STM32G071RB IoT Project User Manual

Embedded Systems Project

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Abstract

This user manual provides comprehensive documentation for the STM32G071RB IoT prototype system featuring SX1262 LoRa wireless communication and BME680 environmental sensor integration. The system enables wireless sensor data transmission, environmental monitoring, and remote command control through dual UART interfaces and SPI-based LoRa communication. This manual covers hardware setup, software configuration, command interface usage, troubleshooting, and development guidelines.

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1 System Overview

1.1 Project Description

The STM32G071RB IoT prototype is an embedded system designed for wireless sensor data transmission and environmental monitoring. The system integrates a BME680 environmental sensor for temperature, pressure, and humidity measurements, and an SX1262 LoRa module for long-range wireless communication via SPI interface.

1.2 Key Features

- **Environmental Sensing**: BME680 sensor for temperature, pressure, and humidity
- **Wireless Communication**: SX1262 LoRa module for long-range data transmission
- **Dual UART Interface**: USART2 and USART4 for command and debugging
- **I2C Communication**: For BME680 sensor interface
- **SPI Communication**: For SX1262 LoRa module interface
- **Real-time Monitoring**: Continuous sensor data acquisition and transmission
- **Command Interface**: Interactive command system for system control
- **BUSY Pin Monitoring**: Automatic SX1262 busy state detection

1.3 Technical Specifications

Parameter	Specification
Microcontroller	STM32G071RBT6
System Clock	16 MHz
Operating Voltage	3.3V
LoRa Frequency	868 MHz (EU band)
LoRa Spreading Factor	SF7
LoRa Bandwidth	125 kHz
LoRa Coding Rate	4/5
UART Baud Rate	115200 bps
I2C Speed	100 kHz
SPI Speed	8 MHz

Table 1: System Technical Specifications

2 Hardware Setup

2.1 Required Components

- STM32G071RB Nucleo-64 board
- BME680 environmental sensor module
- SX1262 LoRa HAT module
- USB-to-UART converter (for USART4)

- Breadboard and jumper wires
- 4.7kOhm pull-up resistors (for I2C)
- Power supply (3.3V)
- LoRa antenna (868 MHz)

2.2 Pin Connections

2.2.1 STM32G071RB Pinout

Pin	Function	Connection
PA2	USART2 TX	USB-to-UART RX
PA3	USART2 RX	USB-to-UART TX
PA0	USART4 TX	USB-to-UART RX
PA1	USART4 RX	USB-to-UART TX
PA9	I2C1 SCL	BME680 SCL
PA10	I2C1 SDA	BME680 SDA
PA5	SPI1 SCK	SX1262 SCK
PA6	SPI1 MISO	SX1262 MISO
PA7	SPI1 MOSI	SX1262 MOSI
PA4	SPI1 NSS	SX1262 NSS
PC0	GPIO	SX1262 RESET
PC1	GPIO	SX1262 BUSY
PA8	GPIO	SX1262 DIO1

Table 2: STM32G071RB Pin Connections

2.2.2 BME680 Sensor Connections

BME680 Pin	STM32 Pin	Description
VCC	3.3V	Power supply
GND	GND	Ground
SCL	PA9	I2C clock line
SDA	PA10	I2C data line

Table 3: BME680 Sensor Connections

2.2.3 SX1262 LoRa Module Connections

3 Software Architecture

3.1 Project Structure

The project follows a modular architecture with the following components:

- **main.c**: System initialization and main loop
- **bme680_interface.c**: BME680 sensor driver and interface
- **lora_interface.c**: SX1262 LoRa communication interface

SX1262 Pin	STM32 Pin	Description
VCC	3.3V	Power supply
GND	GND	Ground
SCK	PA5	SPI clock
MISO	PA6	SPI data in
MOSI	PA7	SPI data out
NSS	PA4	SPI chip select
RESET	PC0	Module reset (active low)
BUSY	PC1	Busy signal (input)
DIO1	PA8	Interrupt line

