RENESAS

VOICE-RA4E1 Engineering Manual
Renesas VUI Reference Solution

Renesas Advanced (RA) Family
RA4 Series

Renesas Electronics
www.renesas.com

Rev.1.0 June 2022

Renesas VUI Reference Solution

VOICE-RA4E1 Engineering Manual

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1. Overview

VOICE-RA4E1 is an edge voice recognition evaluation kit designed to be used by Ecosystem Partners, Application Engineers, Field Application Engineers, and for Business Development opportunities. The primary purpose is to evaluate the functionality of projects developed by Ecosystem Partners, and to facilitate the development of additional partner projects. The kit design to use the RA4E1 MCU with QFN 48pin package as the core logic device, with QSPI flash, OPAMP and power devices chosen from the Renesas product portfolio.

2. Kit Contents

The following components are included in the kit:
1. VOICE-RA4E1 board
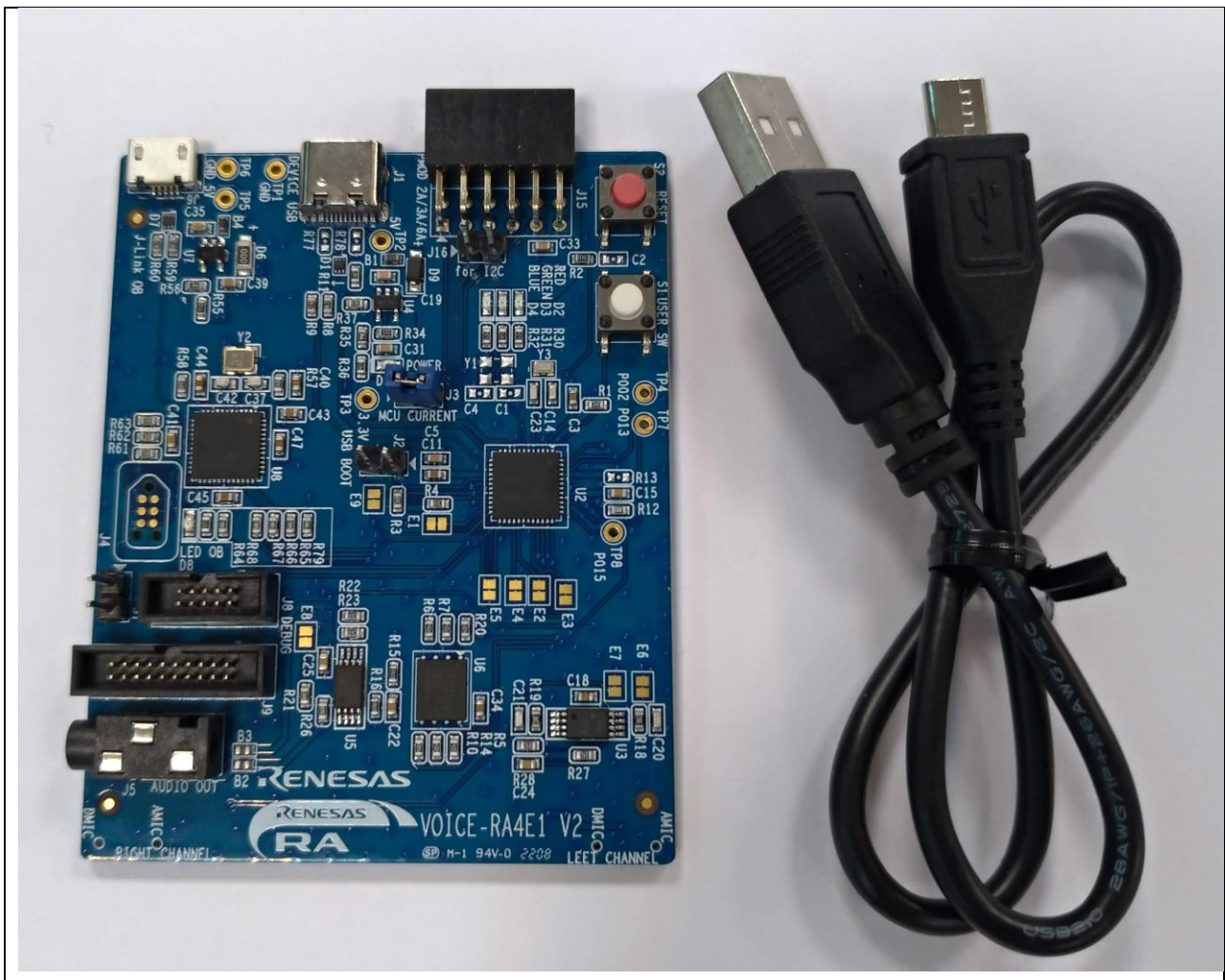2. Micro USB device cable (type-A male to micro-B male)

