Application note

Driving an external RF front-end with the BlueNRG-LP

Introduction

The BlueNRG-LP is an ultra-low-power Bluetooth Low Energy SoC device which can achieve +8 dBm of output power at antenna connector. Nevertheless, Bluetooth standards allow a maximum output power of +20 dBm (local regulations can still limit the output power to a lower value).

Especially for this reason, the BlueNRG-LP gives the possibility to control an external RF front-end, that can increase the output power by using the integrated power amplifier.

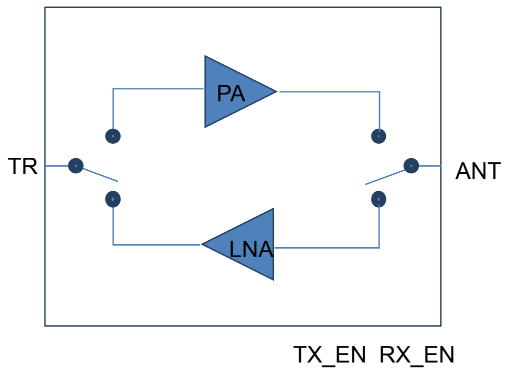
In addition to a power amplifier (PA), RF front-ends can usually integrate a low noise amplifier (to improve sensitivity), TX/RX switching circuitry, matching network and harmonic filters.

1 RF control signals

An external front-end usually has at least 2 pins to control an RF switch which can connect selectively the Antenna either to the output of the PA or to the input of the LNA. The LNA may not be present. In this case the RF switch can directly connect the TX/RX pin with the antenna.

A simple block diagram example of an external front-end is shown below. There could be other blocks inside the front-end (e.g. a harmonic filter on the PA), or a bypass path between TX/RX port and the antenna.

Figure 1. Basic block diagram example of a front-end



To control the external front-end, some signals need to be generated from the SoC. Usually two signals are enough: the former to control the TX path, the latter to control the RX path. The way these signals control the front-end varies from one manufacturer to another.

Moreover, there is always the need to anticipate TX_EN/RX_EN signals before the radio is in transmission or reception state. This is because power amplifiers need time before power is stable and can consume so much current that the BueNRG-LP PLL could be destabilized.

Therefore, the radio sequencer generates two signals:

- TX_SEQUENCE, which is raised when the radio sequencer is going to start a transmission, and it is put back to low when internal PA is switched off.
- RX_SEQUENCE, which is raised when the radio sequencer is going to start a reception, and it is put back to low when radio leaves RX state.

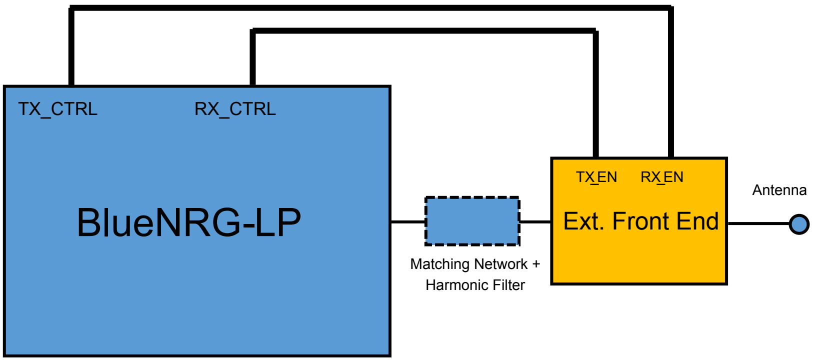
Transition from low to high of TX_SEQUENCE occurs before first bit is transmitted over-the-air. Also, RX_SEQUENCE transition from low to high occurs before radio is in reception state. These timings depend on the state (TX or RX) and on PLL calibration whether it is done or not. PLL calibration is done each time a different RF channel is used. Timings are reported in Table 1. Delay between RF control signals and TX/RX state. These timings are based on hardware requirements and set by the firmware accordingly.

Table 1. Delay between RF control signals and TX/RX state

	With PLL calibration	Without PLL calibration
TX_SEQUENCE	118 µs	58 µs
RX_SEQUENCE	116 µs	56 µs

In the figure below, a block diagram shows the necessary connections between the BlueNRG-LP and the external front-end. TX_CTRL and RX_CTRL are the pins used to control the front-end, and they can be different depending on the used control mode. The matching network and harmonic filter may not be needed if impedance is already matched and an appropriate harmonic filter is integrated inside the front-end.

Figure 2. **Block diagram of connections between the BlueNRG-LP and an RF front-end**



2 RF control modes

In the BlueNRG-LP there are two options to use TX/RX sequence signals generated by the radio sequencer.