Table 4: SX1262 LoRa Module Connections

- **command_interface.c**: Command processing and user interface
- **sx126x.c**: SX126x LoRa driver (external library)

3.2 System Initialization Flow

1. Hardware initialization (GPIO, UART, I2C, SPI)
2. BME680 sensor detection and initialization
3. SX1262 LoRa module detection and configuration
4. Command interface startup
5. Main loop execution

3.3 Communication Protocols

3.3.1 I2C Protocol (BME680)

- **Clock Speed**: 100 kHz
- **Device Address**: 0x76 (default) or 0x77
- **Data Format**: 8-bit data, 7-bit address
- **Pull-up Resistors**: 4.7kOhm recommended

3.3.2 SPI Protocol (SX1262)

- **Clock Speed**: 8 MHz
- **Mode**: SPI Mode 0 (CPOL=0, CPHA=0)
- **Data Order**: MSB first
- **Chip Select**: Active low
- **BUSY Pin**: Automatic busy state monitoring

3.3.3 UART Protocol

- **Baud Rate**: 115200 bps
- **Data Bits**: 8
- **Parity**: None
- **Stop Bits**: 1
- **Flow Control**: None

4 Command Interface

4.1 Getting Started

1. Connect the hardware according to the wiring diagram
2. Power on the STM32 board
3. Open a terminal application (PuTTY, Tera Term, etc.)
4. Configure the terminal:
    - Baud Rate: 115200
    - Data Bits: 8
    - Parity: None
    - Stop Bits: 1
    - Flow Control: None
5. Connect to the appropriate COM port
6. Type `start` to begin the command interface

4.2 Available Commands

4.2.1 Sensor Commands

Command	Alias	Description
`read temperature`	`rt`	Read temperature from BME680
`read pressure`	`rp`	Read pressure from BME680
`read humidity`	`rh`	Read humidity from BME680
`test sensor`	`ts`	Test BME680 sensor functionality
`raw registers`	`rr`	Read raw BME680 registers
`raw adc`	`ra`	Read raw BME680 ADC values
`calib data`	`cd`	Check BME680 calibration data
`scan i2c`	`si`	Scan I2C bus for devices

Table 5: Sensor Commands

Command	Alias	Description
`lora broadcast`	`lb`	Broadcast sensor data via SX1262 LoRa
`lora config`	`lc`	Show SX1262 LoRa configuration
`lora test`	`lt`	Test SX1262 LoRa transmission
`lora scan`	`ls`	Scan for LoRa signals (5s)
`lora monitor`	`lm`	Start continuous monitoring
`lora stop`	`lst`	Stop LoRa monitoring
`lora rssi`	`lr`	Get current RSSI
`lora detect`	`ld`	Test SX1262 module detection
`lora reset`	`lrst`	Test SX1262 hardware reset
`lora init`	`li`	Test SX1262 initialization

Table 6: SX1262 LoRa Commands

Command	Description
`help`	Show help menu
`start`	Start the command interface

Table 7: System Commands

4.2.2 SX1262 LoRa Commands

4.2.3 System Commands

4.2.4 Math Operations

4.3 Command Examples

4.3.1 Sensor Data Reading

```
> start
System started! Type 'help' for available commands.
> rt
Temperature: 23.45 C
> rp
Pressure: 1013.25 hPa
> rh
Humidity: 45.67%
> ts
Sensor Test Results:
- Temperature: 23.45 C
- Pressure: 1013.25 hPa
- Humidity: 45.67%
- Status: OK
```

Listing 1: Reading Sensor Data

4.3.2 SX1262 LoRa Communication

```
> lt
Testing SX1262 LoRa transmission...
    SX1262 transmission test successful

> lb
Broadcasting sensor data via SX1262 LoRa...
    Sensor data sent successfully via SX1262 LoRa

> lc
```

Command	Description
`sum <num1> <num2>`	Add two numbers
`sub <num1> <num2>`	Subtract num2 from num1
`mul <num1> <num2>`	Multiply two numbers
`div <num1> <num2>`	Divide num1 by num2

