**📋 SHRAVYA: A Cognitive Ear Worn Assistant with on-board AI Assistant  
Complete Hardware Connection Documentation**

**System Overview**

* **Power Architecture:** EK-RA8D1 5V → AMS1117 LDO → 3.3V Distribution
* **Grounding Strategy:** Single-point star ground configuration
* **Protection:** Comprehensive ESD protection on all digital I/O lines

**Section 1: Power Distribution System**

**1.1 Primary Power Source**

* **Source:** EK-RA8D1 5V Pin (VIN connector section)
* **Destination:** AMS1117 LDO Input (VIN pin)
* **Wire:** Red 22AWG jumper wire
* **Current Rating:** 800mA max (LDO specification)

**1.2 Voltage Regulation (AMS1117 LDO)**

**Input Connections:**

* VIN Pin ← EK-RA8D1 5V Pin
* GND Pin ← Star Ground Point (breadboard ground rail)

**Output Connections:**

* VOUT Pin → 3.3V Power Rail (breadboard positive rail)
* GND Pin → Star Ground Point

**Support Capacitors:**

* 0.1µF Ceramic: VOUT to GND (high-frequency noise suppression)

**1.3 Star Ground Implementation**

* **Primary Reference Point:** AMS1117 GND pin
* **Ground Bus:** Breadboard star ground rail (negative power rail)
* **All Component Grounds Connected To:** Star ground point

**Section 2: Analog Signal Chain**

**2.1 AD623 Instrumentation Amplifier**

**Power Connections:**

* Pin 7 (+Vs) ← 3.3V Rail (red wire)
* Pin 4 (-Vs/GND) ← Star Ground (black wire)

**Input Signal Connections:**

* Pin 3 (IN+) ← Left Ear Electrode (via 30AWG wire + jumper extension)
* Pin 2 (IN-) ← Right Ear Electrode (via 30AWG wire + jumper extension)

**Reference Voltage (1.65V Bias):**

* Two 10kΩ resistors in series between 3.3V rail and ground
* Midpoint junction → AD623 Pin 5 (REF)
* 10µF capacitor from midpoint to ground (reference filtering)

**Output Connection:**

* Pin 6 (OUT) → ADS1263 A0 input AND LM358 Pin 3 (+IN)

**Input Protection:**

* 100Ω resistor in series with each electrode input (ESD protection)

**Power Supply Filtering:**

* 0.1µF ceramic across +Vs to GND (power supply bypassing)
* 10µF electrolytic across +Vs to GND (power supply smoothing)

**2.2 Input Filtering Capacitors**

* 0.01µF ceramic from AD623 Pin 3 (IN+) to ground
* 0.01µF ceramic from AD623 Pin 2 (IN-) to ground
* **Purpose:** Anti-aliasing and RF noise rejection

**2.3 Electrode Wire Management**

**30AWG Wire Extension:**

* Left Electrode Wire: Soldered to male jumper wire end
* Right Electrode Wire: Soldered to male jumper wire end
* Reference Electrode Wire: Soldered to male jumper wire end
* Heat Shrink Tubing: Applied over all solder joints
* Total Wire Length: <30cm per electrode

**Section 3: Analog-to-Digital Conversion**

**3.1 ADS1263 32-bit ADC Module**

**Power Connections:**

* 5V Pin ← EK-RA8D1 5V Pin (direct connection)
* GND Pin ← Star Ground
* ACOM Pin ← Star Ground (analog common)
* AGND Pin ← Star Ground (analog ground)

**Analog Input:**

* A0 Pin ← AD623 Pin 6 (OUT) - Primary EEG signal
* A1 Pin ← Star Ground (reference for single-ended measurement)

**Input Filtering:**

* 0.001µF ceramic from A0 to AGND (input filtering)
* 0.001µF ceramic from A1 to AGND (balance filtering)
* 0.000113µF ceramic for internal reference filtering (if VREF pad available)

**SPI Communication Interface:**

* SCK Pin ← EK-RA8D1 SPI Clock (mikroBUS section)
* MOSI Pin ← EK-RA8D1 SPI MOSI (mikroBUS section)
* MISO Pin → EK-RA8D1 SPI MISO (mikroBUS section)
* CS Pin ← EK-RA8D1 GPIO (mikroBUS CS pin)

**Control Signals:**

* DRDY Pin → EK-RA8D1 A4 (Analog In section) - Data Ready interrupt
* RST Pin ← EK-RA8D1 GPIO (manual reset control)

**Power Supply Filtering:**

* 0.1µF ceramic across 5V to GND (digital supply bypassing)
* 0.1µF ceramic across analog supply to AGND (analog supply bypassing)

**Section 4: Driven Right Leg (DRL) Circuit**

**4.1 LM358 Dual Op-Amp Configuration**

**Power Connections:**

* Pin 8 (VCC) ← 3.3V Rail
* Pin 4 (VEE/GND) ← Star Ground

**DRL Circuit (Op-Amp A):**

* Pin 3 (+IN) ← AD623 Pin 6 (OUT) - EEG signal
* Pin 2 (-IN) ← 3M Reference Electrode (forehead)
* Pin 1 (OUT) → 1kΩ Resistor → Reference Electrode (feedback loop)

