Adjustable PWM feature for NRF52xx

We need you to program “Stimulation modes” by adjusting what we will call the “POWER SIGNAL”, “POWER SIGNAL INTERVAL”, “PWR_INTERVAL”, “STIMULATING SIGNAL”, “STIMULATING SIGNAL INTERVAL”, and “STM_INTERVAL” PWM attributes which we have detailed further in this document (see **Figure 1** and **Figure 2** for reference) on the following NRF52xx pins

a. P0.05
b. P0.04
c. P0.26
d. P0.27

The image below shows the logic analyzer data of one of the stimulation modes from the product’s module for 4 PWM Pins of the microcontroller. The objective is to mimic these PWM patterns via NRF52xx PWM pins.

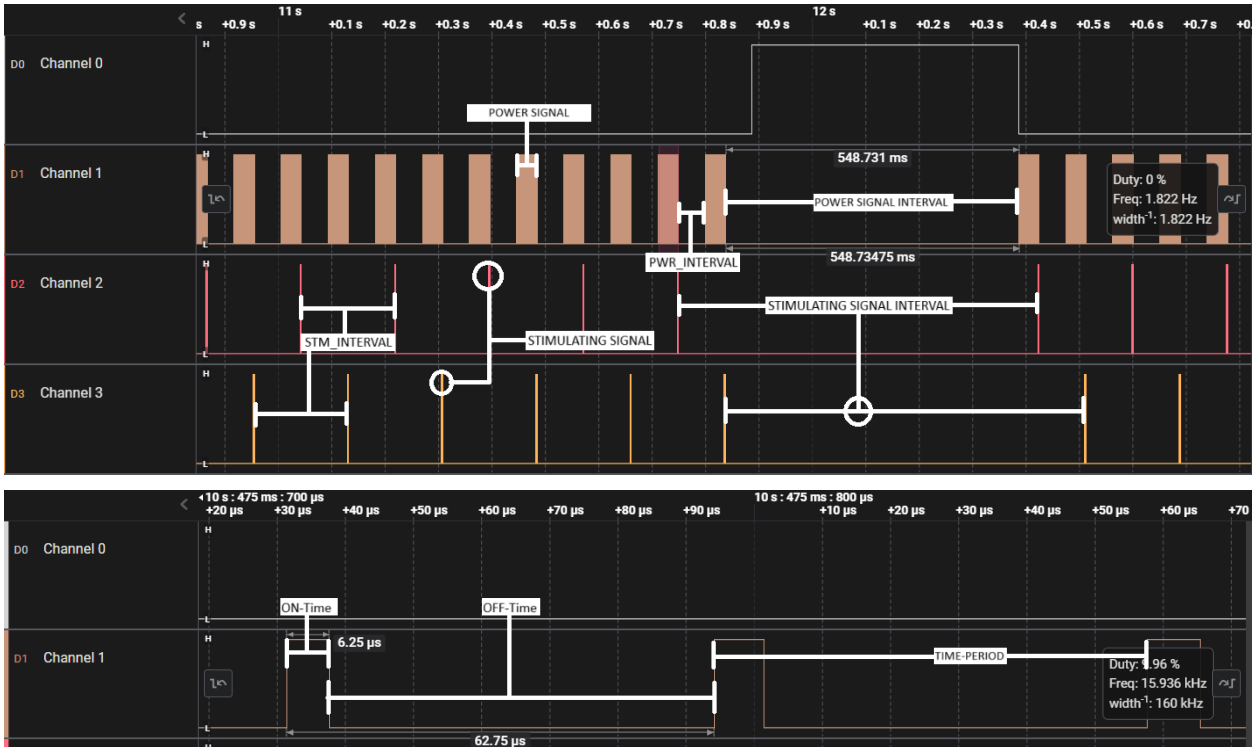


Figure 1 and **Figure 2**: Keyword references for the documentation

Here,
Channel 0 - P0.05 i.e. NRF_BST_CAP/AIN2 (see the Schematic for reference)
Channel 1 - P0.04 i.e. NRF_BST_IND/AIN3 (see the Schematic for reference)
Channel 2 - P0.26 i.e. Electrode 1 PWM (Schematic reference is not provided)
Channel 3 - P0.27 i.e. Electrode 2 PWM (Schematic reference is not provided)

