PREINJECTOR GUN UPGRADE, TIMING AND SYNCHRONIZATION AND PREPARATION FOR THE TOP-UP INJECTION IN ELETTRA

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Abstract

Elettra is the third generation light source in operation in Trieste since 1993, upgraded with a full energy booster injector last year. Top-up operation is on schedule in the near future but already the new timing system and gun are ready to operate in this mode. The paper describes all tasks and requirements needed to satisfy top-up injection including custom made hardware, interaction with controls and radiation protection system.

REQUIREMENTS FOR TOP-UP

The following requirements are to be satisfied for Top-Up operations:

- Shot to shot intensity difference better than 5%;
- High Injection efficiency >=80%;
- Maximum injected charge 0.2 nC (1mA =0.864nC for the storage ring);
- Booster operation with maximum 0.2 mA current at 3 Hz;
- Operation in multibunch single bunch or few bunch mode;
- Injection top up software latency less than 200 mSec;
- Real time operating system for Top up CUP supervisor.

General Layout and Timing Elements

The timing system is essential to synchronize all injection pulse magnets, ramping magnets, beam diagnostics and injection programmed patterns of electrons in Elettra.

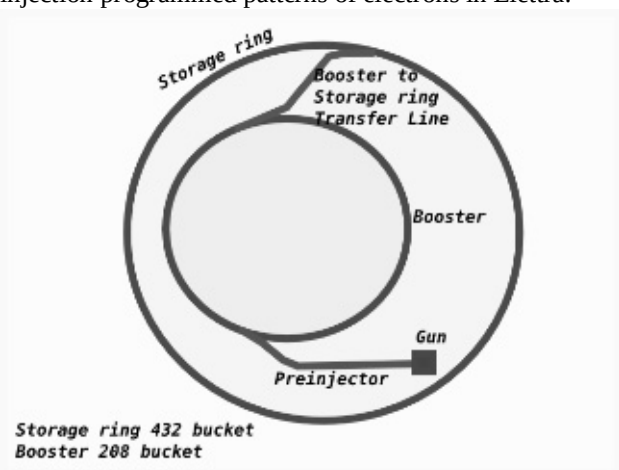

Figure 1: Elettra and pre-injector layout.

A general purpose VME Programmable Delay [PDELAY] [3] was developed for this application under the following specification.

Table 1: Delay Classification.

Delay type	Range	Max jitter
General	20 ns to 160 ms	<=5 ns
Medium	20 ns to 160 ms	<= 2 ns
High Precision	2 to 128 us	<=200 ps
Cascade	40 ns to 320 ms	<=5 ns

- Output delay can be Optical or electrical
- 3 types of optical drives can be mounted to achieve the requested jitter
- Input can be Optical or Electrical.
- 500 MHz master reference is needed for PDELAY that use High Precision output

The main timing Unit VME CRATE is located in the Pre-injector area, from there all main synchronization signals are generated;

The first PDELAY produce the COINCIDENCE trigger; its harmonic number is 4752 or 9504 ns being the lowest common denominator of the harmonics number of Booster (198) [2]and Elettra (432);

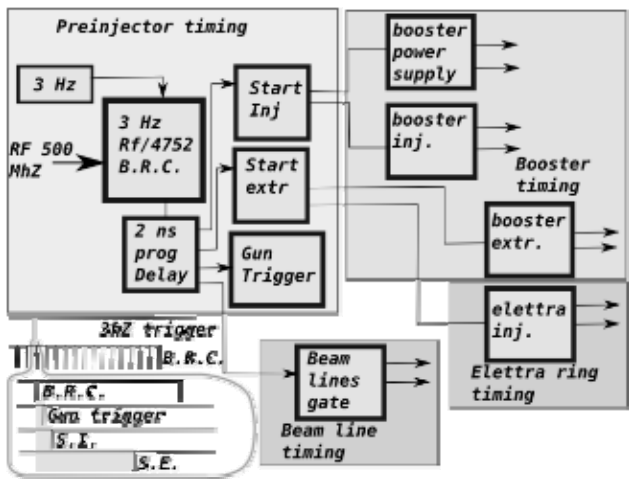

Figure 2: Timing. Schematic block diagram.

This trigger is called BRC and has a frequency of 0,105218 MHz

Delaying this signal in 2 ns steps a programmable trigger can be produced that point each one of 432 bucket in Elettra, called GUN trigger;

From the GUN two other main signals are produced;

Start Injection (S.I.) and Start Extraction (S.E.) that is the main branches trigger to inject in booster and extract from it. All others triggers are produced in cascade from those; Disabling S.E. all trigger related to extraction from booster and injection in Elettra are disabled.

