User Guide to the
LoRa® 2.4GHz 3 Channels
Single SF Reference Design
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1 Introduction

This user guide introduces the Semtech LoRa® 2.4GHz 3 Channels Single SF Reference Design V1.0 and how to set it up with a Raspberry Pi 3.

The reference design consists on a MCU, four SX1280 RF transceivers, three dedicated to RX and one dedicated to TX, a T/R switch + LNA in a front-end module, and all of the necessary filters and power supplies to deliver a high performance 3 channels single spreading factor LoRa gateway.

![LoRa® 2.4 GHz 3 Channels Single SF Reference Design V1.0](image)

*Figure 1: LoRa® 2.4 GHz 3 Channels Single SF Reference Design V1.0 bottom*
Figure 2: LoRa® 2.4 GHz 3 Channels Single SF Reference Design V1.0 top
2 Hardware Overview

2.1 Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Item</th>
<th>Minimum</th>
<th>Typical</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Supply Voltage</td>
<td>-0.3</td>
<td>3.3V</td>
<td>3.6</td>
<td>V</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-40</td>
<td>25</td>
<td>85</td>
<td>°C</td>
</tr>
<tr>
<td>Maximum RF Input Level</td>
<td></td>
<td></td>
<td>+10</td>
<td>dBm</td>
</tr>
</tbody>
</table>

Table 1: Absolute Maximum Ratings

2.2 RF Front-End Architecture

The RF front-end architecture of the 2.4GHz 3 Channels Single SF Reference Design displays the following characteristics:

- Half-duplex mode i.e. can’t receive and transmit simultaneously
- Simultaneously receive 3 LoRa® channels single-data rates selectable (SF7 ~ SF12 / 812.5 kHz)
- Maximum transmit output power = +12dBm
- Typical sensitivity level:
  - -116 dBm at SF7 BW 812.5 kHz
  - -129 dBm at SF12 BW 812.5 kHz
- Ability to work in hostile RF environments such as close to cellular mobile phones, WiFi routers, Bluetooth devices
2.3 LoRa® 2.4 GHz 3 Channels Single SF Reference Design block diagram

On-board Mother board main requirements:
- 1 x USB : coming from host to the MCU USB interface
- 3.3V power supply

2.4 Power Consumption

<table>
<thead>
<tr>
<th>MODE</th>
<th>DESCRIPTION</th>
<th>TYPICAL CURRENT CONSUMPTION</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDLE</td>
<td>HAL packet_forwarder OFF</td>
<td>12.6 mA</td>
<td>mA</td>
</tr>
<tr>
<td>3 RX CHANNELS ON TX OFF</td>
<td>HAL packet_forwarder ON</td>
<td>33.3 mA</td>
<td>mA</td>
</tr>
<tr>
<td>3 RX CHANNELS OFF TX ON AT 13 DBM 2.4 GHZ</td>
<td>HAL packet_forwarder ON</td>
<td>43.5 mA</td>
<td>mA</td>
</tr>
</tbody>
</table>

Table 2: Typical Current Consumption at 5.0 V
3 Software Overview

The 2.4GHz 3 Channels Single SF Reference Design software can be split in two main parts:

The **packet forwarder** is a program running on the host of a LoRa® gateway that forwards RF packets received by the concentrator to a server through an IP/UDP link, and emits RF packets that are sent by the server.

The **gateway_2g4_hal** is a host driver/HAL to build a LoRa® 2.4 GHz 3 Channels Single SF Reference Design which communicates through USB with a concentrator board based on Semtech SX1280 RF transceivers.

![Software Overview Diagram](image)

**Figure 4: Software Overview**

The packet_forwarder (gateway application) as well as gateway_2g4_hal source code can be found under LoRa® Github:

[https://ch02git1.semtech.com/lora-2g4-gateway/gateway_2g4_hal](https://ch02git1.semtech.com/lora-2g4-gateway/gateway_2g4_hal)

For more details see the readme.md file in the followings directories:

- gateway_2g4_hal
- gateway_2g4_hal/libloragw
- gateway_2g4_hal/libtools
- gateway_2g4_hal/mcu_bin
- gateway_2g4_hal/util_boot
- gateway_2g4_hal/packet_forwarder
- gateway_2g4_hal/util_net_downlink
- gateway_2g4_hal/util_chip_id
For basic testing, utilities such as test_loragw_hal_tx, test_loragw_hal_rx, are provided on the LoRa® Github repository:

https://github.com/Lora-net/gateway_2g4_hal/libloragw

Notice!
The default configuration file “global_conf.json” is given as an example and may need to be adapted to your design. Several configuration file examples are located in the following directory: [PATH]/gateway_2g4_hal/packet_forwarder.

