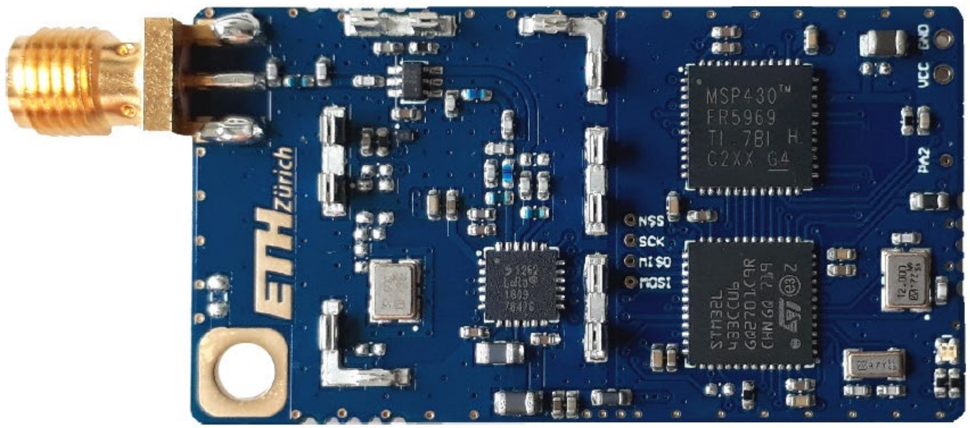
ETH zürich

BOLT
MSP430 with FRAM

DPP2 compatible
interconnect



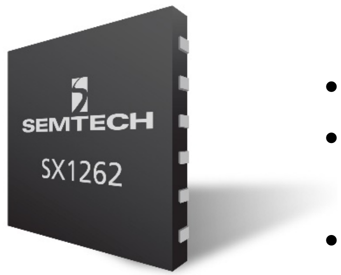
SX1262

STM32L433CC

DPP2 LoRa Communication Board

Motivation

- New communication board with increased performance
  - 3rd Generation: TinyNode 584 (2005) → CC430 (2011) → SX1262 (2018)



- +22 dBm Tx
- -170 dB link budget (~ 50 km)
- 4.6 mA Rx current

- Flexibility in transmission modes allows to scale
  - Throughput
  - Distance
  - Power consumption

Major Components

MCU (STM32L433CC)

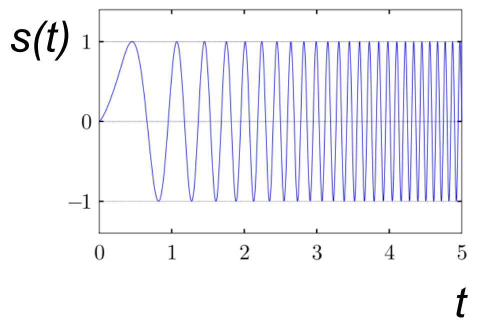
- ARM Cortex-M4 with FPU
- 80MHz system clock
- 64KiB SRAM, 256KiB Flash
- 280nA sleeping current with RTC enabled (Standby Mode, SRAM powered off)

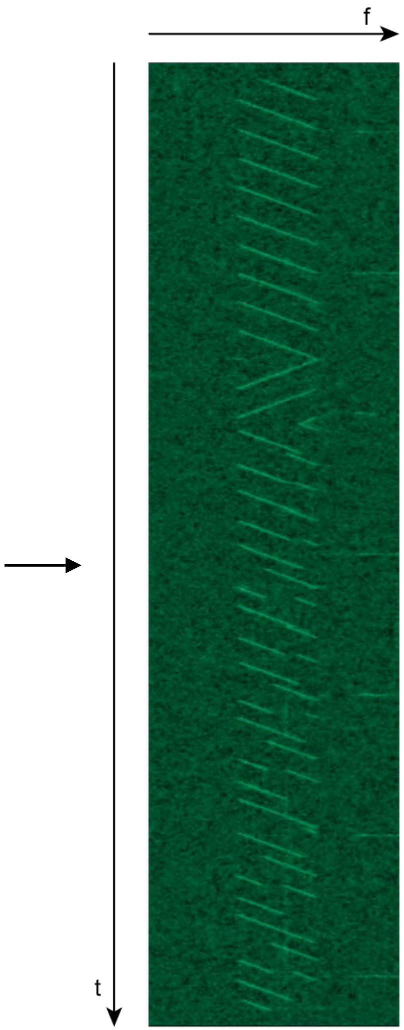
Radio (Semtech SX1262)

