🔌 Electronics Connections Guide — Wireless 3D-Printed Robotic Arm

This document explains every connection in the system: **Raspberry Pi Pico → PCA9685 → Servos → ESP32 Receiver → NRF24L01 → Power Supply** and the **custom ESP32 wireless transmitter**.

Raspberry Pi Pico ↔ PCA9685 Connections (I²C)

PCA9685 Pin	Connects To	Notes
VCC	Pico 3.3V	⚠ Never connect to 5V; logic is 3.3V
GND	Pico GND	Must be common ground
SDA	Pico GP0	
SCL	Pico GP1	
OE	GND	Enable PWM output

Key reminders:

✓ Use short wires for I²C (≤20–25 cm)
✓ If jitter seen → add 4.7k pull-ups on SDA/SCL
✓ Logic voltage = **3.3V only**

PCA9685 → Servo Connections

PCA Row	Connects To
Signal (orange/white)	Servo control wire
V+ (red)	External 5V supply
GND (brown/black)	Power supply GND

Key reminders:

✓ Power **7 servos from 5V supply**, NOT from Pico
✓ Servo grounds MUST join **Pico ground**
✓ Add a **1000µF capacitor** across 5V & GND near PCA9685 to prevent voltage dips

ESP32 Receiver → Raspberry Pi Pico (UART)

ESP32 RX Module	Connects To	Notes
TX (GPIO17 recommended)	Pico RX (e.g., GP5)	ESP32 → Pico command flow
RX (GPIO16 recommended)	Pico TX (e.g., GP4)	Only needed if Pico sends responses
GND	Pico GND	Required reference
VIN	5V OR 3.3V	Depends on ESP32 board

Key reminders:

✓ Match UART baud on both boards
✓ If noise issues occur → twist TX+GND pair or shorten wire length

ESP32 Receiver ↔ NRF24L01 Connections (SPI)

NRF24L01 Pin	ESP32 GPIO
GND	GND
VCC	3.3V
CE	GPIO 4
CSN	GPIO 5
SCK	GPIO 18
MOSI	GPIO 23
MISO	GPIO 19
IRQ	❌ Not required (optional)

Key reminders:

✓ Never power NRF24L01 from **5V**
✓ Add **10µF capacitor across VCC–GND on the NRF module**
✓ Use **PA+LNA (long-range) modules only with AMS1117 / regulator**, not direct to 3.3V pin

ESP32 Transmitter ↔ NRF24L01 Connections (Controller Side)

💡 Same pinout as receiver (Section 5).
Additionally connect:

- Joysticks → ESP32 ADC pins
- Buttons → ESP32 digital input pins

Key reminders:

✓ Add **0.1µF caps on joystick pots** to reduce analog noise
✓ Use **pull-down resistors** for all button inputs

Power Wiring

Component	Voltage
Raspberry Pi Pico	USB (5V)
PCA9685 logic	3.3V
Servos	5V (10A recommended)
ESP32 boards	5V or 3.3V depending on board

Power rules (very important)

✓ **Common ground for EVERYTHING**
✓ NEVER power servos from Pico 3.3V regulator
✓ Always power NRF24L01 from **regulated 3.3V**
✓ Servos under load may briefly spike 2–5A each → reason for 10A supply

Safety Checklist Before Power-On

Check	Status
Common ground connected	✓
PCA9685 VCC = 3.3V only	✓
NRF24L01 powered from 3.3V	✓
Servo rail powered externally	✓
Capacitor on PCB 5V line	✓
No signal wires touching V+	✓
UART TX/RX crossed correctly	✓

Short Troubleshooting Notes

Symptom	Cause	Fix
Servos twitch	Power noise	Add capacitor, shorten 5V wiring
NRF disconnects	Weak 3.3V rail	Use capacitor + stable 3.3V
Commands lag	Packet size too large	Compress packet structure
Pico resets	Ground not common	Connect power ground to logic ground