4 Use with Raspberry Pi

The Semtech LoRa® Concentrator reference design has been tested with Raspberry Pi 3 model B


4.1 LoRa® 2.4 GHz 3 Channels Single SF Reference Design + Interface board + Raspberry Pi Connection

Simply connect the 2.4GHz 3 Channels Single SF Reference Design to the interface board through the Raspberry pi USB as depicted on the picture below:

Figure 5: LoRa® 2.4 GHz 3 Channels Single SF Reference Design + interface board + raspberry pi Connection
4.2 Raspberry Pi Image Software Installation

- Download the Raspbian image:
  - Go to address https://www.raspberrypi.org/downloads/raspbian/
  - Choose “RASPBIAN BUSTER LITE”

- Refer to following guide to setup your SD card with the downloaded image:
  - Format the SD card:
    https://www.sdcard.org/downloads/formatter/eula_windows/

- Write the image previously downloaded on the SD card:
  https://sourceforge.net/projects/win32diskimager/

Figure 6: SDFormatter

Figure 7: Win32 Disk Imager
4.3 Starting Raspberry Pi

Once the SD card is burned, insert it in the Raspberry Pi and choose a way to login Raspberry Pi:

- HDMI monitor and USB keyboard
- SSH connection:
  - Enable **SSH** by placing a file named “ssh” (without any extension) onto the boot partition of the SD card:

![Figure 8: enable SSH connection on RPI](image)

Below is the description through an SSH client enabled from raspi-config tool, **Interfacing Option (is activated by HDMI monitor and USB keyboard)**

4.3.1 Login: pi and Password: raspberry

![Figure 9: MobaXterm SSH Client](image)
4.3.2 Resize Partition / FS

- On larger SD cards, the root partition can be resized to use extra space, using the `Expand Filesystem` option from raspi-config menu:

  ```
  $ sudo raspi-config
  ```

  ![Figure 10: raspi-config Menu](image)

  - Select 1 `Expand Filesystem` from raspi-config menu and press Enter:

  ![Figure 11: raspi-config “Expand Filesystem”](image)

  - The system must be then rebooted:

  ```
  $ sudo reboot
  ```

  For more details, go to the following address:
4.3.3 Update and configure the RPI

**Update**

Enter the following commands:
- `$ sudo apt-get update`
- `$ sudo apt-get upgrade`
- `$ sudo apt-get dist-upgrade`
- `$ sudo rpi-update`

**Install Git**

- `$ sudo apt install git`

4.3.4 Clone Semtech HAL + Packet Forwarder

Get the latest Semtech software package from LoRa® Github (requires a connection to internet):

$ git clone https://github.com/Lora-net/gateway_2g4_hal

Figure 12: Git clone
### 4.3.5 Install dfu-util Tool

- `$ cd ~/gateway_2g4_hal/`
- `$ sudo apt-get install autoconf`
- `$ git clone https://git.code.sf.net/p/dfu-util/dfu-util`
- `$ cd dfu-util`
- `$ ./autogen.sh`
- `$ sudo apt-get install libusb-1.0-0-dev`
- `$ ./configure`
- `$ make`
- `$ sudo make install`

![Figure 13: Dfu-util Make Install](image)
4.3.6 Load STM32F446RC MCU Binary

For the first time only, load the STM32F446RC MCU binary:

1. Press the “BOOT0” button of the GW while resetting the gateway:

![Figure 14: STM32 MCU Boot0 Button](image)

2. On the Raspberry Pi, load the binary into the STM32F446RC MCU with the following command:

```bash
$ cd gateway_2g4_hal/dfu-util

$ sudo dfu-util -a 0 -s 0x08000000:leave -t 0 -D ../mcu_bin/rlz_fwm_gtw_2g4_00.02.16.bin
```