Figure 1. VOICE-RA4E1 Kit Contents

3. Kit Ordering Information

VOICE-RA4E1 kit orderable part number: **TW001-VUIA4E1POCZ**

4. Kit Peripheral Features

Following is a list of the specific features that have been implemented:

- QSPI: One QSPI flash memory device, Dialog AT25SF641B-MHB-T, 64M-bit (8MB).

- PMOD: 1 Digilent PMOD connectors, supporting UART, SPI and I2C configurations.

- Microphones: 1 I2S MEMS digital microphones and 2 MEMS analog microphones, distance between each pair of microphones is 50mm which is suitable for beamforming applications.

- Audio out: One stereo audio headphone jack supporting mono output on both channels.

- LEDs: Five LEDs, D2 (Red), D3 (Green) and D4 (Blue) configurable by user, D5 (Blue) as a 3.3V power indicator, D8(Green) as a JLOB (J-LINK on board) indicator.

- Buttons: One RESET button (S2), and one USER button (S1).

- Debug: J-Link On-Board debug interface, supporting JTAG or SWD debug port.

- USB: Micro USB-B (J6) for power input and J-Link On-Board function, USB-C (J1) for power input and RA4E1 USB Full Speed port as a USB device.

- Form Factor: 7.5 x 6 cm

5. MCU Feature Support

The RA4E1 MCU supports a full array of peripheral functions. The published features of the MCU are listed below. Features highlighted in **BOLD** text are directly supported by the kit hardware for voice applications.

- **Arm Cortex-M33 Core with Floating Point Unit (FPU)**

  - Armv8-M architecture with DSP instruction set

  - Maximum operating frequency: 100 MHz

  - Support for 4-GB address space

  - On-chip debugging system: JTAG, **SWD**

  - Boundary scan and Arm Memory Protection Unit (Arm MPU)

- **Memory**

  - Up to 512KB code flash memory

  - 8-KB data flash memory (100,000 program/erase cycles minimum)

  - Up to 128KB SRAM

  - 1KB Standby SRAM

  - Flash Cache (FCACHE)

  - Memory Protection Units (MPU)

  - Memory Mirror Function (MMF)

