $\times$ 38 mm $\times$ 2.5 mm Weight: about 12 g
Operating Temperature	Normal operating temperature: -40℃ to +85℃ Extended operating temperature : -40℃ to +95℃
Storage Temperature	-40℃ to +95℃
Humidity	RH5% to RH95%
Power Voltage	DC 3.8 V to 4.2 V (typical value is 4.0 V)
Antenna Interface	antenna pad x 6

Table 2. NAD Physical Properties

4.3 WLAN

The TCU has a Wireless LAN module. It supports both 2.4 GHz and 5 GHz operation with 2x2 MIMO. The chipset has a Dual MAC for supporting 11ax on one Mac and 11ac on the 2nd MAC simultaneously. Chipset uses 1024 QAM modulation in 11ax and 256 QAM in 11ac but limited to 80 MHz BW. The module supports 802.11 a/b/g/n/ac/ax networks. UNII 1 & 3 bands are supported. Both Master and Slave modes are supported. DFS is not supported.

- o WLAN Antenna 1 (TX) → 802.11 b/g/n (2.4GHz) AND 802.11a/n/ac/ax (5GHz, and less than 6GHz)
- o WLAN Antenna 2 (TX) → 802.11 b/g/n (2.4GHz) AND 802.11a/n/ac/ax (5GHz, and less than 6GHz)

4.4 Audio

4.4.1 Audio Amplifier

In order to fulfill the requirement of 3W Average Audio output, it is necessary to have an Audio Amplifier. The amplifier is used only in case of an emergency call, when the head unit is not functional. The audio downlink path from the

4.4.2 Audio Amplifier configuration.

The amplifier has to be configured as below at startup. .

Amplifier Control:

Gain:	26dB
Switching Freq.:	400 kHz
Speaker guard:	9.8Vpeak

Table 3: -- Amplifier Control

All settings have to be done via the I2C control interface. The device communicates with the system processor via the I2C serial communication bus as an I2C slave-only device. The processor can poll the device via I2C to determine the operating status. All reports of fault conditions and detections are via I2C. The I2C interface is active approximately 1ms after the STANDBY pin is high.

The I2C interface controls the following device features:

• Changing gain setting to 20 dB, 26 dB, 32 dB, or 36 dB.

• Controlling peak voltage value of Speaker Guard protection circuitry

• Reporting load diagnostic results

• Changing of switching frequency for AM radio avoidance

4.4.3 A2B Interface:

The Zoox Vehicle has 3 TCUs for redundancy and the audio routing is done as below on the A2B bus. The normal calls from the Cellular network are routed over the A2B bus from TCU3 to the Infotainment unit, which will route the audio to the main Vehicle speaker and Microphones.

In case of an emergency when the head unit is not functional, then the audio is routed to the dedicated Speaker and Mic connected to the TCU1.

4.5   Ethernet PHY

The TCU implements the automotive 1000BASE-T1

It implements the Ethernet physical layer following the definition in IEEE 802.3 bw, for 100BASE-T1, and IEEE 802.3bp for 1000BASE-T1. This includes auto-negotiation and link-synchronization.
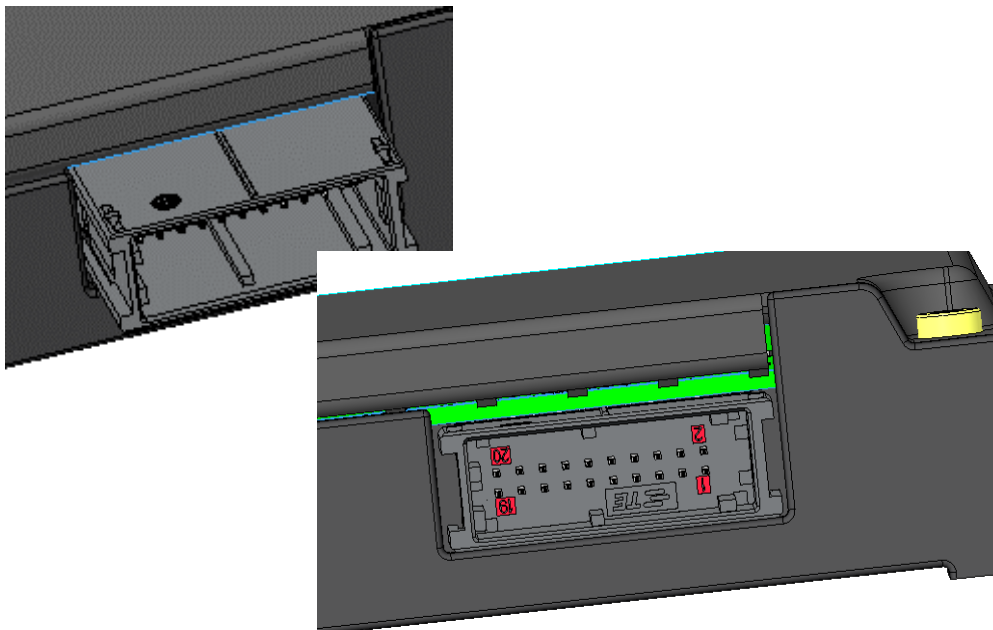
4.6   Connectors
- Main System Connector (20 pin):