![Figure 15: Load STM32F446RC MCU Binary](image)

Note: potentially the MCU will be not up to date, it must be programmed with the latest version available into the mcu_bin folder.
For any future STM32F446RC MCU binary update, there should be no need to press the “BOOT0” button, simply connect the GW to any USB port of the Raspberry Pi and type following commands:

- $ lsusb

To check GW is recognized:

```
pi@raspberrypi:/~$ lsusb
Bus 001 Device 000: ID 05eb:0574 TDK-Lambda Corp.
Bus 001 Device 001: ID 05eb:0574 emulator EMU-USB
```

Figure 16: “lsusb” Command Result

- $ dmesg

To know the COM device to be used to access to the GW (here “ttyACM0”):

```
pi@raspberrypi:/~$ dmesg
[ 7334.408972] ttyACM0: USB ACM device
[ 7335.168637] ttyACM0: New USB device found, idVendor=05eb, idProduct=0574, bcdDevice=2.00
```

Figure 1712: “dmesg” Command Result

- $ cd ~/gateway_2g4_hal/util_boot
- $ make
- $ ./boot -d /dev/ttyACM0
- $ lsusb

```
pi@raspberrypi:/~$ lsusb
Bus 001 Device 000: ID 0483:df11 STMControl STM Control Hal in DFU Mode
```

Figure 1813: DFU mode

```
$ cd ~/gateway_2g4_hal/dfu-util
$ sudo dfu-util -a 0 -s 0x08000000:leave -t 0 -D ../mcu_bin/rlz_fwm_gtw_2g4_01.00.01.bin

⇒ Your GW is updated !
```
4.3.7 Compile Semtech HAL + Packet Forwarder

- $ cd ~/gateway_2g4_hal/
- $ make clean all

The executables are copied in the different folders.

Test functions are in the libloragw folder:

```
pi@raspberrypi:~/gateway_2g4_hal/libloragw $ ls -l
```

```
total 528
drwxr-xr-x 2 pi pi 4096 Jan 9 09:33 inc
-rw-r--r-- 1 pi pi 72142 Jan 9 09:33 libloragw.a
-rw-r--r-- 1 pi pi 289 Jan 9 09:05 library.cfg
-rw-r--r-- 1 pi pi 1997 Jan 9 09:05 Makefile
drwxr-xr-x 2 pi pi 4096 Jan 9 09:33 obj
-rw-r--r-- 1 pi pi 8590 Jan 9 09:05 readme.md
```

Figure 1914: libloragw executables

For instance:

- Test_hal_tx : simple TX LoRa
- Test_hal_rx : simple RX LoRa

Packet forwarder is in packet_forwarder folder

```
pi@raspberrypi:~/gateway_2g4_hal/packet_forwarder $ ls -l
```

```
total 196
-rw-r--r-- 1 pi pi 1344 Jan 9 09:05 global_conf.json
-rwrxr-xr-x 2 pi pi 4096 Jan 9 09:05 inc
-rwrxr-xr-x 1 pi pi 149508 Jan 9 09:33 lora_pkt_fwd
-rw-r--r-- 1 pi pi 1551 Jan 9 09:05 Makefile
drwxr-xr-x 2 pi pi 4096 Jan 9 09:33 obj
-rw-r--r-- 1 pi pi 15651 Jan 9 09:05 PROTOCOL.md
-rw-r--r-- 1 pi pi 10737 Jan 9 09:05 readme.md
```

Figure 20: packet forwarder executable

Lora_pkt_fwd is the executable.
4.3.8 Semtech HAL Compilation Check

The program `test_hal_reg` is used to check the reliability of the link between the host platform and the LoRa® concentrator register file that is the interface through which all interactions with the LoRa® concentrator happen.