  - 128-bit unique ID

- Connectivity

  - **USB 2.0 Full-Speed (USBFS) module**

    - On-chip transceiver with voltage regulator

  - **Serial Communications Interface (SCI) with FIFO × 4**

  - **Serial Peripheral Interface (SPI) × 1**

  - I2C bus interface (IIC) × 1

  - **Quad Serial Peripheral Interface (QSPI)**

- Analog

  - **7 channel 12-bit A/D Converter (ADC12) with sample-and-hold circuits**

- **12-bit D/A Converter (DAC12) × 1**
- **Timers**
  - **General PWM Timer 32-bit (GPT32) × 2**
  - **General PWM Timer 16-bit (GPT16) × 2**
  - Asynchronous General-Purpose Timer (AGT) × 5
- Safety
  - FACI command protection by FENTRYR register
  - Flash memory is protected by FWEPROR register
  - The user area is protected by the block protect setting
  - Error is detected when unintended commands or prohibited settings occur. The FACI command is not accepted after an error detection.
  - The start-up area select function allows customer to safely update the boot firmware. The size of the start-up area is 8 KB.
- System and Power Management
  - Low power modes
  - Battery backup function (VBATT)
  - Realtime Clock (RTC) with calendar and VBATT support
  - Event Link Controller (ELC)
  - Data Transfer Controller (DTC)
  - DMA Controller (DMAC) × 8
  - Power-on reset
  - Low Voltage Detection (LVD) with voltage settings
  - Watchdog Timer (WDT)
  - Independent Watchdog Timer (IWDT)
- Security and Encryption
  - ARMv8-M TrustZone security
  - Device lifecycle management
  - Debug access level
  - Key injection
  - Secure pin multiplexing
  - Secure Crypto Engine 9 (SCE9)
  - Symmetric algorithms: AES
  - Asymmetric algorithms: RSA, ECC, and DSA
  - Hash-value generation: SHA224, SHA256, GHASH
  - 128-bit unique ID.
- Multiple Clock Sources
  - Main clock oscillator (MOSC) (8 to 24 MHz)
  - **Sub-clock oscillator (SOSC) (32.768 kHz)**
  - **High-speed on-chip oscillator (HOCO)** (16/18/**20 MHz**)
  - Middle-speed on-chip oscillator (MOCO) (8 MHz)
  - Low-speed on-chip oscillator (LOCO) (32.768 kHz)
  - IWDT-dedicated on-chip oscillator (15 kHz)

- **Clock trim function for HOCO/MOCO/LOCO**
- **General-Purpose I/O Ports**
  - 5V tolerance, open drain, input pull-up, switchable driving ability
- Operating Voltage
  - VCC: 2.7 to 3.6 V