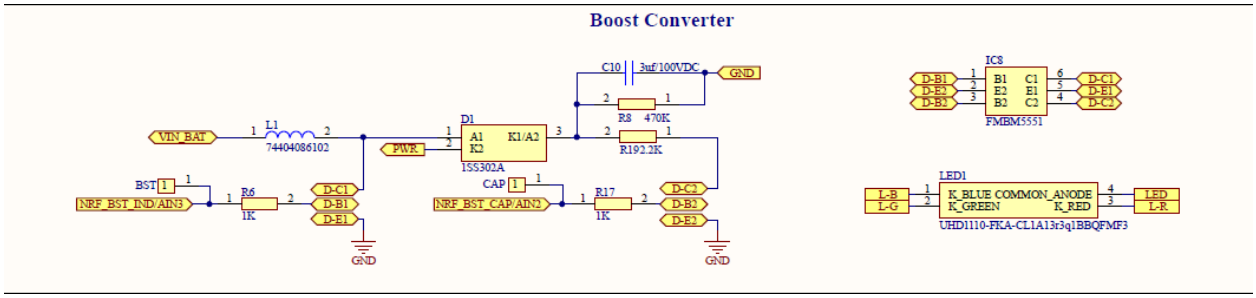


Figure 3: Boost converter schematic reference for pins P0.05 and P0.04

MODES

Let's take the example of the Stimulation pattern in **Mode-1**,

The 4 channels operate at their own individual and different TIME PERIOD/DUTY CYCLE, PWR/STM_INTERVALS and a POWER/STIMULATING SIGNAL INTERVAL which combined form a repeating unit for the pattern. The block of signal that we see in Channel 1 will be referred to as POWER SIGNAL and STIMULATION SIGNAL for both Channel 2 and 3.

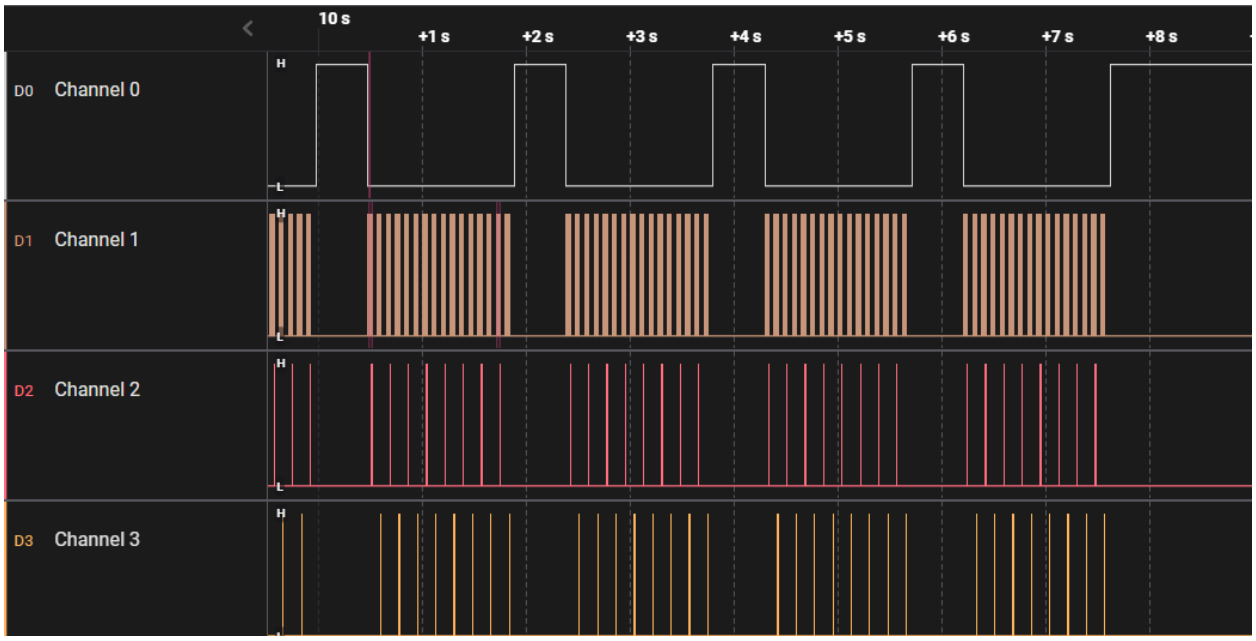


Figure 4: Stimulation Mode-1 Logic analyzer data

In **Figure 4**, By beginning at the 10s mark for Channel 0,

Signal Initialization and Termination settings (all 4 modes)
During initialization and termination of the stimulating modes Channel-1, Channel-2, and Channel-3 are set to the "LOW" state and Channel-0 is set to the "HIGH" state in all the modes.