Table 8: Math Operations

```
=== SX1262 LoRa Configuration ===
Status: Module detected
Initialized: Yes
Frequency: 868 MHz (EU band)
Spreading Factor: SF7
Bandwidth: 125 kHz
Coding Rate: 4/5
TX Power: 14 dBm
Sync Word: 0x12
Payload Length: 64 bytes
Preamble Length: 8 symbols
CRC: Enabled
IQ Inversion: Disabled
========================

> ls
Scanning for LoRa signals...
RSSI: -85 dBm
Signal detected at 868.0 MHz
```

Listing 2: SX1262 LoRa Communication

5 Troubleshooting

5.1 Common Issues and Solutions

5.1.1 BME680 Sensor Issues

Problem	Cause	Solution
Sensor not detected	Wrong I2C address	Check SDO pin connection
Communication errors	Missing pull-up resistors	Add 4.7kOhm resistors to SCL/SDA
Invalid readings	Power supply issues	Ensure 3.3V stable supply
I2C bus errors	Wiring issues	Verify SCL/PA9 and SDA/PA10 connections

Table 9: BME680 Troubleshooting

5.1.2 SX1262 LoRa Module Issues

5.1.3 UART Communication Issues

5.2 Diagnostic Commands

Use these commands to diagnose system issues:

- `scan i2c`: Check I2C bus for connected devices
- `raw registers`: Read raw BME680 registers for debugging

Problem	Cause	Solution
Module not detected	SPI wiring issues	Check SCK, MISO, MOSI, NSS connections
BUSY timeout	BUSY pin not connected	Verify PC1 connection to SX1262 BUSY pin
Reset failures	RESET pin issues	Check PC0 connection and timing
Transmission failures	Antenna not connected	Connect proper LoRa antenna
Low signal strength	Wrong frequency	Verify 868 MHz configuration
Communication errors	SPI speed too high	Reduce SPI clock frequency

Table 10: SX1262 LoRa Troubleshooting

Problem	Cause	Solution
No communication	Wrong COM port	Check Device Manager for correct port
Garbled text	Wrong baud rate	Set to 115200 bps
Missing characters	Flow control enabled	Disable hardware flow control
Connection drops	Driver issues	Update USB-to-UART driver

Table 11: UART Troubleshooting

- `lora detect`: Test SX1262 module detection
- `lora reset`: Test SX1262 hardware reset
- `lora init`: Test SX1262 initialization
- `lora config`: Verify SX1262 LoRa configuration
- `lora rssi`: Check signal strength

5.3 System Status Messages

The system provides status messages during initialization:

```
========================================
IoT Prototype System - STM32G071RB
========================================
System Clock: 16 MHz
I2C1 Configuration: PA9 (SCL), PA10 (SDA)
USART2: PA2 (TX), PA3 (RX) - 115200 baud
USART4: PA0 (TX), PA1 (RX) - 115200 baud
SPI1: PA5 (SCK), PA6 (MISO), PA7 (MOSI), PA4 (NSS)
SX1262: PC0 (RESET), PC1 (BUSY), PA8 (DIO1)
LED Status: PA5
========================================
```

Listing 3: System Initialization Messages

6 Development Guidelines

6.1 Adding New Commands

To add new commands to the system:

1. Add command handler in `command_interface.c`
2. Update help menu with new command description
3. Implement command functionality

4. Test with both USART2 and USART4 interfaces

6.2 Modifying Sensor Configuration

To modify BME680 sensor settings:

```
struct bme68x_conf conf;
conf.os_hum = BME68X_OS_2X;     // Humidity oversampling
conf.os_pres = BME68X_OS_4X;    // Pressure oversampling
conf.os_temp = BME68X_OS_2X;    // Temperature oversampling
conf.filter = BME68X_FILTER_SIZE_3; // IIR filter
conf.odr = BME68X_ODR_1000_MS; // Output data rate
```