6. Kit Architecture
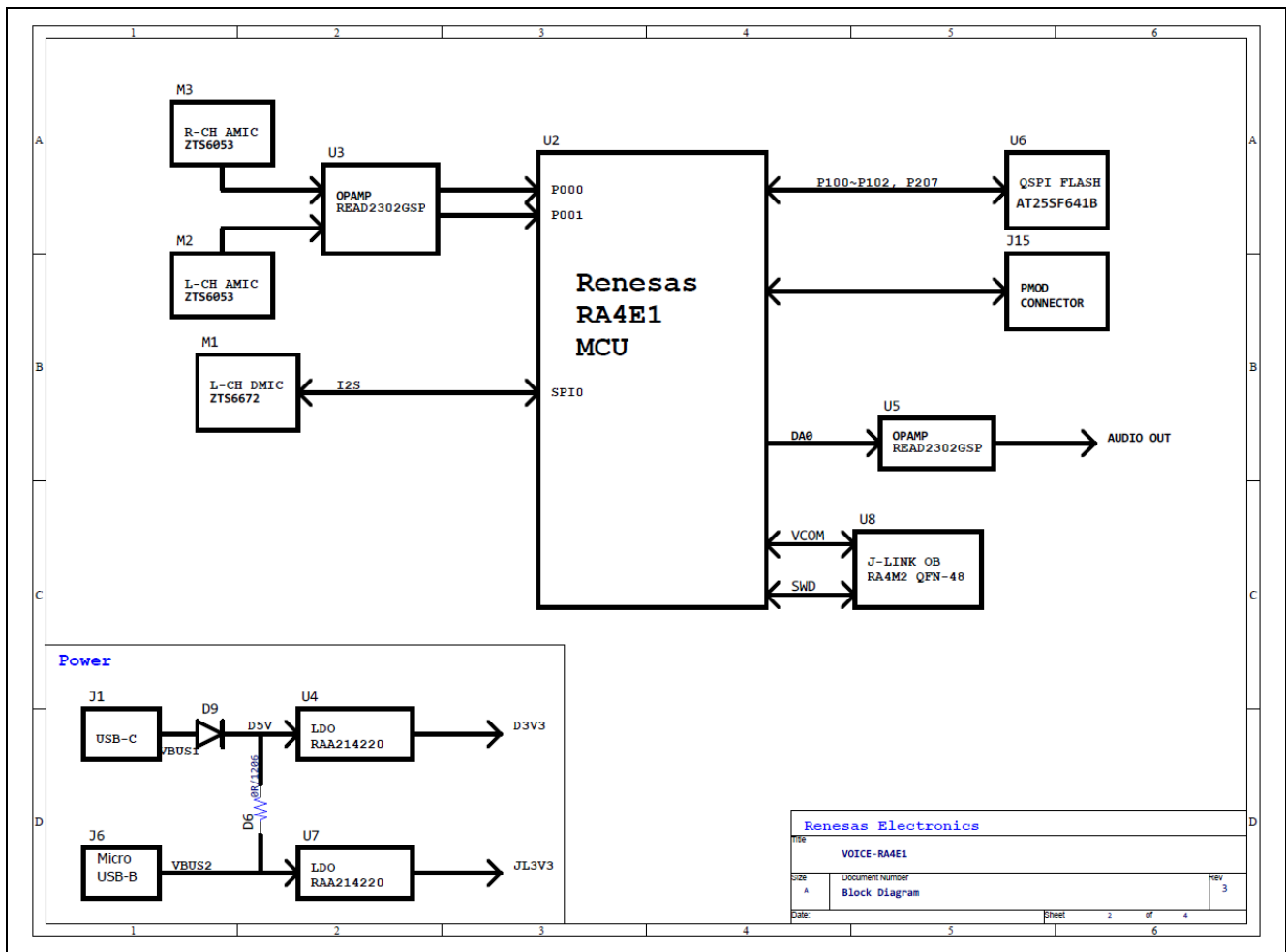
6.1 System Block Diagram

Figure 2. System Block Diagram

6.2 Jumper Settings

Two types of jumpers are provided on the VOICE-RA4E1 board.
1. Traditional pin header jumpers copper jumpers
2. Copper jumpers (trace-cut type and solder bridge type)

6.2.1 Traditional Pin Header Jumpers

These jumpers are traditional small pitch jumpers that require an external shunt to open/close them. The traditional pin jumpers on the VOICE-RA4E1 board are 2.54mm pitch headers and require compatible 2.54mm shunt jumpers.

Default Jumper Configuration

The following table describes the default settings for each jumper on the VOICE-RA4E1 board. This includes copper jumpers (Ex designation) and traditional pin jumpers (Jx designation.)

Functional details for many of the listed jumpers may be found in sections associated with each functional area of the kits.

Table 1. Default Jumper Settings

Location	Default Open/Closed	Function
J2	Open	USB Boot mode : Close to configures the RA4E1 MCU enter USB boot mode, code can be download through J1 USB TYPE-C connector.
J3	Short	For MCU current measurement, remove this jumper wire and serial with a current meter to measure MCU current.
J7	Open	Short with a jumper wire to set on board debug RA4M2 MCU(U8) in RESET for disable on board debug.
J16	open	Short with jumper wire to route I2C SDA signal to J15 PMOD connector pin 4.

6.2.2 Copper Jumpers

Copper jumpers are of two types, designated trace-cut and solder-bridge.

A trace-cut jumper is provided with a narrow copper trace connecting its pads. The silk screen overlay printing around a trace-cut jumper is a solid box. To isolate the pads, cut the trace between pads adjacent to each pad, then remove the connecting copper foil either mechanically or with the assistance of heat. Once the etched copper trace is removed, the trace-cut jumper is turned into a solder-bridge jumper for any later changes.

A solder-bridge jumper is provided with two isolated pads that may be joined together by one of three methods:

- Solder may be applied to both pads to develop a bulge on each and the bulges joined by touching a soldering iron across the two pads.
- A small wire may be placed across the two pads and soldered in place.
- A SMT resistor, size 0805, 0603, or 0402, may be placed across the two pads and soldered in place. A zero-ohm resistor shorts the pads together.

For any copper jumper, the connection is considered closed if there is an electrical connection between the pads (default for trace-cut jumpers.) The connection is considered open if there is no electrical connection between the pads (default for the solder-bridge jumpers.)
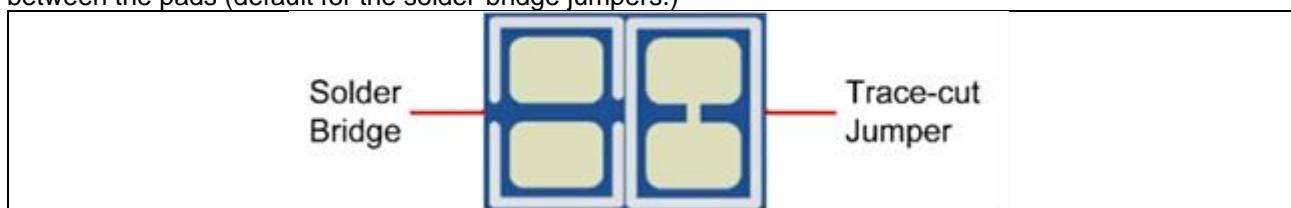