Disabling S.I. all trigger related to injection in booster are disabled.

GUN BOARD

Design of Gun board was done considering the possibility of operating in single or multi bunch with pulse length from 8 ns to 200 ns.

Regulation of the intensity of the gun is also possible; Fast gun inhibit is supported from various sources of the interlock coming from the access control, radiation control and vacuum interlocks;

The PIC16F688 microprocessor locally controls this board sending and receiving signal through an optical serial line; this board operates at high negative voltage in floating mode;

A commercial CRT triple monolithic driver designed for high-resolution colour monitor applications was used in the final stage for multi bunch driving;

The device operates with a 80V and 12V power supplies and features a 400 MHz, cascade output stage capable of driving 40pF, 40 V p-p swing at a maximum rise / fall time of 3.1 ns. A stock of spare parts of this driver was bought due to the fast market transition from CRT to LCD monitor;

Single bunch stage was designed using a tricky and unspecified characteristic of some transistor that can operate in avalanche [4] region having rise and fall time in the order of nanosecond and high output voltage and current.

A push-pull avalanche output stage was designed and produces a fast pulse with rise time better of 600ps and fall time less than 1 ns with amplitude higher than 150 Volts; This extreme driving voltage compensates the relative low bandwidth of GUN emitting valve triode.

Stress test was done on this circuit using high repetition rate (10 kHz) and high voltage 500 Volts to reproduce an equivalent of 20 years of operation without observing any performance degradation;

A measured single bunch pulse length of electron beam at the end of preinjector was <=1 ns; modulation of intensity and pulse length at 3 Hz shot-by-shot is also possible

Fast Current Transformer

In the next programmed shutdown of Elettra in June, a Fast Current Transformer will be installed in the storage ring; essentially it is a wideband AC transformer with a rise time down to 300 ps and a bandwidth up to 2GHz.

Using a fast analog-to-digital converter, sampling and averaging the current for many turns, it is expected to obtain for each bunch an intensity measure with a precision of about 5% in less than 100 ms. The intensity of each bunch will be stored in a data array and will be processed by a real time Top-up CPU that reads also the integrated current of the storage ring;

This CPU calculates the filling patter for the next injection;