- +22 dBm Tx Power for -170 dB link budget
- 4.6 mA Rx current
- Hybrid modem
  - LoRa: max. 62.5 kb/s
  - FSK: max. 300 kb/s
- 12 Mbit/s SPI interface
- 160 nA sleep mode

LoRa PHY

- Supports 433, 868 & 915 MHz SRD/ISM Bands
- Chirp Spread Spectrum (CSS)
  - Period defined by
    - Spreading Factor (SF)
    - Bandwidth
  - SNR ≪ 0
- Built-in forward-error-correction (FEC) and packet engine





SX1262 LoRa

Table 6-1: Range of Spreading Factors (SF)

Spreading Factor (SF)	5	6	7	8	9	10	11	12
2^SF (Chips / Symbol)	32	64	128	256	512	1024	2048	4096
Typical LoRa® Demodulator SNR [dB]	-2.5	-5	-7.5	-10	-12.5	-15	-17.5	-20

A higher spreading factor provides better receiver sensitivity at the expense of longer transmission times (time-on-air).

With a knowledge of the key parameters that can be selected by the user, the LoRa® symbol rate is defined as:

$$Rs = \frac{BW}{2^{SF}}$$

Table 6-2: Signal Bandwidth Setting in LoRa® Mode

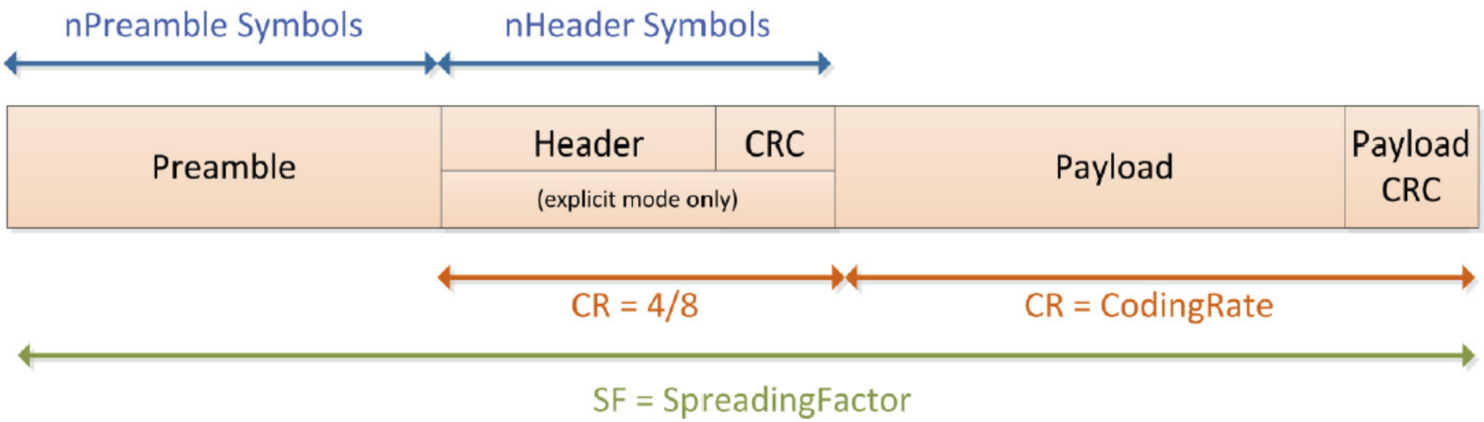
Signal Bandwidth	0	1	2	3	4	5	6	7	8	9
BW_L [kHz]	7.81	10.42	15.63	20.83	31.25	41.67	62.5	125	250 [1]	500 [1]

1. For RF frequencies below 400 MHz, there is a scaling between the frequency and supported BW, some BW may not be available below 400 MHz

SX1262 LoRa

6.1.3 LoRa® Frame

The LoRa® modem employs two types of packet formats: explicit and implicit. The explicit packet includes a short header that contains information about the number of bytes, coding rate and whether a CRC is used in the packet. The packet format is shown in the following figure.