Figure 3. Copper Jumpers

Table 2. Default Copper Jumper Settings

Location	Default Open/Closed	Function
E1	Closed	WS output to I2S digital microphone
E2	Closed	SSL input for SPI0
E3	Closed	SCK output to I2S digital microphone
E4	Closed	SCK input for SPI0
E5	Closed	MOSI for I2S digital microphone left channel
E6	Closed	ADC0, Analog microphone left channel
E7	Closed	ADC1, Analog microphone right channel
E8	Closed	DA out to OPAMP, audio out
E9	Closed	P201/MD signal, cut it then the J8, J9 can be debug out function

7. MCU Port Mapping

Here are the port and pin assignments for the kit.

Table 3. MCU Port Assignments

Port	Assigned Function(s)
P000	Analog microphone, left channel
P001	Analog microphone, right channel
P002	Test point 4 (TP4)
P013	Test point 7 (TP7)
P014	Audio out DAC
P015	Test point 8 (TP8)
P100	If configure as QSPI, it is QSPI CLK signal for QSPI flash. If configure as PMOD, it can be RXD/SCL/MISO signal.
P101	If configure as QSPI, it is QSPI DQ1 signal for QSPI flash. If configure as PMOD, it can be TXD/SDA/MOSI signal.
P102	If configure as QSPI, it is QSPI DQ0 signal for QSPI flash. If configure as PMOD, it can be NC/NC/SCK signal.
P103	If configure as PMOD, it can be CTS_RTS/NC/SS signal.
P104	GPT1 output for SCK to I2S D-MIC
P108	Debug, SWDIO for SWD or TMS for JTAG
P109	MOSI for I2S digital microphone left channel, when debug, it is TDO for JTAG
P110	Debug, TDI for JTAG, or PMOD GPIO3
P111	SPICLK input
P112	SPI SS input
P200	NMI, pull-high with 10K
P201/MD	Boot Mode, The MCU enter SCI and USB boot mode if the MD pin is held low on release the reset signal, it is for download code to MCU flash memory. or PMOD GPIO1
P206	PMOD GPIO2
P207	QSPI_CS# for QSPI flash
P212/EXTAL	LED3, user LED, blue color
P213/XTAL	LED2, user LED, green color
P300	Debug, SWCLK for SWD or TCK for JTAG
P301	WS output to I2S digital microphone
P302	PMOD, can be GPIO or IRQ5
P402	User switch(S1), also IRQ4
P407	USB VBUS, USB cable connection monitor pin
P408	JLOB VCOM TXD
P409	JLOB VCOM RXD
P500	LED1, user LED, red color

8. Implementation Details

8.1 QSPI NOR flash

There is one QSPI NOR Flash on board. The device is Dialog AT25SF641B-MHB-T, 64 Mbit (8 Mbyte) in a 8-pad Ultra-Thin DFN (5 x 6 x 0.6mm) package. The QSPI port of RA4E1 is configured as Fast Read Dual I/O mode on this kit.

Table 4. QSPI Flash Port Assignments

MCU Port	QSPI Signal	QSPI Pin
P100	CLK	6
P207	Chip Select	1
P102	DQ0	5
P101	DQ1	2

8.2 PMOD

One PMOD type 2A/3A/6A connectors (2x6 pin, dual row, right angle socket) is included. If the RA4E1 SCI0 has been configured as Simple I2C, please insert a jumper on header J16 to route SDA signal to PMOD connector pin 4 for meet PMOD 6A pin definition.

