Minutes of LHC-CP Link Meeting 6

Subject : LHC Controls Project

Date : 16:00 7th November 2000

Place : 936 Conference Room

Participants :

Billen, R		SL-MR
Brahy, J		LHC-IAS
Carlier, E		SL-BT
Ciapala, E		SL-HRF
Di Maio, F		PS-CO
Epting, U		ST-MO
Gavaggio, R		LHC-VAC
Gayet, P		LHC-ACR
Gras, JJ		SL-BI
Heinze, W		PS-CO
Jonker, M		SL-CO
King, Q	(Secretary)	SL-PO
Lamont, M		SL-OP
Lauckner, R	(Chairman)	SL-DI
Rodriguez Mateos, F		LHC-ICP
Vanden Eynden, M		SL-CO
Wolf, R		LHC-MMS

Excused :

Bruning, O	SL-AP
Martel, P	EST-ISS

Absent :

Pezzetti, M	LHC-ECR
De Rijk, G	SL-MS
Schmidt, R	AC-TCP
Walckiers, L	LHC-MTA

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Agenda :

1. Minutes from previous meeting	
2. Controls News	R. Lauckner
3. Industrial Components : Review and Proposal	P. Gayet
4. SL/PO: Function Generators	Q. King
5. AOB	

1. Minutes from Previous Meeting

There were no comments on the minutes from meeting 5.

2. Controls News — R. Lauckner

The chairman reported that core team member Mike Lamont had presented the real-time requirements for LHC control to the LHC-CP steering committee (SLTC):

http://lamontm.home.cern.ch/lamontm/lawg/subsytem/subsystem.htm

They approved the creation of a real-time control system and agreed that a real-time working group be set up as an LHC-CP sub-project. This is in progress with Pedro Ribeiro as the prospective chairman.

Following the presentation by Thomas Pettersson at the last LHC-CP meeting, Marc Vanden Eynden has investigated the use of EDMS to manage documents generated by the LHC-CP. He has had discussions with Johannes Muller of EST-ISS about the creation of a new EDMS workspace. Marc noted the following points:

1. We need to propose an effective hierarchy in advance as it is not very easy to change once the workspace is in use.
2. We need to define template documents. Marc has looked at LHC templates and Atlas templates for technical proposals and technical design reports. They provide little more than a front page and style definitions. Marc asked if LHC-CP templates should go further to support the structure of the document contents.
3. EDMS provides a document approval system. LHC-CP needs to decide what level of approval system it needs for the documents in its workspace.

It was noted that several groups represented within the LHC-CP already use EDMS and can bring valuable experience to the development of the LHC-CP workspace. A useful step will be to include good example documents, taken from member groups, which can act as templates both for style and content.

3. Industrial Components : Review and Proposal — P. Gayet

Phillipe Gayet presented the status of work on industrial components, following the related session at the first LHC-CP workshop (see the attached slides).

This focused on three main categories of components:

1. Fieldbuses
2. PLCs
3. SCADAs

Fieldbuses are the subject of a controls board recommendation, which has identified Profibus, WorldFIP and CAN as the three technologies to be used in LHC. Profibus will be widely used with PLC solutions, especially those from Siemens. WorldFIP will be used for time critical applications such as magnet current control, and CAN is of particular interest to the experiments but is not foreseen in the LHC control system. It is felts that there are still open questions related to the control board recommendation, for example, the role of ethernet as a potential fieldbus. There is also the issue of long term support which may be more efficiently addressed collectively rather than by individual groups or projects.

PLCs are also the subject of a controls board recommendation, with Siemens and Schneider named as acceptable suppliers.

There is a recommendation on its way for SCADAs for LHC. This remains a complex issue, with guidelines needed on the integration of SCADAs into the LHC controls infrastructure.

There is now a list of projects which will use industrial components, and information about each project has been compiled, including milestones. However, many questions remain and to a great extent, work by different groups is proceeding without co-ordination.

For this reason, Phillipe presented a proposal for a Working Group on Industrial Components. It would aim to draw together the different groups involved to the benefit of all. Issues such as technologies, specifications, configuration management, naming, support and training can be approached collectively. The new working group would integrate with many existing working groups and would be careful not to duplicate work already undertaken elsewhere.