Figure 2: -- System Connector Pin details

Pin #:	Signal name:	Current:	Notes:
1	Terminal30 (Main Battery +)		
2	GND		
3	Terminal30 (Main Battery +)		
4	GND		
5	NC		No Connect
6	ECallSpeaker+		Pin 6 and 8 are one twisted pair
7	Wakeup_Line		
8	ECallSpeaker-		Pin 6 and 8 are one twisted pair
9	GND		
10	eCALL_Button		
11	A2B_AN		Pin 11 and 13 are one twisted pair
12	eCALL_LED		
13	A2B_AP		Pin 11 and 13 are one twisted pair
14	NC		No Connect
15	GND		Connect shield of twisted pairs at pin 11,13 and 17,19 to pin 15
16	MiC_IN+		Pin 16 and 18 are one twisted pair
17	A2B_BP		Pin 17 an 19 are one twisted pair
18	MiC_IN-		Pin 16 and 18 are one twisted pair
19	A2B_BN		Pin 17 an 19 are one twisted pair
20	MiC shield		Shield for twisted pair on pin 16, 18

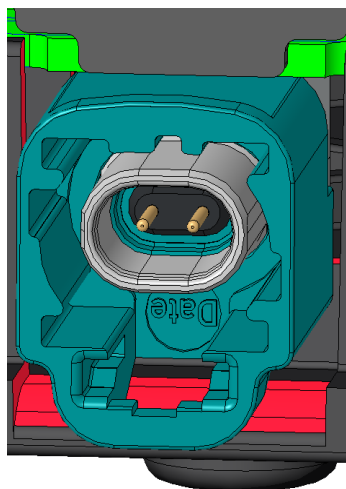**Table 4: -- Main System Connector 20 pins**

- Ethernet Connector:

Figure 3: -- Ethernet connector pin details

Pin #:	Signal name:	Current:	Notes:
1	2110_BR_P		Pins 1 and 2 use Z-diff 100 ohm Twisted pair with shielded CAT6 Grade cable
2	2110_BR_N		Pins 1 and 2 use Z-diff 100 ohm Twisted pair with shielded CAT6 Grade cable

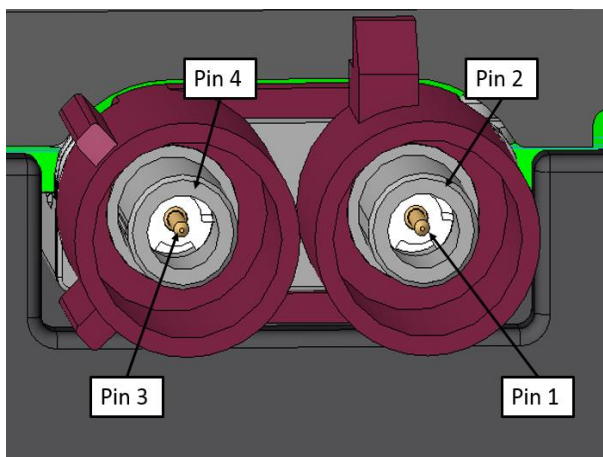**Table 5: -- Ethernet Connector**

- WiFi Antenna Connector

Figure 4: -- WiFi Antenna Connector Pin details

Pin #:	Signal name:	Current:	Notes:
1	WLAN Antenna 1		Pins 1 and 2 use Coax 50 Ohm Cable
2	GND		
3	WLAN Antenna 2		Pins 3 and 4 use Coax 50 ohm Cable
4	GND		