Table 5. PMOD Port Assignments (J15)

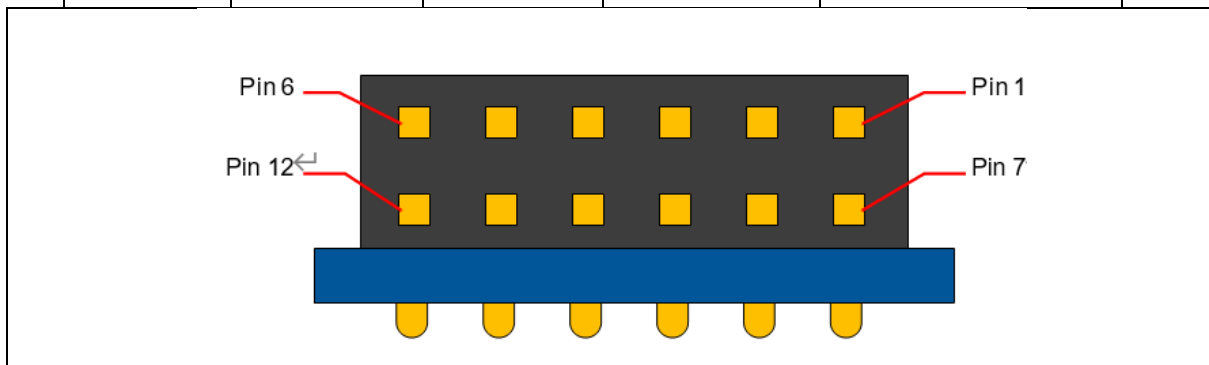| MCU Port	PMOD Type 2A Signal (SPI)	PMOD Type 3A Signal (UART)	PMOD Type 6A Signal (I2C)	PMOD connector Pin
P103	SS	CTS_RTS		1
P101	MOSI	TXD		2
P100	MISO	RXD	SCL	3
P102	SCK		SDA(P101)	4
	GND	GND	GND	5
	+3.3V	+3.3V	+3.3V	6
P302	INT	INT	INT	7
P303	GPIO	GPIO	GPIO	8
P304	GPIO	GPIO	GPIO	9
P208	GPIO	GPIO	GPIO	10
	GND	GND	GND	11
	+3.3V	+3.3V	+3.3V	12

Figure 4. PMOD connector

8.3 Microphones

This board includes a pair of analog MEMS microphones (M2 & M3, ZillTek ZTS6053). These 2 analog microphone signals are amplified by Renesas READ2302GSP OPAMP, then fed to RA4E1 ADC channels 0 & 1. One digital I2S MEMS microphone (M1, ZillTek ZTS6672) is also provided, which is connected to RA4E1 SPI0 channels. The physical distance between each 2 microphones is 50mm to support beamforming applications.

Table 6. Analog MEMS Microphone left channel (M2) Port Assignments

MCU Port	MEMS microphone Pin
P000	1 – OUT
	2 – GND
	3 – GND
	4 – GND
	5 – VDD

Table 7. Analog MEMS Microphone right channel (M3) Port Assignments

MCU Port	MEMS microphone Pin
P001	1 – OUT
	2 – GND
	3 – GND
	4 – GND
	5 – VDD

Table 8. Digital I2S MEMS Microphone left channel (M1) Port Assignments

MCU Port	SPI0 Signal	MEMS microphone Pin
P112	SSLA0	1 – LRC (Word Select)
	GND – for Select as left channel	2 – SELECT
	GND	3 – GND
P111	RSPCK0	4 – BCLK
	3.3V	5 – VDD
P109	MOSI0	6 – DATA
		7 – CONFIG

8.4 Audio out

A stereo headphone jack is connected to the MCU DAC. The DAC signals are connected through an OPAMP. The device is Renesas READ2302GSP, in ultra-small 8 pins TSSOP packages.

Table 9. Headphone Jack Pin Assignments

MCU Port	Audio out Signal	Headphone Jack Pin
P014 (DA0)	VOUT1	1 (Sleeve)
	VOUT2	2 (Mono signal)
	VOUT2	3 (Mono signal)

8.5 LEDs

3 LED are included on the board and are connected to the MCU I/O. These are Red, Green, and Blue, and can be used for any user defined functions.

Table 10. User LED Port Assignments

MCU Port	Connected User LED
P500	Red (D2)
P213	Green (D3)
P212	Blue (D4)

D5 (blue) is power LED, and D8 (Green) is debug status LED to indicate the status of the JLOB connection.