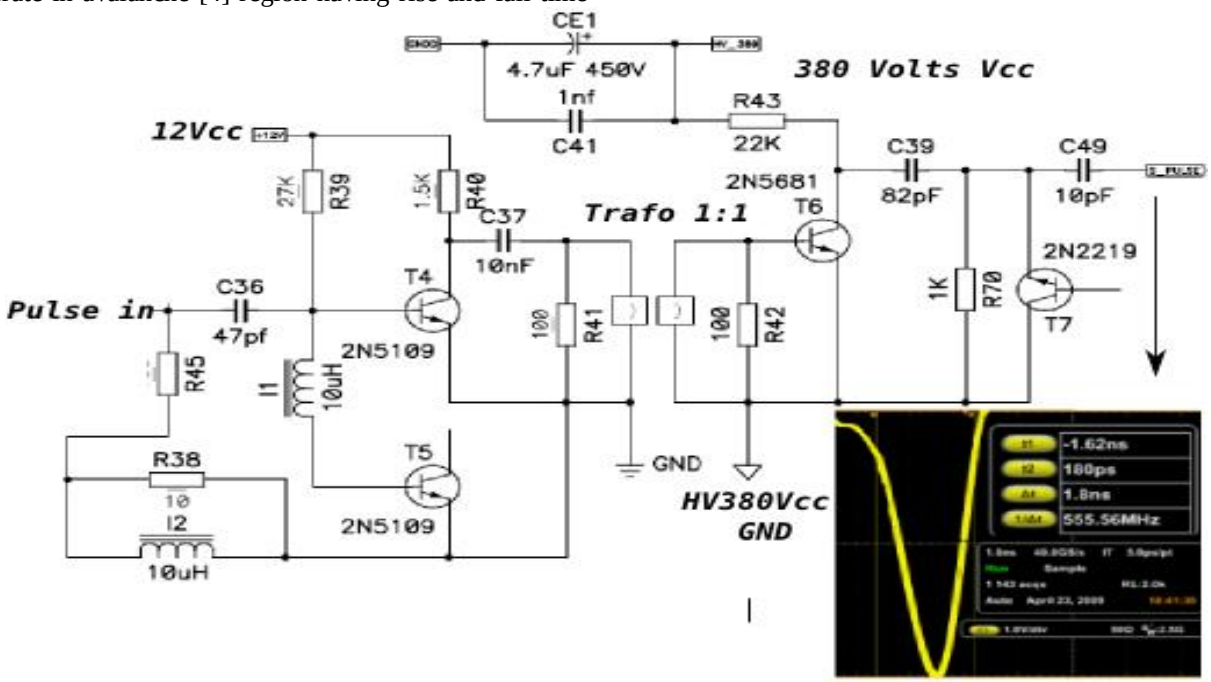

Figure 3: Schematic of single bunch pulse generator - this circuit generates an ultra short negative pulse <1.8 ns and amplitude >120 Volts with few cheap components; To obtain similar pulses from a commercial generator a very big budget is needed.

Control and High Level Software

High level software supervises the top-up and its principal task is to control the preinjector, the booster and the injection in Elettra;

Requirements to be satisfied before entering in top-up mode are:

- Energy matching between booster, transfer line and storage ring.
- Current threshold for storage ring current
- User ID in operation
- Efficiency injection in booster

During top-up the software controls the storage ring intensity and when is lower than the programmed threshold enables the Gun and the injection elements in Elettra; Using the array of stored current value for each bucket an algorithm decides in which bucket number and how much current will be injected; the software also decides how long to maintain the GUN on and in case to switch in single bunch mode to fill a specific bunch;
Hybrid filling with mixed single and multi bunch injection is also possible.

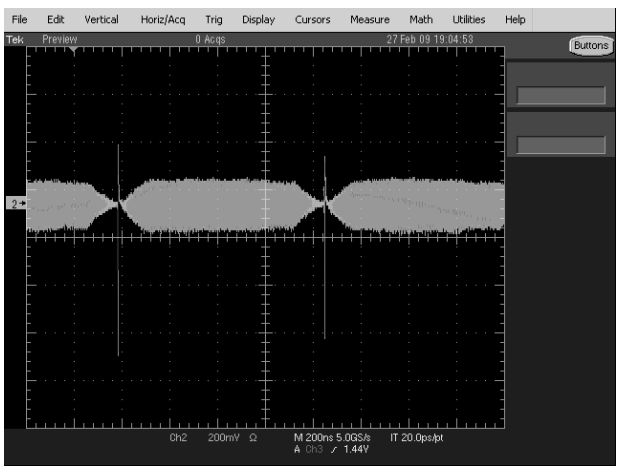

Figure 4 : Hybrid filling in Elettra.

Interlock and Radio Protection System

At present Elettra in not yet ready for top-up operation but studies and tests of all equipments with the beam line shutters closed can be made.

The interlock system will provide safety during operation in top-up mode; the top-up PLC supervisor checks the injection cycles ensuring that the transport efficiency is over the specified limit;

Table 2: Safety operating parameter for top-up.

	Typical	Max	Min
Top-up current per shot	150pC	200pC	20pC
Repetition rate	3 Hz	1Hz	3Hz
Transport Efficiency	85 %*	100%*	60%*
Working energy	2 GeV	2.5 GeV	0.9 GeV

* To be defined after some radiation survey measure

When some of the above conditions are lost or some fault occurs the interlock system will disable the top-up mode and the operator must identify the problem; If the beam is lost or the intensity is much lower that the minimum specified the refill will be performed in the non-top-up mode i.e. shutters closed and Ids open.
Accelerator Physics time is allocated to measure the radiation levels also in the beam lines during top-up; this will define the minimum transport efficiency tolerated between booster and storage ring in order to perform a safe injection with the beam line shutters open.

CONCLUSIONS

Elettra is expected soon to operate in top-up mode provided that all equipment will be installed and all necessary interlock and radioprotection tests will be performed; Preliminary tests [1] are already done with good results for the short term (up to 12 hours) injection stability and transport efficiency; more intensive tests are programmed to study the long term top-up mode operation stability once all system will be installed.

REFERENCES

[1] E. Karantzoulis, A. Carniel, S. Krecic, Elettra, Trieste, Italy “Operational Advances at Elettra and its New Full Energy Injector” these Proceedings
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[3] S. Bassanese, A.Carniel, R.De Monte, M.Ferianis, G.Gaio; EPAC 08 Genova Italy; “Timing System of the new Elettra Injector”
[4] ZETEX application Note 8 Issue 2 Jan 1996; “The ZTX415 Avalanche mode transistor”