RF Timing Requirements

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Part 1: Generalities

When do we use timing?

When independent equipments have to act synchronously

- kickers, low level RF and BI at injection
- voltage of 200 MHz and 400 MHz cavities during bucket transfer
- ....

The Ring Identifier

- The RF equipments for the two rings are INDEPENDENT. This is also the case for the transfer lines and injection hardware -> **timing events must identify the relevant ring.** This information can not be provided by another control (a command sent before the reception of the timing event) because it must be in the SPS MTG. (The SPS uses different transfer lines for the 2 rings).
- A possible implementation is **a field like the e+/e- cycle type field** in the SPS MTG.
- **Some events should however be unique** (they concern both rings): start of the ramping, preparation for collision.

The Injection Identifier

- Each ring is filled by a minimum of 12 transfers with each transfer filling different LHC buckets.
- No assumption can be made on the sequence of transfers. (Some limits will however come from the kickers).
- Missed transfers will be repeated.
- Some equipment (dampers) may have to react differently for each transfer.

This implies that

- The total duration of filling is not predictable and **a timing based on absolute time is not practical**: We can not say “start ramp at 12:00:34...” because we may still be desperately repeating the first transfer then... **During filling, the LHC must be viewed as a cycling machine** with a cycle locked to the injector chain. Only after filling does the LHC loose its cyclic nature.
- **The events used during filling should identify the injection index** (inj1, inj2, ..., inj12). A possible implementation is to use a table, programmed before the begining of the fill, defining the correspondance between injection index and actual LHC bucket number. After each injection, a decision is taken concerning the next injection and the event with the corresponding index is inserted into the LHC timing of the next cycle.

Events at a given energy

- In some cases, a timing would best be generated **when the ramp reaches a defined energy level** (emittance blow-up for example).

Part 2: RF operations through the cycle

Preparing the RF before filling.

- Low level

  Synchronism between independent equipments is not always required here but the sequence below acts on switches that are later piloted by the timing.

  - preset the frequency program to the injection frequency (value of frequency program during filling) [function]
  - set the gain of the phase loop amplifier to the filling value [function]
  - set the gain and time constant of the synchronisation loop amplifier to the filling value [function]
  - close the phase loop around the vco (freq prgm/vco) [timing]
  - switch the RF DRIVE ON [timing]
  - switch the phase loop to the cavity sum signal (freq prgm/cavity sum) [timing]
  - reset the revolution frequency generator [timing]. (This must be followed by a reset of the TTC transmission).

- The 200 MHz system, 400 MHz system and transverse damper are mainly controlled by commands

Filling: On the first injection in a given ring

- Low level
  - switch the phase loop onto the beam (beam/cavity sum) [timing]
  - switch synchro loop on (either freq prgm/beam or freq prgm/cavity sum or freq prgm/vco) [timing]

Filling: On all injections (including the first one in a given ring)

- Low level
  - before each injection, update the bucket selector (common freq. sent to SPS) and the phase of the 400 MHz sent to the SPS. We need a timing (with a field) identifying the bucket. The identification of the ring (ring number) must also be in the timing [timing]
  - generate injection pulses for the kickers [timing]
  - generate injection pulses for BI [timing]
- 200 MHz cavities
  - resynchronise the divider that provides the gating of the long. feedback input/output to act on the incoming batch only [timing]
  - raise the gain of the longitudinal feedback [timing]
  - some time after injection (after damping of transient) reduce the gain of the feedback progressively (to avoid injecting RF phase noise) [function]

- Transverse damper

  (Probably similar to the longitudinal damper.)

  - resynchronize the divider that provides the gating of the feedback input/output to act on the incoming batch only [timing]
  - raise the gain of the feedback [timing]
  - some time after injection (after damping of transient) reduce the gain of the feedback progressively (to avoid blowing up the emittance) [function]

Ring filled, before ramping

Transfer the bunches from the 200 MHz bucket into the 400 MHz bucket. Measure the longitudinal emittance and readjust the voltage functions for the ramp.

- 200 MHz cavities
  - start a voltage reduction with a voltage function [function]
  - park the cavities in passive damping (or detuned) [command or timing]
- 400 MHz cavities
  - start a voltage increase with a voltage function [function]
  - change coupler and tuner offset to ramp position [command or timing]

- Transverse damper
  - re-scale the analog front end (change gain) to cover the full ADC range. Reduce analog output gain accordingly. [command and timing and function]

Ramping

- Low level
  - start the function giving the value of the energy to the frequency program [function]
  - enable the frequency program output to the synthesiser [timing]
  - switch radial loop on (For commissioning only. In operation we remain on the synchro loop) [timing]
  - vary the gain of the phase loop amplifier during the ramp [function]
  - vary the gain and time constant of the synchronisation loop amplifier during the ramp [function]
- 400 MHz system (eventually 200 MHz also)
  - voltage function through the ramp [function]
- Transverse feedback
  - gain function through the ramp [function]
  - on request from BI: change gain for a while, switch damper off, excitation, ...[timing, command and function]

At some energy during the ramp 1. Emittance blow-up

- 400 MHz
  - emittance blow-up (1 eVs to 2.5 eVs) at a chosen energy (1 TeV?) [timing and function]

At some energy during the ramp 2. Reduce bunch length

- 400 MHz (eventually 200 MHz also)
  - raise the voltage to the maximum [function]

At top energy before colliding 1. Re-phasing

- Low level
  - set the gain of the phase loop amplifier for re-phasing [function]
  - set the gain and time constant of the synchronisation loop amplifier for re-phasing [function]
  - switch the reference of the synchronisation loop to re-phasing [timing]
- 400 MHz
  - set the voltage to the value for re-phasing [function]

At top energy before colliding 2. Adjust collision point, reduce noise sources

- Low level
  - set the gain of the phase loop amplifier to the value for low noise [function]
  - set the gain and time constant of the synchronisation loop amplifier to the values for low noise [function]
  - adjust the collision point by phasing the two rings [trim]
- Transverse damper
  - adjust the gains to the values for low noise [function]
  - switch revolution frequency and RF references to common one for the two rings [timing or command]

Physics

- 400 MHz
  - trim the 400 MHz voltage to improve lifetime [trim]
- Transverse damper
  - trim the gain value to improve lifetime [trim]

Dumping the beam

Some action must be token on the power amplifiers to avoid an over-current when the beam is dumped (strong RF feedback and heavy beam loading).

Ramping down

Power saving actions on the power amplifiers.