8.6 Buttons

There are two mechanical push-button switches on the board. One button is for system/MCU reset (S2). The second button is a user programmable button (S1).

Table 11. User Button Port Assignment (S1)

MCU Port	User Button Interrupt
P402	IRQ4

8.7 Debug

The VOICE-RA4E1 board supports following three debug modes.

Debug Modes	Debug MCU (one that connects to the IDE on PC)	Target MCU (one that is being debugged)	Debugging Interface/Protocol	Connector Used
Debug on-board	RA4M2 (on-board)	RA4E1 (on-board)	SWD, JTAG	Micro USB (J6)
Debug in	External debugging tools	RA4E1 (on-board)	SWD, JTAG	20-pin connector (J9) or 10-pin connector (J8)
Debug out	RA4M2 (on-board)	Any external RA MCU	SWD, JTAG	20-pin connector (J9) or 10-pin connector (J8)

Notes:
• Please cut E9 for Debug out function
• See Table 14 for the Debug USB connector pin definition.
• See Table 15 for the 10-pin JTAG connector pin definition.
• See Table 16 for the 20-pin JTAG connector pin definition.

Table 12. Jumper Connection Summary for Different Debug

Debug Modes	J7
Debug on-board	Open
Debug in	Closed
Debug out	Open

The J-Link On-Board (JLOB) debug interface supporting JTAG, SWD debug interface and also supports the VCOM (Virtual COM port) function. The debug MCU is a Renesas RA4M2, programmed with J-Link firmware licensed by Segger. This interface includes one USB micro-B connector (J6) for host debug through the J-Link MCU, one 10-pin and one 20-pin debug header (supporting JTAG and SWD).

Table 13. Debug USB Connector

Debug USB Connector(J6)		VOICE-RA4E1
Pin	**Description**	**Signal / Bus**
J6-1	+5VDC	VBUS2 / TP5
J6-2	Data-	D_N
J6-3	Data+	D_P
J6-4	USB ID, jack internal switch, cable inserted	N.C.
J6-5	Ground	GND / TP6

Table 14. 10-pin JTAG/SWD Connector (J8)

Pin	JTAG Pin Name	SWD Pin Name	Signal/Bus
J9-1	Vtref	Vtref	+3V3
J9-2	TMS	SWDIO	P108/SWDIO
J9-3	GND	GND	GND
J9-4	TCK	SWCLK	P300/SWCLK
J9-5	GND	GND	GND
J9-6	TDO		P109
J9-7	Key	Key	N.C.
J9-8	TDI		P110
J9-9	GND Detect	GND Detect	GND
J9-10	nSRST	nSRST	RESET#

Table 15. 20-pin JTAG/SWD Connector (J9)

Pin	JTAG Pin Name	SWD Pin Name	Signal/Bus
J9-1	Vtref	Vtref	+3V3
J9-2	TMS	SWDIO	P108/SWDIO
J9-3	GND	GND	GND
J9-4	TCK	SWCLK	P300/SWCLK
J9-5	GND	GND	GND
J9-6	TDO		P109
J9-7	Key	Key	N.C.
J9-8	TDI		P110
J9-9	GND Detect	GND Detect	GND
J9-10	nSRST	nSRST	RESET#
J9-11	GND	GND	GND
J9-12	N/A	N/A	N.C.
J9-13	GND	GND	GND
J9-14	N/A	N/A	N.C.
J9-15	GND	GND	GND
J9-16	N/A	N/A	N.C.
J9-17	GND	GND	GND
J9-18	N/A	N/A	N.C.
J9-19	N/A	N/A	GND
J9-20	N/A	N/A	N.C.