In the following discussion it was noted that the relationship between the LHC middleware and SCADAs will be very significant for the software applications. Frank Di Maio explained that in PS there are a number of PLCs being used in Isolde, and there will be studies on SCADAs, although nothing is in operation at the moment.

4. Presentation: SL/PO Function generators Q. King

The chairman introduced the subject of function generators by stating that they are vital for beam operation and that there should be only one standard "motor" for ramping. He also noted that function generation is intimately linked with the subject of synchronisation and events.

Quentin King then presented the SL/PO/CC digital controller. As well as slides, a prototype controller was shown to the group and a brief demonstration of the simulated operation of a 13kA power converter was provided. Real test results were then displayed using Matlab. These are available online from:

http://proj-lhc-mccs-private.web.cern.ch/proj-lhc-mccs-private/Pages/Specialist/TestReports/TestIndex.htm

Finally, there was a very brief introduction to the project web site: http://cern.ch/mccs

The SL/PO/CC approach to the control of power converters for LHC is an evolution of the approached successfully used for LEP. This involves a separate embedded controller for every power converter, linked by a fieldbus to a gateway system, which is connected to the accelerator network. Like LEP, the LHC controller has an ASCII based interface, which allows interaction with the system via nothing more than a dumb terminal.

Quentin initially presented an overview of the MCCS, which will control more than 1700 power converters using about 80 gateway systems. The group was then taken on a quick tour of the prototype hardware, which comprises four computer cards linked by a back-plane. The final hardware for LHC will probably have two cards, or maybe even only one.

The main features of the Digital Controller hardware are:

- Twin processors with more than 0.5MB of RAM between them.
- WorldFIP fieldbus interface (2.5 Mbs).
- RS232 serial interface (9600 baud).
- Four channel 32 bit test data interface (1 kHz).

- Two analogue input channels with either 16 bit or 22 bit performance (4 kHz).
- Single 20 bit DAC analogue output (1 kHz).
- 8 direct digital command output channels (200 Hz).
- 16 direct digital status input channels (200 Hz).
- 720 serialised digital status inputs channels (50 Hz).
- 120 serialised analogue (12 bit) input channels (50 Hz).
- Twin hardware watchdogs.

Next, the subject of reference generation was introduced. A power converter is a voltage source and the digital controller can operate in either open loop (voltage mode) or closed loop (current mode). The units of the reference will be volts or amps accordingly.

Every controller receives a 32 bit value every 10 ms when connected to the WorldFIP fieldbus. This 100 Hz real-time data channel is provided to support beam feedback applications such as tune and orbit control.

The reference can either be a preloaded function, or the real-time data channel value, or a combination of the two. A preloaded function will be "generated" at 1 kHz, while the real-time data channel will run at no more than 100 Hz.

A preloaded reference function will move the reference from its initial value to a final value, which is then held over to become the initial value of the next preloaded function.

Several types of predefined function have already been implemented in the digital controller, include sine, cosine, square wave and PELP. PELP is the form of the baseline energy ramp for LHC which combines parabolic acceleration, exponential acceleration, linear ramp and parabolic deceleration. It is a good function for magnet testing but cannot be used for LHC circuits because of the non-linear calibration between field and current.

It is safe to assume that for LHC, functions will be defined as tables of current against time, and there needs to be a decision about how to link the points.

Linear interpolation is simple, well understood, but has a discontinuous first derivative and may require large numbers of points to ensure accuracy.

Higher order interpolation methods (c-splines, b-splines etc…) were mentioned, and in particular, it was noted that c-splines (cubic splines) are probably not suitable because they impose a point of inflexion, or even overshoot or undershoot.

(Note that there is now a proposal for linear interpolation which can be down loaded from http://proj-lhc-mccs-private.web.cern.ch/proj-lhc-mccs-private/Doc/funcgen_prop.doc)

Following the demonstration and display of test results and the web site, there were a number of questions:

Q: Does the system need the 2.5 Mbs WorldFIP link (rather than 1 Mbs)?

A: Yes, given the 10 ms cycle time and the limit of 30 digital controller per bus. The periodic traffic of a fully populated bus would require 6 ms of every 10 ms. To use a 1 Mbs fieldbus, the cycle time would have to increase to 30 ms or longer.

Q: Is everything 1 kHz based?