1. Automatic mode, i.e. internal TX_SEQUENCE and RX_SEQUENCE signals are routed to SoC GPIOs. These signals may not be compatible with the control logic of the front-end
2. Interrupt mode, i.e. internal TX_SEQUENCE and RX_SEQUENCE signals generate interrupt requests, so that firmware can act according to the control logic needed by the front-end

2.1 Automatic control mode

In automatic mode, TX_SEQUENCE and RX_SEQUENCE signals can be enabled on some of the BlueNRG-LP GPIOs.

Table 2. GPIOs connected RF control signals

	GPIO (alternate functions)
TX_SEQUENCE	PA10 (AF2), PB15 (AF1)
RX_SEQUENCE	PA8 (AF2), PA11 (AF2)

The advantage of this mode is that TX/RX sequence signals are generated autonomously, without any operation from the firmware. The drawback is in flexibility: the control logic of the front-end must be compatible with the signals generated by the radio sequencer. For instance, a front-end with a control logic as in the table below is directly compatible with TX_SEQUENCE and RX_SEQUENCE signals.

Table 3. Example of a compatible control logic table

Front-end mode	TX_EN	RX_EN
Sleep	0	0
RX	0	1
TX	1	0

2.2 Interrupt control mode

In interrupt mode, TX_SEQUENCE and RX_SEQUENCE signals coming from the sequencer can be detected by the system controller, which can generate interrupts. To enable TX/RX sequence interrupts, the following code can be used.

```
LL_APB0_EnableClock(LL_APB0_PERIPH_SYSCFG);

LL_SYSCFG_BLERXTX_SetTrigger(LL_SYSCFG_BLERXTX_TRIGGER_BOTH_EDGE, LL_SYSCFG_BLE_TX_EVENT);
LL_SYSCFG_BLERXTX_SetTrigger(LL_SYSCFG_BLERXTX_TRIGGER_BOTH_EDGE, LL_SYSCFG_BLE_RX_EVENT);

LL_SYSCFG_BLERXTX_SetType(LL_SYSCFG_BLERXTX_DET_TYPE_EDGE, LL_SYSCFG_BLE_TX_EVENT);
LL_SYSCFG_BLERXTX_SetType(LL_SYSCFG_BLERXTX_DET_TYPE_EDGE, LL_SYSCFG_BLE_RX_EVENT);
LL_SYSCFG_BLERXTX_EnableIT(LL_SYSCFG_BLE_TX_EVENT|LL_SYSCFG_BLE_RX_EVENT);
NVIC_EnableIRQ(BLE_SEQ_IRQn);
```

The BLE_RXTX_SEQ_IRQHandler can be defined as follows:

```
void BLE_RXTX_SEQ_IRQHandler(void)
{
    if(LL_SYSCFG_BLERXTX_IsInterruptPending(LL_SYSCFG_BLE_TX_EVENT))
    {
        // Set GPIOs to make RF Front End enter TX mode

        LL_SYSCFG_BLERXTX_ClearInterrupt(LL_SYSCFG_BLE_TX_EVENT);
    }

    else if(LL_SYSCFG_BLERXTX_IsInterruptPending(LL_SYSCFG_BLE_RX_EVENT))
    {
        // Set GPIOs to make RF Front End enter RX mode.

        LL_SYSCFG_BLERXTX_ClearInterrupt(LL_SYSCFG_BLE_RX_EVENT);
    }
}
```

Inside the interrupt service routine, any GPIO can be used to drive the RF front-end.

This mode of operation gives a greater flexibility compared to the automatic control mode, since any control logic can be implemented. The drawback of this method is that the control signal may be delayed if a higher priority interrupt is raised in the meantime. It is suggested to use a priority lower than BLE_TX_RX_IRQHandler but higher than other interrupts. Even if the highest priority is assigned to the BLE_TX_RX_IRQHandler, this does not interfere with the BLE_RXTX_SEQ_IRQHandler. In fact, BLE_TX_RX_IRQHandler is executed only at the end of a TX/RX sequence. Hence, BLE_RXTX_SEQ_IRQHandler is delayed by the execution of BLE_TX_RX_IRQHandler only at the end of a TX/RX sequence, when the external front-end should be driven to exit RX or TX mode, which is not a critical operation.

3 References

1. BlueNRG-LP datasheet
2. BlueNRG-LP reference manual (RM0479)

Revision history

Table 4. **Document revision history**

Date	Version	Changes
06-Nov-2020	1	Initial release.

Contents