LifeLine: Circuit Connection Documentation

Long-Range Emergency and Rural Health Communication System

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1. Introduction

LifeLine is a LoRa-based emergency communication system designed for rural and mountainous regions where conventional communication infrastructure is unavailable. The system consists of two primary units:

1. **Transmitter Unit (Field Device)** – Used to send emergency alerts.
2. **Receiver Unit (Base Station)** – Used to receive and display alerts.

Both units are built around the ESP32 microcontroller and operate using the SX1278 LoRa module at 433 MHz. A 2.8-inch ILI9341 TFT display is used for visual feedback.

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2. System Power Requirements

All components in the LifeLine system operate at **3.3V logic level**.

- The ESP32, SX1278 LoRa module, and ILI9341 TFT display are **not 5V tolerant**.
- Supplying 5V directly to any signal or power pin may cause permanent damage.
- A common ground (GND) must be shared between all components to ensure reliable communication.

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3. Transmitter Unit Circuit Connections

3.1 ESP32 to SX1278 LoRa Module

The SX1278 communicates with the ESP32 using the SPI protocol.

SX1278 Pin	ESP32 Pin
VCC	3.3V
GND	GND
NSS / CS	GPIO 18
RESET	GPIO 23
DIO0	GPIO 19
MOSI	GPIO 27
MISO	GPIO 17
SCK	GPIO 5

Important Notes:

- The DIO0 pin is required for packet detection and must not be left floating.
- Use short SPI wires to reduce noise and improve communication stability.
- An external 433 MHz antenna should always be connected before powering the module.

3.2 ESP32 to ILI9341 TFT Display (SPI Mode)

The TFT display shares the SPI bus with the LoRa module.

TFT Pin	ESP32 Pin
VCC	3.3V
GND	GND
CS	GPIO 16
DC	GPIO 4
RST	GPIO 2
MOSI	GPIO 27
MISO	GPIO 17
SCK	GPIO 5
LED / BL	3.3V (or via resistor)

Important Notes:

- The TFT chip-select (CS) pin must be unique and not shared with the LoRa module.
- Backlight (LED) current should be limited using a resistor if required.
- Display issues such as half-white screens usually occur due to incorrect rotation or power instability.

3.3 ESP32 to 4×4 Matrix Keypad

The keypad allows alert selection and navigation.

Keypad Pin	ESP32 Pin
Row 1	GPIO 32
Row 2	GPIO 33
Row 3	GPIO 25
Row 4	GPIO 26
Column 1	GPIO 14

Keypad Pin	ESP32 Pin
Column 2	GPIO 12
Column 3	GPIO 13
Column 4	GPIO 15

Important Notes:

- GPIO 34–39 cannot be used for keypad inputs because they are input-only and lack internal pull-ups.
- Ensure row and column pins are not shared with SPI or critical peripherals.
- Internal pull-ups provided by the Keypad library are sufficient; no external resistors are required.

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4. Receiver Unit Circuit Connections

The Receiver Unit uses the same ESP32, SX1278 LoRa module, and TFT display wiring as the Transmitter Unit.

4.1 ESP32 to SX1278 LoRa Module

- Connections are identical to the transmitter unit.
- Ensure antenna orientation is vertical for maximum reception range.

4.2 ESP32 to ILI9341 TFT Display

- Connections are identical to the transmitter unit.
- Display is configured in portrait mode for improved readability of alert messages.

4.3 Optional Buzzer (Receiver)

- A buzzer may be connected to any free GPIO (for example GPIO 13) through a current-limiting resistor.
- The buzzer is activated only when a high-priority alert is received.

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5. Grounding and Signal Integrity

- All modules must share a **common ground**.
- Long jumper wires should be avoided, especially for SPI lines.
- For final deployment or exhibition, a soldered perfboard or PCB is recommended over a breadboard.

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6. Antenna and Range Considerations

- A tuned **433 MHz external antenna** significantly improves range.
- Antenna must be connected before powering the LoRa module to avoid RF damage.
- Line-of-sight placement yields the best communication range, especially in mountainous regions.

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7. Safety and Reliability Notes

- Always power down the system before modifying wiring.
- Verify voltage levels with a multimeter before first power-up.
- Avoid running SPI wires near high-current or switching power lines.
- Enclosures should be weather-resistant for real-world deployment.

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8. Conclusion

The above circuit connections provide a stable and reliable hardware foundation for the LifeLine emergency communication system. Following the power, grounding, and wiring guidelines is critical to ensure long-term reliability, especially in harsh rural and mountainous environments.