A: Not exactly. The analogue data acquisition runs at 4 kHz, but this is filtered down to the lower frequencies of 1 kHz and 100 Hz. The DAC output is written at 1 kHz, and this is the main system frequency. The RST feedback algorithm actually runs at 10 ms intervals or multiples of 10 ms.

Q: Is the data acquisition serial?

A: Yes. The ADCs are based on Sigma Delta techniques, which produce a bit stream at either 500 kHz (for internal 16 bit ADCs) or 1 MHz (for external 22 bit ADCs). To use the data, a digital filter is required, and this runs at 4 kHz. The link from external ADCs uses optical fibre, which provides isolation.

Q: Does the serial diagnostic data acquisition use a standard bus like I^2C?

A: No, it is based on an in house development using the Queued Serial Module component of the HC16 microcontroller. This can read up to 256 bits serially without requiring intervention from the CPU.

Q: How does it connect to the timing system?

A: Via the WorldFIP which is, by design, a deterministic fieldbus. Every 10 ms cycle starts with the broadcast of a time packet. The contents provide the absolute time, and the time of arrival is synchronised to GPS time in the Gateway to better than 7μs. This enables the digital controller to disciple its local clock to within about 1 part in 10^7 compared to GPS time. At the moment events (like start of ramp) are defined with absolute time, however, events could be included in the time packet with a granularity of 10 ms.

Q: How much does it cost?

A: The final design is expected to use only two, and possibly 1 board, which will make it cheaper than the 4 card prototype. It is hoped to be between 1000 and 2000SF, excluding the external high precision ADCs (which will be needed for less than 100 circuits).

Q: How are functions defined and used in LEP?

A: Mike Lamont will explain at a future LHC-CP meeting.

5. AOB

None.

Actions	**People**
Establish Real-time and Components sub-projects.	R Lauckner
Set up the LHC Controls Engineering data tree in EDMS	M. Vanden Eynden
Complete planning questionnaire for all LHC controls related sub-projects with a group	All LHC-CP linkmen

Industrial Components

Evolution since Workshop

What remains to do?

objectives?

Last Workshop agenda

- What are the common industrial components?
- What are the applications and their milestones?
- What is required to integrate these systems to the general control systems?
- How should support be organized?
- Are the services set up by the Control Board sufficient - advice, purchasing, training?

Industrial Components (What's IN?)

- Fieldbuses *(Control Board recommendation)*
  - CAN, WorldFIP, PROFIBUS
- PLCs *(Control Board recommendation)*
  - SIEMENS, Schneider
- SCADAs *(Control Board recommendation to be issued)*
- Ethernet *(Working Group)*

Field Bus

- Starting developments based on CAN have to be avoided for accelerator equipment control unless no solutions are available with PROFIBUS and WorldFIP.
- The recommendation for the use of fieldbuses has to be reviewed in order to integrate the actuator and sensors bus.
- no Can development since
- Reactivation of the Fieldbus working group with 3 main topics
  - Ethernet as field network
  - Fieldbus foundation as alter ego of profibus PA but for WorldFip
  - Recommendation for support

Field Bus

- The distribution of machine timing events and absolute time is actually only available on WorldFIP.
- The necessity to provide this kind of facilities on PROFIBUS has to be evaluated before starting development. Nevertheless the time stamping issue for data archiving from PLC through PROFIBUS has to be solved.
- Progressing development of an IRIG-B card for Schneider PLC in collaboration with Schneider
  - (contact R. BRUN)
- New work from Jacky Brahy on the subject

PLC's

- A cursus on PLC programming as been set up by LHC-IAS, it includes a training on methodology.

SCADA

- Strong guidelines for the integration of the SCADA system in the LHC control architecture have to be issued during the next twelve months in order to avoid divergence.
- Recommendation on its way to choose one Scada but still nothing about integration to the LHC control environment (probably from middleware WG)

Identified Applications/Milestones

- **SL-BT, 2001 MKP (1/10)**
  - Siemens PLC,Profibus,Scada
- **SL-RF, 2002**
  - Schneider PLC, Worldfip, Ethernet,
- **LHC-ACR/ECR 2001**
  - Schneider PLC, Worldfip, Ethernet, Profibus, PCVue
- **LHC-VAC 2002**
  - Siemens PLC, Profibus, Ethernet, SCADA??
- **ST-CV 2001**
  - Siemens Schneider PLC, Profibus, Wizcon
- **.... to be extended..**

Integration

- **Architecture :**
  - Multi- layers PLCs and fieldbuses architecture,
  - At one moment a connection to an Ethernet network exist,
  - Access to the equipment is done through a SCADA.
- **Same Communication requirements**
  - Horizontal: distributed around the machine at the field/ automation level
  - Vertical: high level machine operation to field /automation level
  - Based on local and/ or distributed SCADA system, and/ or on front- end server

Integration ?