**Current Limiting & Safety:**

* 1kΩ resistor between LM358 output and reference electrode
* **Purpose:** Limits current to safe levels (<1µA) for human contact
* 100Ω resistor in series with reference electrode input (ESD protection)

**Power Supply Filtering:**

* 0.1µF ceramic across VCC to GND (power supply bypassing)
* 10µF electrolytic across VCC to GND (power supply smoothing)

**Section 5: Haptic Feedback System**

**5.1 Vibration Motors (×2)**

**Motor Specifications:**

* Type: 10mm coin-type vibration motors
* Voltage: 3.3V operating voltage
* Current: ~100mA peak per motor

**Physical Placement:**

* Left Motor: Mounted on breadboard left edge with double-sided tape
* Right Motor: Mounted on breadboard right edge with double-sided tape
* Connect to D4 and D5 pin of the EK-RA8D1 PWM section (Beside mikroBus section)

**5.2 IRLZ44N MOSFET Drivers (×2)**

**MOSFET #1 (Left Motor Control):**

* Gate (Pin 1) ← 1kΩ resistor ← EK-RA8D1 D4 pin
* Drain (Pin 2) → Left Motor Negative Terminal
* Source (Pin 3) → Star Ground

**MOSFET #2 (Right Motor Control):**

* Gate (Pin 1) ← 1kΩ resistor ← EK-RA8D1 D5 pin
* Drain (Pin 2) → Right Motor Negative Terminal
* Source (Pin 3) → Star Ground

**Motor Power Connections:**

* Left Motor Positive ← 3.3V Rail
* Left Motor Negative ← MOSFET #1 Drain
* Right Motor Positive ← 3.3V Rail
* Right Motor Negative ← MOSFET #2 Drain

**Gate Drive Resistors:**

* 1kΩ resistor between each MOSFET gate and MCU GPIO pin
* **Purpose:** Limits gate current and prevents oscillation

**5.3 Flyback Protection Diodes (×2)**

**Motor #1 Protection:**

* 1N4148 Diode Cathode → Left Motor Positive (3.3V)
* 1N4148 Diode Anode → Left Motor Negative (MOSFET drain)

**Motor #2 Protection:**

* 1N4148 Diode Cathode → Right Motor Positive (3.3V)
* 1N4148 Diode Anode → Right Motor Negative (MOSFET drain)

**Purpose:** Clamps inductive voltage spikes when motors switch off

**Section 6: ESD Protection System**

**6.1 Series Protection Resistors**

**Electrode Input Protection:**

* Left Electrode: 100Ω → AD623 Pin 3 (IN+)
* Right Electrode: 100Ω → AD623 Pin 2 (IN-)
* Reference Electrode: 100Ω → LM358 Pin 2 (-IN)

**MOSFET Gate Protection:**

* D4 Pin: 1kΩ → MOSFET #1 Gate
* D5 Pin: 1kΩ → MOSFET #2 Gate

**Section 7: Reference Electrode System**

**7.1 3M ECG Electrode (Forehead Reference)**

**Physical Connection:**

* 30AWG wire soldered to electrode center snap with silver epoxy
* Wire extension via jumper wire connection
* Heat shrink protection over solder joint

**Electrical Connection:**

* Reference Electrode Wire → 100Ω Resistor → LM358 Pin 2 (-IN)
* DRL Output → 47kΩ Resistor → Reference Electrode

**Safety Features:**

* Current limiting via 47kΩ resistor
* ESD protection via 100Ω series resistor
* Isolated feedback loop for noise cancellation

**Section 8: Communication Interfaces**

**8.1 SPI Bus Configuration**

* **Master:** EK-RA8D1 (mikroBUS section)
* **Slave:** ADS1263 ADC Module

**Bus Connections:**

* Clock Line: EK-RA8D1 SCK → ADS1263 SCK
* Master Out: EK-RA8D1 MOSI → ADS1263 MOSI
* Master In: ADS1263 MISO → EK-RA8D1 MISO
* Chip Select: EK-RA8D1 CS → ADS1263 CS

**Interrupt Line:**

* Data Ready: ADS1263 DRDY → EK-RA8D1 A4 (configured as interrupt input)

**8.2 GPIO Control Lines**

**Motor Control:**

* Left Motor: EK-RA8D1 D4 → MOSFET #1 Gate (via 1kΩ)
* Right Motor: EK-RA8D1 D5 → MOSFET #2 Gate (via 1kΩ)

**ADC Control:**

* Reset Line: EK-RA8D1 GPIO → ADS1263 RST (manual reset control)

**Section 9: Power-On Sequence & Testing**

**9.1 Startup Sequence:**

1. Verify all connections against this documentation
2. Apply 5V power from EK-RA8D1 to AMS1117
3. Confirm 3.3V output from LDO before connecting circuits
4. Power analog circuits (AD623, LM358) first
5. Initialize digital circuits (ADS1263, MCU) last

**9.2 Verification Checkpoints:**

* **Power Rail Voltages:** 5V and 3.3V within ±5% tolerance
* **Ground Continuity:** All grounds connected to star point
* **ESD Protection:** All Zener diodes properly oriented
* **Motor Operation:** Both motors respond to GPIO control
* **SPI Communication:** Data exchange with ADS1263 confirmed

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