Listing 4: BME680 Configuration Example

6.3 Modifying SX1262 LoRa Parameters

To modify SX1262 LoRa communication parameters:

```
#define SX1262_FREQUENCY_HZ         868000000  // 868 MHz (EU band)
#define SX1262_TX_POWER_DBM         14         // 14 dBm output power
#define SX1262_SPREADING_FACTOR     7          // SF7
#define SX1262_BANDWIDTH            125        // 125 kHz
#define SX1262_CODING_RATE          1          // 4/5
#define SX1262_PREAMBLE_LENGTH      8
#define SX1262_PAYLOAD_LENGTH       64
#define SX1262_SYNC_WORD            0x12
```

Listing 5: SX1262 LoRa Configuration Example

7 Performance Characteristics

7.1 Sensor Performance

Parameter	Range	Accuracy
Temperature	-40C to +85C	+/-0.5C
Pressure	300 hPa to 1100 hPa	+/-1 hPa
Humidity	0% to 100%	+/-3%

Table 12: BME680 Performance Specifications

7.2 SX1262 LoRa Performance

Parameter	Value	Description
Frequency	868 MHz	EU band operating frequency
Range	Up to 15 km	Line of sight
Data Rate	5.47 kbps	With SF7, 125 kHz BW
TX Power	14 dBm	Maximum output power
Spreading Factor	SF7	LoRa spreading factor
Bandwidth	125 kHz	LoRa bandwidth
Coding Rate	4/5	Forward error correction

Table 13: SX1262 LoRa Performance Specifications

7.3 System Performance

- **Command Response Time**: $<$ 100 ms
- **Sensor Read Time**: $<$ 50 ms
- **SX1262 Transmission Time**: $<$ 200 ms
- **Power Consumption**: 50 mA (active mode)

8 Advanced Features

8.1 Continuous Monitoring

The system supports continuous SX1262 LoRa monitoring for detecting signals from other devices:

```
> lm
Starting continuous SX1262 LoRa monitoring...
Monitoring for signals...
RSSI: -87 dBm
Packet received: {"temp":24.1,"press":1012.8,"hum":48.2,"node":"Node2"}
RSSI: -92 dBm
Signal detected (no packet)
> lst
Monitoring stopped.
```

Listing 6: Continuous Monitoring

8.2 Sensor Data Broadcasting

Automatic broadcasting of sensor data in JSON format via SX1262:

```
> lb
Broadcasting sensor data via SX1262 LoRa...
    Sensor data sent successfully via SX1262 LoRa
```

Listing 7: Sensor Data Broadcast

8.3 I2C Bus Scanning

Automatic detection of I2C devices:

```
> si
Scanning I2C bus for devices...
Device found at address: 0x76
Total devices found: 1
```

Listing 8: I2C Bus Scan

9 Maintenance and Support

9.1 Regular Maintenance

- Check physical connections monthly
- Verify sensor calibration annually
- Update firmware as needed

- Monitor system logs for errors
- Check SX1262 antenna connection

9.2 Calibration

The BME680 sensor includes factory calibration data. For high-precision applications:

- Use reference instruments for comparison
- Apply offset corrections in software
- Consider environmental factors
- Document calibration procedures

9.3 Technical Support

For technical support and questions:

- Check this user manual first
- Review troubleshooting section
- Verify hardware connections
- Test with known good components
- Use diagnostic commands for SX1262