Now, A close-up view of Channel 0 (**Figure 5**) shows that at the 10-sec mark, the PWM Signal for Channel 0 begins with a "HIGH" state for an "ON-Time" period of 498.7445 ms with Channel 1 and all other channels being at a "LOW" State followed by a **1411.629** ms (as 1910.3735 ms - 498.7445 ms = **1411.629** ms) POWER SIGNAL on Channel 1 for a "LOW/OFF-Time" state on Channel 0.

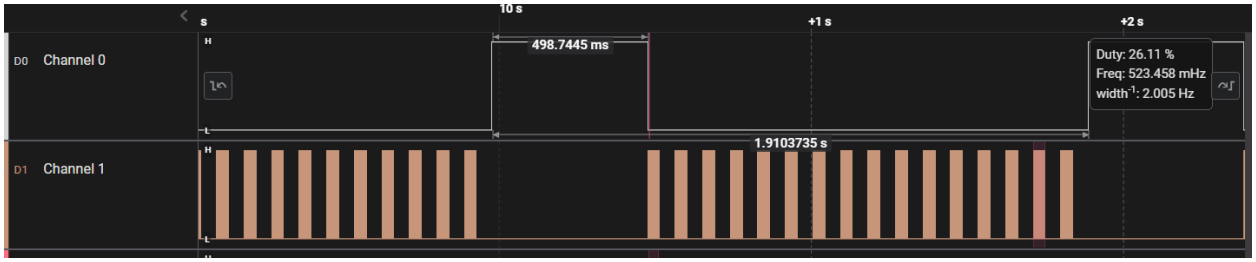


Figure 5: PWM SIGNAL INTERVAL duration in Mode-1

So for every corresponding Channel 0 PWM “OFF-time”, there is a corresponding PWM Signal for the other 3 channels.

POWER SIGNAL Duty Cycle

For channel 1, the First “HIGH/ON-pulse” signal hits once Channel 0 pulls a LOW signal for ~64 ms (TIME PERIOD).

For the POWER SIGNAL on Channel 1, the “ON-time” of the PWM is ~7 ms with a TIME PERIOD of ~64 ms (shown in the image below). Altering these durations of “ON-time” and “TIME PERIOD” will change to elicit a different **stimulation intensity**.

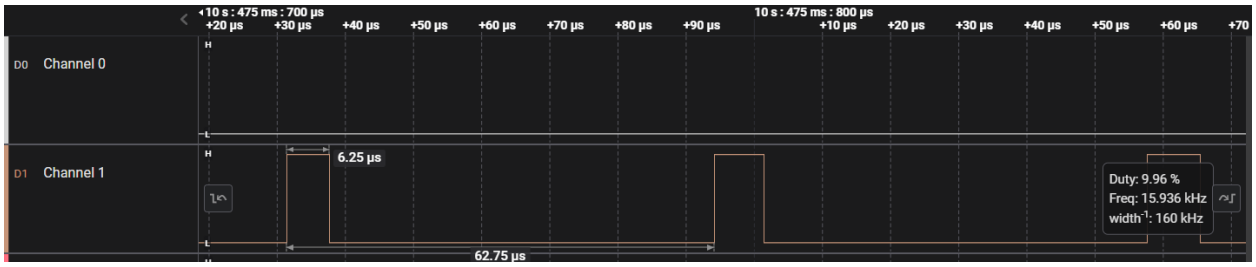


Figure 6: POWER SIGNAL duty cycle in Mode-1

This will then generate the POWER SIGNAL PWM for Channel 1. Each POWER SIGNAL for this channel continues for a duration of ~40 ms followed by a PWR_INTERVAL of ~50 ms (**Figure 8**) in Mode 1. A POWER SIGNAL INTERVAL of ~550 ms is also there between two consecutive POWER SIGNALs (**Figure 7**).