Table 6: -- WiFi Antenna connector

- LTE Antenna Connector
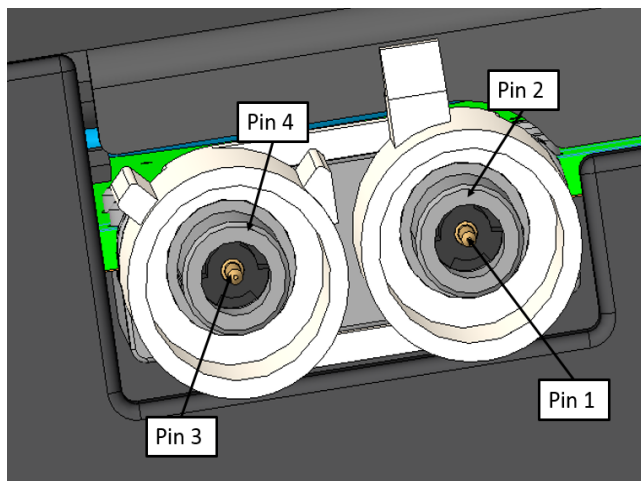
Figure 5: -- LTE Antenna Connector pin details

Pin #:	Signal name:	Current:	Notes:
1	LTE Antenna 2 (Diversity Antenna)		Pins 1 and 2 use Coax 50 ohm Cable
2	GND		
3	LTE Antenna 1 (Primary antenna)		Pins 1 and 2 use Coax 50 ohm Cable
4	GND		