6.1.4 LoRa® Time-on-Air

The packet format for the LoRa® modem is detailed in Figure 6-3: Fixed-Length Packet Format and Figure 6-4: Variable-Length Packet Format. The equation to obtain Time On Air (ToA) is:

$$ToA = \frac{2^{SF}}{BW} * N_{symbol}$$ with:

- *SF*: Spreading Factor (5 to 12)
- *BW*: Bandwidth (in kHz)
- *ToA*: the Time on Air in ms
- N_{symbol}: number of symbols

The computation of the number of symbols differs depending on the parameters of the modulation.

For SF5 and SF6:

$$N_{symbol} = N_{symbol_{preamble}} + 6.25 + 8 + ceil\left(\frac{\max\left(8 * N_{byte_{payload}} + N_{bit_{CRC}} - 4 * SF + N_{symbol_{header}}, 0\right)}{4 * SF}\right) * (CR + 4)$$

For all other SF:

$$N_{symbol} = N_{symbol\_preamble} + 4.25 + 8 + ceil\left(\frac{\max(8*N_{byte\_payload}+N_{bit\_CRC}-4*SF+8+N_{symbol\_header}, 0)}{4*SF}\right) * (CR + 4)$$

For all other SF with Low Data Rate Optimization activated:

$$N_{symbol} = N_{symbol\_preamble} + 4.25 + 8 + ceil\left(\frac{\max(8*N_{byte\_payload}+N_{bit\_CRC}-4*SF+8+N_{symbol\_header}, 0)}{4*(SF-2)}\right) * (CR + 4)$$

With:

- N_bit_CRC = 16 if CRC activated, 0 if not
- N_symbol_header = 20 with explicit header, 0 with implicit header
- CR is 1, 2, 3 or 4 for respective coding rates 4/5, 4/6, 4/7 or 4/8

SX1262 FSK

6.2.1 Modulation Parameter

The FSK modem is able to perform transmission and reception of 2-FSK modulated packets over a range of data rates ranging from 0.6 kbps to 300 kbps. All parameters are set by using the command *SetModulationParams(...)*. This function should be called only after defining the protocol.

The bitrate setting is referenced to the crystal oscillator and provides a precise means of setting the bit rate (or equivalently chip) rate of the radio. In the command *SetModulationParams(...)*, the bitrate is expressed as 32 times the XTAL frequency divided the real bit rate used by the device. The generic formula is:

$$BR = \frac{F_{XOSC}}{BitRate} * 32$$

FSK modulation is performed inside the PLL bandwidth, by changing the fractional divider ratio in the feedback loop of the PLL. The high resolution of the sigma-delta modulator, allows for very narrow frequency deviation. The frequency deviation Fdev is one of the parameters of the function *SetModulationParams(...)* and is expressed as:

$$Fdev = \frac{FdevHz}{FreqStep}$$

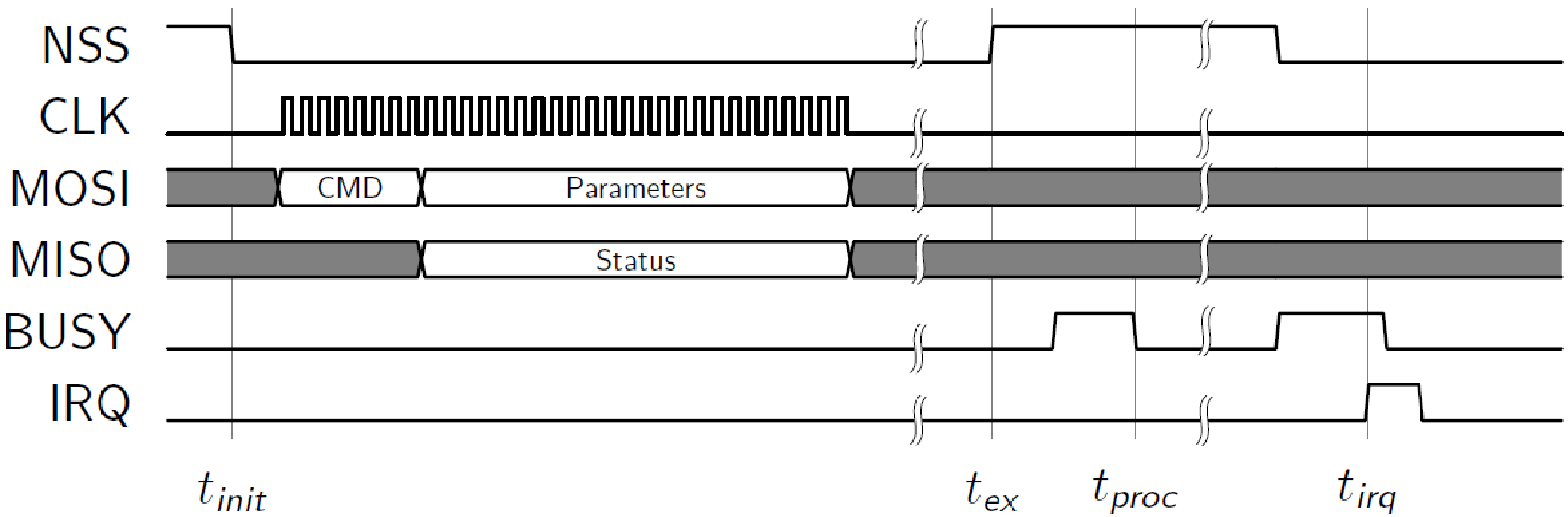
where:

$$FreqStep = \frac{XtalFreq}{2^{25}}$$

Additionally, in transmission mode, several shaping filters can be applied to the signal. In reception mode, the user needs to select the best reception bandwidth depending on its conditions. To ensure correct demodulation, the following limit must be respected for the selection of the bandwidth:

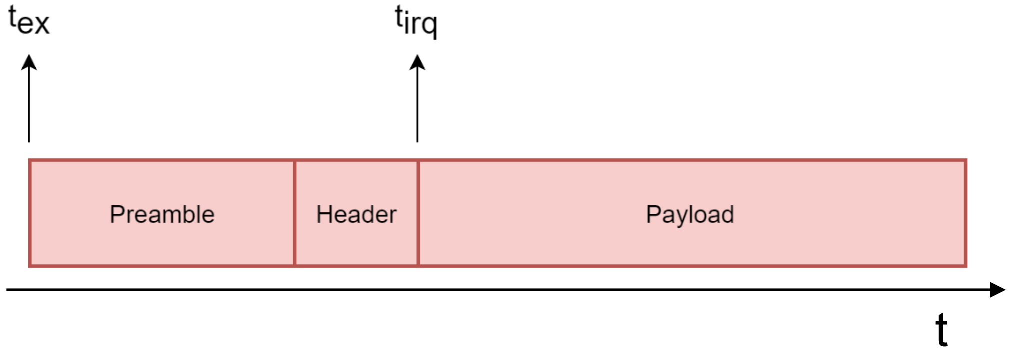
$$(2 * Fdev + BR) < BW$$

Precise Timing of SX1262 commands



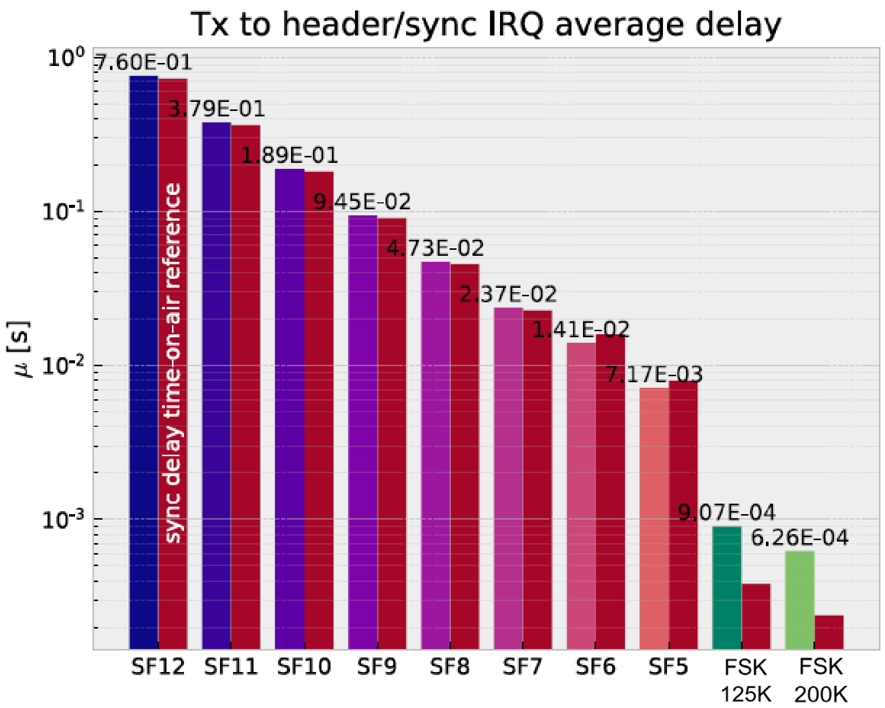
Synchronization

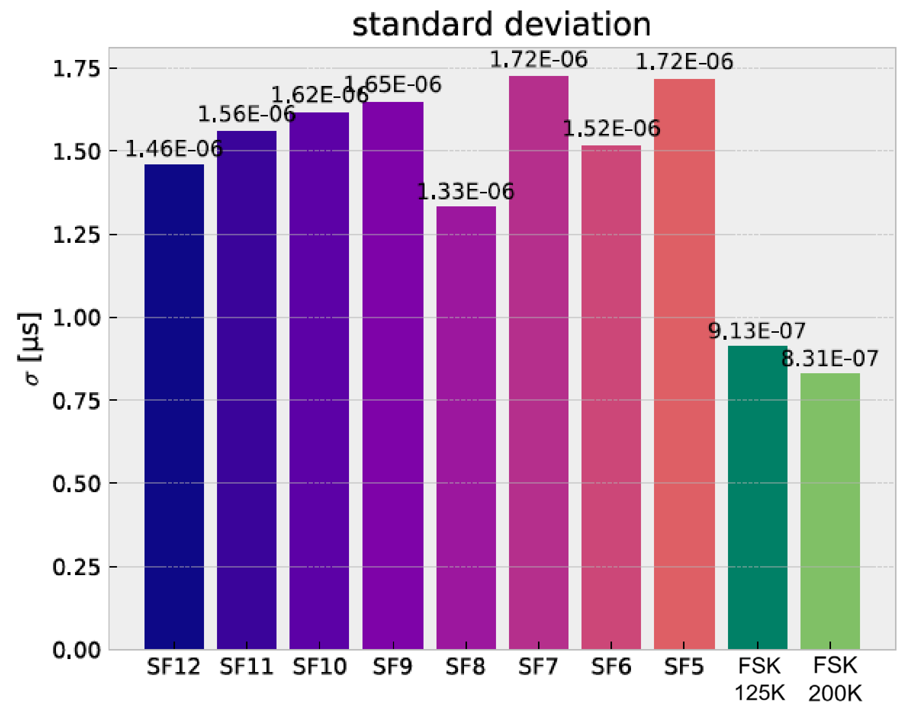
- DevKit A sends message to DevKit B
- Measure time between
  - "SetTx" execution (NSS positive-edge, t_{ex}) on DevKit A
  - "HeaderValid" (LoRa) or "SyncwordDetected" (FSK) IRQ (DIO1 positive-edge, t_{IRQ}) on DevKit B



- Determine accuracy of reconstructing t_{ex} out of t_{IRQ} on DevKit B

Synchronization





- Accuracy largely independent of speed (with the exception of FSK)
- SX1262 allows for sub-microsecond time synchronization schemes (FSK)