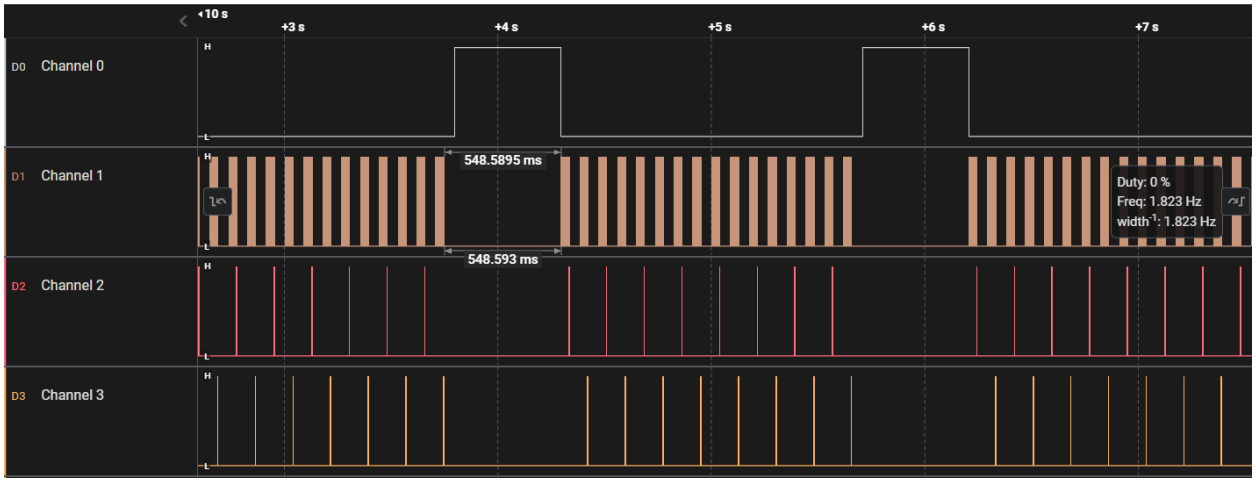


Figure 7: POWER SIGNAL INTERVAL duration between two consecutive POWER SIGNAL in Mode-1

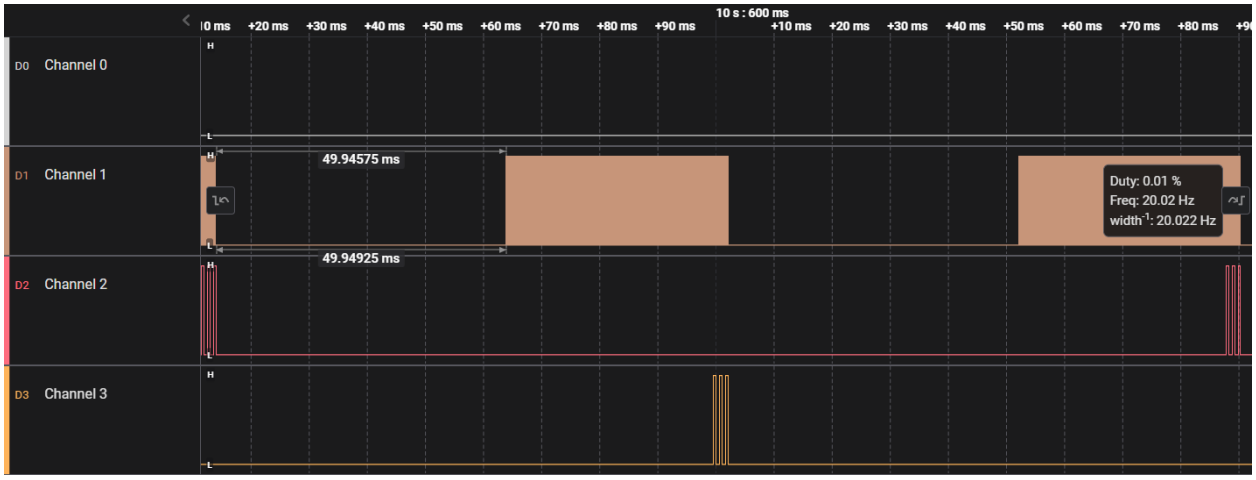
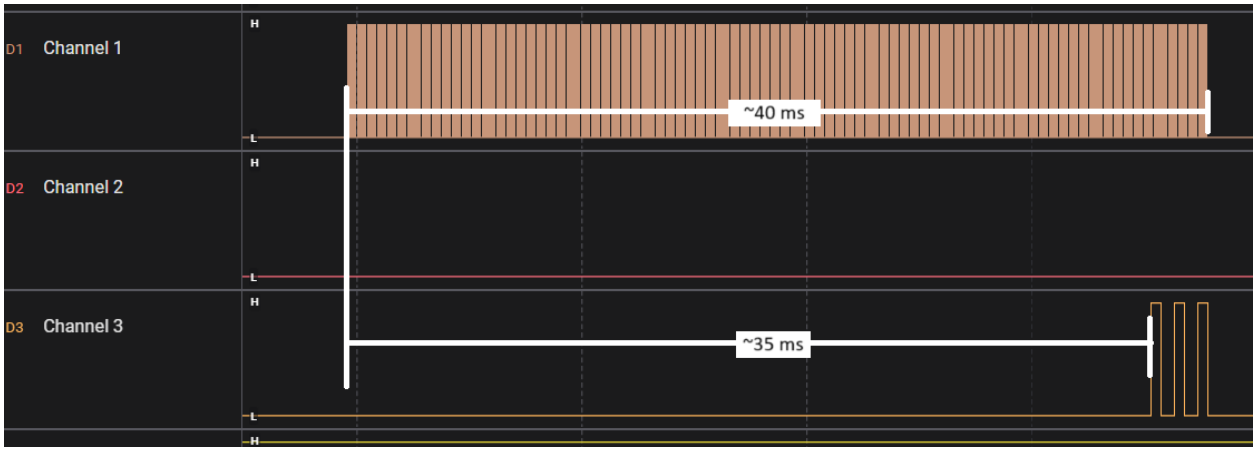