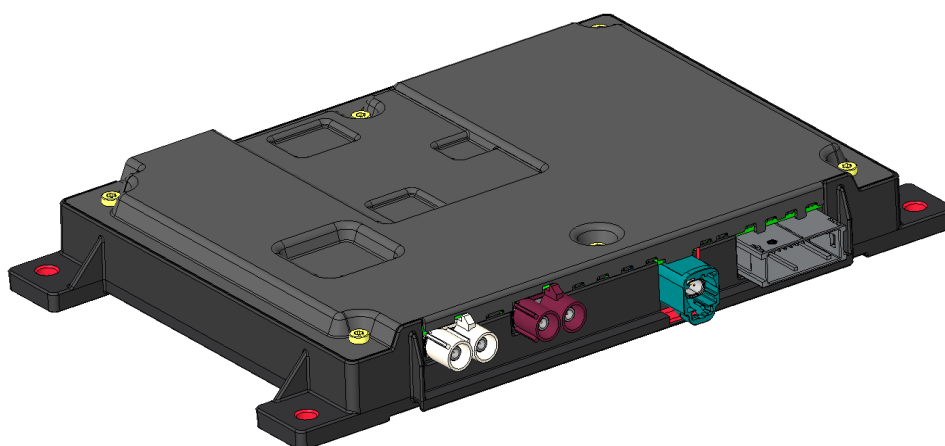**Table 7: -- LTE Antenna Connector**

- Mechanical Connectors Placement Overview

Figure 6: -- Connectors Placement Overview

4.7   Wake Up Controller

Zoox TCU uses a microcontroller for wake up function.
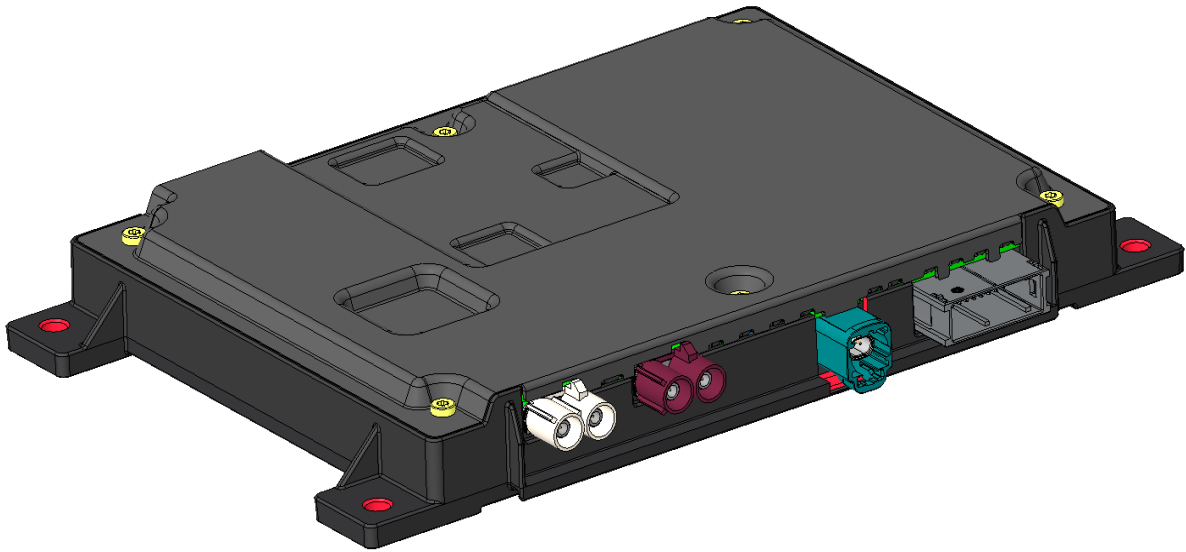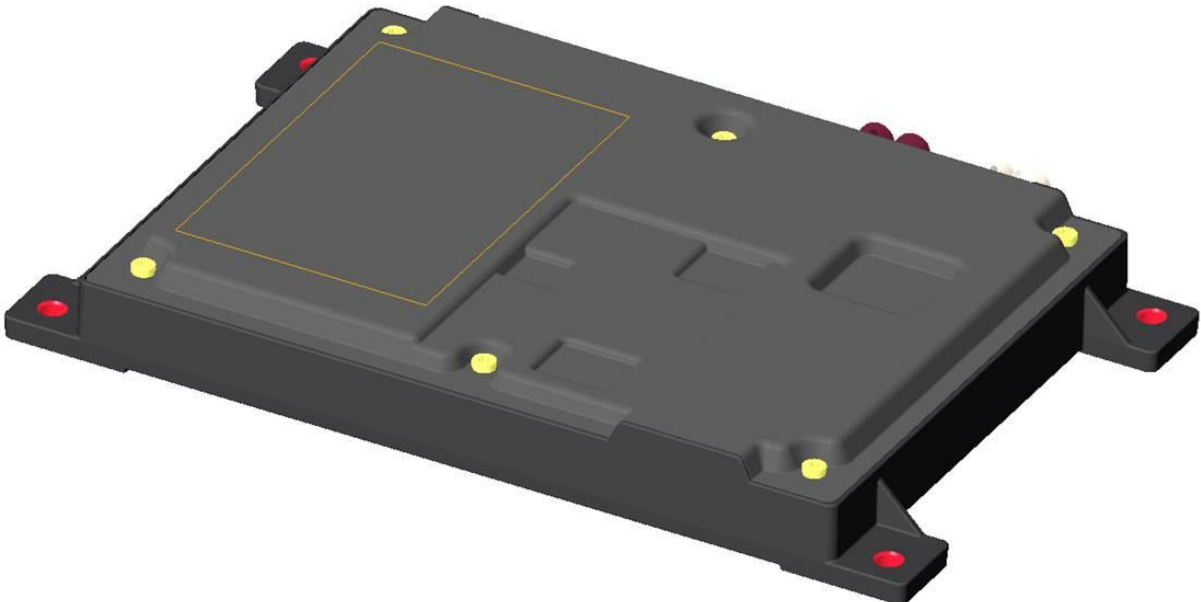
5 Product Pictures

Figure 7: -- Zoox TCU connector side

Figure 8: -- Zoox TCU Back side