- $ cd ~/gateway_2g4_hal/libloragw
- $ ./test_hal_reg

The output looks like this:

```
pi@raspberrypi:~/gateway_2g4_hal/libloragw $ ./test_hal_reg
### LoRa 2.4GHz Gateway - Radio Register Read/Write ###
Read register 0x08c1: 0x21
Write register 0x08c1: 0xaa
Read register 0x08c1: 0xaa
### Exiting ###
pi@raspberrypi:~/gateway_2g4_hal/libloragw $
```

Figure 151: test_loragw_reg

4.3.9 Get the Unique ID to the Gateway

The 2.4GHz 3 Channels Single SF Reference Design has a unique ID given at production. This ID can be used as a 64-bit MAC address for the 2.4GHz 3 Channels Single SF Reference Design.

```
$ cd ~/gateway_2g4_hal/util_chip_id
$ ./chip_id
```

Return a unique ID like the following:

```
chip ID:
INFO: Channel 0 is disabled
INFO: Channel 1 is disabled
INFO: Channel 2 is disabled
### opening /dev/ttyACM0
INFO: Concentrator MCU version is v00.02.16
INFO: concentrator EUI: 0x165138333293035
### closing /dev/ttyACM0
pi@raspberrypi:~/gateway_2g4_hal/util_chip_id $
```

Figure 16: util chip ID

The gateway ID could be then replaced in the global_conf.json file within the repository:

```
~/gateway_2g4_hal/packet_forwarder/global_conf.json
```
The chip id unicity is no guaranteed yet, please choose your own waiting for an improvement.

```
"gateway_conf": {
    "gateway_ID": "1651383332393035", // Do not let it in auto
    /* change with default server address/ports */
    "server_address": "semtech.eu1.cloud.thethings.industries",
    "serv_port_up": 1700,
    "serv_port_down": 1700,
    /* adjust the following parameters for your network */
    "keepalive_interval": 10,
    "stat_interval": 30,
    "push_timeout_ms": 100,
    ...
    ...
    ...
```

### 4.3.10 Test the HAL TX

The program `/test_loragw_hal_tx` is used to test the emission of the 2.4GHz GW 3+1 reference design with settings set by the user.

The tests run endlessly or until an error is detected: press Ctrl+C to stop the application.

```
- $ cd ~/gateway_2g4_hal/libloragw
- $ ./test_hal_tx -f 2402 -s10 -b800 -l24 -n10000 -z24 -p13 -t 100
```

The command above send a LoRa frame at 2.402 GHz and the power from the SX1280 set to 13dBm (-p).

For more information, enter:

```
$ ./test_loragw_hal_tx -h
```
### 4.3.11 Run Packet Forwarder

The Packet Forwarder is a program running on the host of a LoRa® Gateway that forward RF packets received by the concentrator to a server through an IP/UDP link, and emits RF packets that are sent by the server.

Run Packet Forwarder for a functional check:
```
$ cd ~/gateway_2g4_hal/packet_forwarder
$ ./lora_pkt_fwd
```

The output looks like this:

![Packet Forwarder Output](image)

**Figure 23: Packet Forwarder**
5 JSON file for RF Parameter Tuning

Edit the file `~/gateway_2g4_hal/packet_forwarder/global_conf.json` update the following RF parameters:

- *freq*, to set frequency channels
  - Frequency channels in Hz
- *Bandwidth*, to set bandwidth channels
  - Bandwidth channels in Hz
- *Spreading factor*, to set spreading factor channels
  - Spreading factor between 7 and 12
A typical LoRa® 2.4 GHz GW 3+1 reference design global_conf.json file looks like this:

```json
{
    "radio_conf": {
        "tty_path": "/dev/ttyACM0",
        "antenna_gain": 0, /* antenna gain, in dBi */
    },
    "chan_0": {
        "enable": true,
        "freq": 2403000000,
        "bandwidth": 812000,
        "spread_factor": 12,
        "rssi_offset": 0.0
    },
    "chan_1": {
        "enable": true,
        "freq": 2479000000,
        "bandwidth": 812000,
        "spread_factor": 12,
        "rssi_offset": 0.0
    },
    "chan_2": {
        "enable": true,
        "freq": 2425000000,
        "bandwidth": 812000,
        "spread_factor": 12,
        "rssi_offset": 0.0
    },
    "tx": {
        "enable": true,
        "tx_freq_min": 2400000000,
        "tx_freq_max": 2500000000
    },
    "gateway_conf": {
        "gateway_ID": "1651383332393022",
        /* change with default server address/ports */
        "server_address": "semtech.eu1.cloud.thethings.industries",
        "serv_port_up": 1700,
        "serv_port_down": 1700,
        /* adjust the following parameters for your network */
        "keepalive_interval": 10,
        "stat_interval": 30,
        "push_timeout_ms": 100,
        /* forward only valid packets */
        "forward_crc_valid": true,
        "forward_crc_error": false,
        "forward_crc_disabled": false
    }
}
```
6 References