Table 16. Debug Port Signal Assignments

RA4E1 MCU Port	Debug signal usage
P108	TMS/SWDIO
P109	TDO
P110	TDI
P300	TCK/SWCLK

8.8   Power

5 V may be supplied from an external USB host to the USB Debug connector (J6) labelled with **J-Link OB** on the board or from USB type-C connector(J1) labelled with **DEVICE USB**.
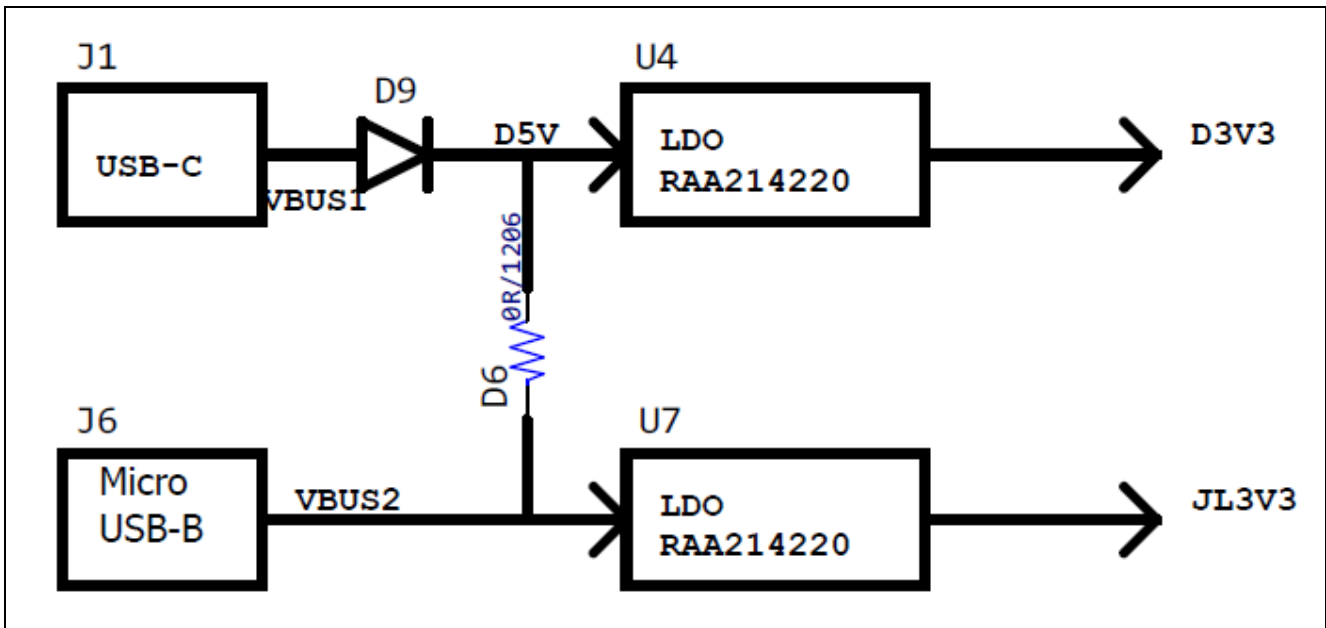

Figure 5. VOICE-RA4E1 Power Block Diagram

8.9   USB

The board includes one USB TYPE-C connector (J1), supporting USB Full Speed device mode.

Table 17. USB Full Speed / USB Type-C Signal Assignments (J1)

MCU Port	USB FS Signal	USB-C Signal Name	USB-C Connection
	GND	GND	A1
	N.C.	TXp1	A2
	N.C.	TXn1	A3
	VBUS1	VBUS	A4
	N.C.	CC1	A5
USB_DP	USB1_P	DP1	A6
USB_DN	USB1_N	DN1	A7
	N.C.	SBU1	A8
	VBUS1	VBUS	A9
	N.C.	RXN2	A10
	N.C.	RXP2	A11
	GND	GND	A12
	GND	GND	B1
	N.C.	TXP2	B2
	N.C.	TXN2	B3
	VBUS1	VBUS	B4
	N.C.	CC2	B5
USB_DP	USB1_P	DP2	B6
USB_DN	USB1_N	DN2	B7
	N.C.	SBU2	B8
	VBUS1	VBUS	B9
	N.C.	RXN1	B10
	N.C.	RXP1	B11
	GND	GND	B12

9. Certifications

To support international distribution, the following certification requirements are met, both by design and test.

Americas: FCC Class B

Europe: CE Class B

Revision History

Rev.	Date	Description	
		Page	**Summary**
1.0	June 2022		Initial release

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