- **Three different approaches:**
  - Turn- key DCS or integrated Scada/PLC
  - Partially subcontracted: sub- system and/ or specific functionality subcontracted to industry, integration stays behind CERN responsibility
  - Home made: development and integration completely behind CERN responsibility
- **As many approaches as team (technical architecture/ project management)**
  - How to integrate *homogeneously* those different approaches in the LHC control architecture?
- **A lot of basic technical choices have been already done and those choices are tightly link with the industry standards.**

Support & Maintenance

- Support to the equipment groups appears to be necessary during the different phases of their project (development, integration and operation) on hardware (fieldbuses, PLC) and software (SCADA, OS).
- The level of the support expected from the equipment group vary significantly between users.
- A clear definition of responsibilities have to be established between the different “actors” of the control system.
- Return from industry seems to be very poor in this domain
- Simultaneously, it appears necessary to establish a common policy for PLC and SCADA software maintenance since the beginning of the project. (Software version consistency, upgrade policy,industry market follow- up policy, software compatibility, maintenance…)

Additionnal request

- **Protocol used on fieldbus, on ethernet, between SCADA and PLC, up to**
  - which OSI layer? i.e. S7-Protocol suite?
- **PLCs:**
  - Activation of site license (for STEP7) ?
  - Management of site license ?
  - How to maintain database coherency between PLC and SCADA?
  - Evaluation of new products ? Guidelines for potential users ?
- **Equipment addressing? Variable naming convention (recommendation)?**
  - This will be an important subject if a product like OPC will be used

Conclusion

- Several progress have been made since the workshop, on the field-buses, SCADA, PLC. But there is no coordination between this progress and the project.
- There is not a forum between the Support groups and the equipment group to develop the necessary policy.
- There is several request from equipment groups with no answer
- For several equipment there is a lot of interference with other accelerator project which imply to to keep an homogeneity at the equipment level between the different accelerator
- There is as many approach as groups

Proposal

- **We propose the creation of an industrial Component WG.**
  - With equipment and Support group representatives
    - IT-CO, LHC-ACR, LHC-ECR, LHC-IAS, LHC-VAC, SL-BT, SL-RF, ST-MO, ST-CV,...
  - Identify the requirements for
    - Common infrastructures (wireless ethernet, cable handling,powering ....)
    - Development Tools (analysis, ...)
  - Identify what has been done what will be done by support groups
  - Establish a model of specification including
    - PLC & Fieldbuses and SCADA requirements.
    - Architecture models for Hardware and Software.
    - Maintenance policy
  - Establish the support/training policy for :
    - SCADA
    - Fielbuses & Ethernet
    - PLC
  - Prepare the operation phase
    - support for common technology (maintenance team, site licence, new product evaluation,...)
    - common solution for maintenance software
    - configuration management (hardware & software)
    - naming convention for industrial control system
  - This work shall be conducted in coordination with the existing working group (fieldbus, SCADA,...) or user groups (Guapi) in order to follow their recommendations and to improve the synergy and not duplicate what's already exists. But is aim is to be focused on LHC

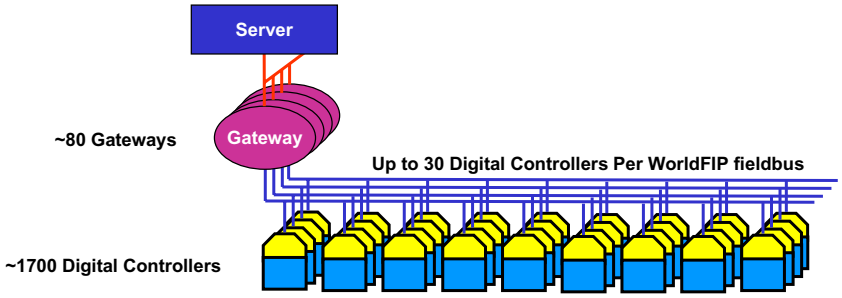
The SL/PO Digital Controller (Function Generator)