7 Part Number

[1] 2.4GHz 3 Channels Single SF Reference Design development kit Part Number: SX1280Z3DSFGW1

8 Revision History

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Modifications</th>
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</thead>
<tbody>
<tr>
<td>1.0</td>
<td>April 2020</td>
<td>First Release</td>
</tr>
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9 Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>BB</td>
<td>BaseBand</td>
</tr>
<tr>
<td>BoM</td>
<td>Bill Of Materials</td>
</tr>
<tr>
<td>BW</td>
<td>BandWidth</td>
</tr>
<tr>
<td>CLK</td>
<td>Clock</td>
</tr>
<tr>
<td>CW</td>
<td>Continuous Wave</td>
</tr>
<tr>
<td>ETSI</td>
<td>European Telecommunications Standard Institute</td>
</tr>
<tr>
<td>DFU</td>
<td>Device Firmware Update</td>
</tr>
<tr>
<td>EU</td>
<td>Europe</td>
</tr>
<tr>
<td>EUI</td>
<td>Extended Unique Identifier</td>
</tr>
<tr>
<td>GB</td>
<td>GigaByte</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>GW</td>
<td>GateWay</td>
</tr>
<tr>
<td>HAL</td>
<td>Hardware Abstraction Layer</td>
</tr>
<tr>
<td>HDMI</td>
<td>High-Definition Multimedia Interface</td>
</tr>
<tr>
<td>HW</td>
<td>HardWare</td>
</tr>
<tr>
<td>IP</td>
<td>Intellectual Property</td>
</tr>
<tr>
<td>ISM</td>
<td>Industrial, Scientific and Medical applications</td>
</tr>
<tr>
<td>LAN</td>
<td>Local Area Network</td>
</tr>
<tr>
<td>LBT</td>
<td>Listen Before Talk</td>
</tr>
<tr>
<td>LO</td>
<td>Local Oscillator</td>
</tr>
<tr>
<td>LoRa®</td>
<td>LOnge RAnge modulation technique</td>
</tr>
<tr>
<td>LoRaWAN</td>
<td>LoRa® low power Wide Area Network protocol</td>
</tr>
<tr>
<td>LPF</td>
<td>Low Pass Filter</td>
</tr>
<tr>
<td>LSB</td>
<td>Least Significant Bit</td>
</tr>
<tr>
<td>LUT</td>
<td>Look Up Table</td>
</tr>
<tr>
<td>MAC</td>
<td>Media Access Control address</td>
</tr>
<tr>
<td>MCU</td>
<td>Micro-Controller Unit</td>
</tr>
<tr>
<td>MPU</td>
<td>Micro-Processing Unit</td>
</tr>
<tr>
<td>PA</td>
<td>Power Amplifier</td>
</tr>
<tr>
<td>RSSI</td>
<td>Received Signal Strength Indication</td>
</tr>
<tr>
<td>RF</td>
<td>Radio-Frequency</td>
</tr>
<tr>
<td>RX</td>
<td>Receiver</td>
</tr>
<tr>
<td>SAW</td>
<td>Surface Acoustic Wave filter</td>
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<td>SD Card</td>
<td>Secure Digital Card</td>
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<tr>
<td>SF</td>
<td>Spreading Factor</td>
</tr>
<tr>
<td>SPI</td>
<td>Serial Peripheral Interface</td>
</tr>
<tr>
<td>SPDT</td>
<td>Single-Pole, Double-Throw switch</td>
</tr>
<tr>
<td>SSH</td>
<td>Secure SHeIl</td>
</tr>
<tr>
<td>SW</td>
<td>SoftWare</td>
</tr>
<tr>
<td>TX</td>
<td>Transmitter</td>
</tr>
<tr>
<td>UART</td>
<td>Universal Asynchronous Receiver/Transmitter</td>
</tr>
<tr>
<td>UDP</td>
<td>User Datagram Protocol</td>
</tr>
<tr>
<td>USB</td>
<td>Universal Serial Bus</td>
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