10 Appendices

10.1 Appendix A: Pin Definitions

```
// UART Pins
#define UART2_TX_PIN GPIO_PIN_2
#define UART2_TX_PORT GPIOA
#define UART2_RX_PIN GPIO_PIN_3
#define UART2_RX_PORT GPIOA

#define UART4_TX_PIN GPIO_PIN_0
#define UART4_TX_PORT GPIOA
#define UART4_RX_PIN GPIO_PIN_1
#define UART4_RX_PORT GPIOA

// I2C Pins
#define I2C1_SCL_PIN GPIO_PIN_9
#define I2C1_SCL_PORT GPIOA
#define I2C1_SDA_PIN GPIO_PIN_10
#define I2C1_SDA_PORT GPIOA

// SPI Pins
#define SPI1_SCK_PIN GPIO_PIN_5
#define SPI1_SCK_PORT GPIOA
#define SPI1_MISO_PIN GPIO_PIN_6
#define SPI1_MISO_PORT GPIOA
#define SPI1_MOSI_PIN GPIO_PIN_7
#define SPI1_MOSI_PORT GPIOA
#define SPI1_NSS_PIN GPIO_PIN_4
#define SPI1_NSS_PORT GPIOA
```

```
27
28 // SX1262 Control Pins
29 #define LORA_RESET_PIN GPIO_PIN_0
30 #define LORA_RESET_PORT GPIOC
31 #define LORA_BUSY_PIN GPIO_PIN_1
32 #define LORA_BUSY_PORT GPIOC
33 #define LORA_DIO1_PIN GPIO_PIN_8
34 #define LORA_DIO1_PORT GPIOA
```

Listing 9: Pin Definitions in main.h

10.2 Appendix B: Configuration Constants

```
1  // SX1262 LoRa Configuration
2  #define SX1262_FREQUENCY_HZ         868000000
3  #define SX1262_TX_POWER_DBM         14
4  #define SX1262_SPREADING_FACTOR     7
5  #define SX1262_BANDWIDTH            125
6  #define SX1262_CODING_RATE          1
7  #define SX1262_PREAMBLE_LENGTH      8
8  #define SX1262_PAYLOAD_LENGTH       64
9  #define SX1262_SYNC_WORD            0x12
10
11 // BME680 Configuration
12 #define BME68X_I2C_ADDR_LOW         0x76
13 #define BME68X_I2C_ADDR_HIGH        0x77
14 #define BME68X_CHIP_ID              0x61
15
16 // System Configuration
17 #define CMD_BUFFER_SIZE             128
18 #define SYSTEM_CLOCK_HZ             16000000
```

Listing 10: Configuration Constants

10.3 Appendix C: Error Codes

Error Code	Description	Action
BME68X_OK	Operation successful	None
BME68X_E_COM_FAIL	Communication failure	Check I2C connections
BME68X_E_DEV_NOT_FOUND	Device not found	Check sensor power and address
SX126X_STATUS_OK	SX1262 operation successful	None
SX126X_STATUS_ERROR	SX1262 operation failed	Check SPI connections
HAL_OK	HAL operation successful	None
HAL_ERROR	HAL operation failed	Check hardware connections

Table 14: Error Codes and Descriptions

10.4 Appendix D: Command Reference

Command	Alias	Description
`start`	-	Start command interface
`help`	-	Show help menu
`read temperature`	`rt`	Read temperature (C)

Command	Alias	Description
`read pressure`	`rp`	Read pressure (hPa)
`read humidity`	`rh`	Read humidity (%)
`test sensor`	`ts`	Test BME680 sensor
`raw registers`	`rr`	Read raw registers
`raw adc`	`ra`	Read raw ADC values
`calib data`	`cd`	Check calibration data
`scan i2c`	`si`	Scan I2C bus
`lora broadcast`	`lb`	Broadcast sensor data via SX1262
`lora config`	`lc`	Show SX1262 LoRa config
`lora test`	`lt`	Test SX1262 LoRa transmission
`lora scan`	`ls`	Scan for signals (5s)
`lora monitor`	`lm`	Start monitoring
`lora stop`	`lst`	Stop monitoring
`lora rssi`	`lr`	Get RSSI
`lora detect`	`ld`	Test SX1262 detection
`lora reset`	`lrst`	Test SX1262 reset
`lora init`	`li`	Test SX1262 initialization
`sum <n1> <n2>`	-	Add numbers
`sub <n1> <n2>`	-	Subtract numbers
`mul <n1> <n2>`	-	Multiply numbers
`div <n1> <n2>`	-	Divide numbers