Figure 8: PWR_INTERVAL duration in the POWER SIGNAL in Mode-1

For Channels 2 and 3 there is an **alternating rule** which is followed throughout the POWER SIGNAL in Channel 1.

Like in **Figure 4** for each POWER SIGNAL in Channel 1 if Channel 2 operates, then for the next POWER SIGNAL iteration in Channel 1, the STIMULATING SIGNAL for Channel 3 will be initiated. This pattern is repeated throughout Mode 1 and all the other modes will also follow the same rule.

Specifically in Mode 1, for the case when the POWER SIGNAL is present in Channel 1 a STIMULATING SIGNAL is initiated for Channel 2, and the first HIGH/ON-pulse of the STIMULATING SIGNAL for Channel 2 hits ~35ms after the POWER SIGNAL for Channel 1 is initiated(**Figure 9**).



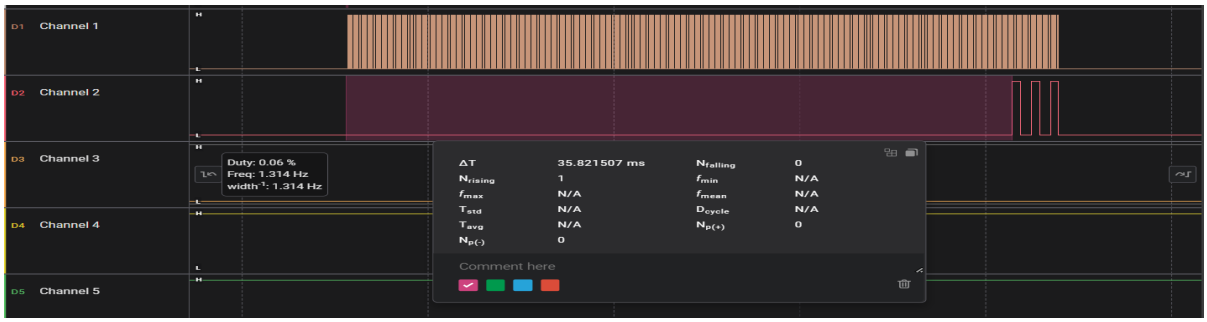


Figure 9 and **Figure 10**: ~40ms POWER SIGNAL duration and ~35ms break duration before Channel 2 starts the STIMULATION SIGNAL during POWER SIGNAL

In the same case, post the PWR_INTERVAL, during the POWER SIGNAL, the same ~35 ms break will cause Channel 3 to operate in place of Channel 2. Thus, completing the alternating cycle and one repeating unit for the combined stimulating cycle.

STIMULATING SIGNAL Duty Cycle

The STIMULATING SIGNAL for Channel 2/ Channel 3 has a TIME PERIOD of 1 ms with an ON-Time of 449.25 microS and has exactly 3 pulses in Mode-1 (**Figure 9**).

The STIMULATING Signal for Channel 3 ends in tandem with Channel 1. These values will remain constant throughout the lifespan of POWER SIGNAL and will decide the type of stimulation in this case Mode 1.

Figure 11: ON-Time and Time-Period reference for STIMULATING SIGNAL on Channel 2 & 3 for Mode-1

Channel 3 is initiated with the same duty cycle as Channel 2*

* This is true for Mode 1, but it can be varied to get different modes with different stimulating duty cycles and the number of pulses in the STIMULATING SIGNAL.