Quentin King

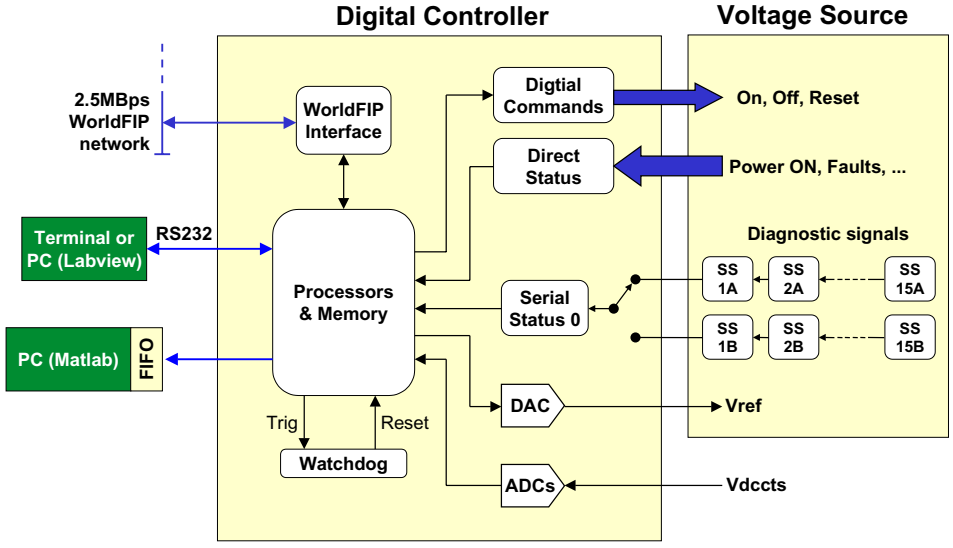
Presentation

- Overview
- Tour of the Hardware
- Defining the reference
- Function generation
- Demonstration
- Tour of the Web Site
- Test Results

System Overview



Hardware 1- Overview

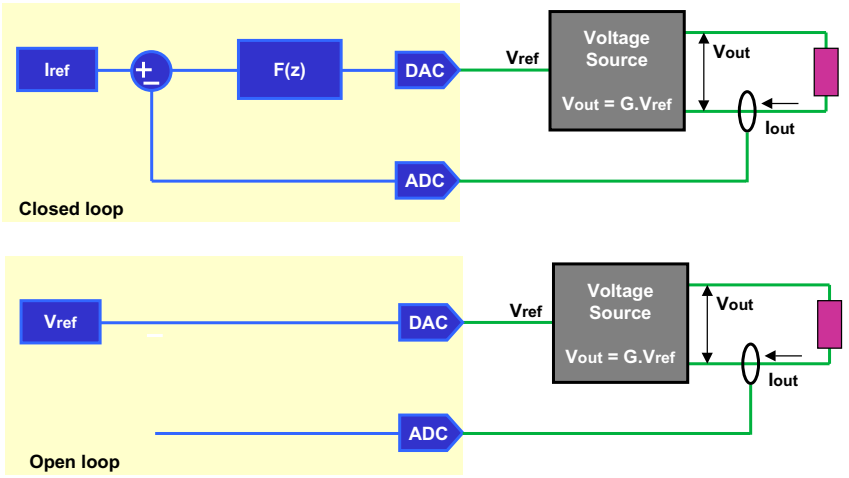


Hardware 2 - Cards

DIGITAL	ANALOG	DICOLOOP	DISPLAY
• Digital Commands - 8 Channels - Watchdog • Direct Status - 16 Channels - HW debounce - 200Hz • Serial Status - 124 12bit analog IPs - 744 digital IPs, SW debounce. - 50Hz Daughter board: Serial Status 0 - Vout, 5V, +/-15V	• Digital Filter MPX - Optical IP A&B - ADC16 A & B - Filter Calibration • ADC16 A & B • Analogue MPX - DCCT A & B - DAC - Front panel I/P - Calibration	• Processors - 16MHz HC16 - 40MHz C32 • Memory - 0.75MB SRAM - 128KB NvSRAM - 8KB EEPROM - 16KB EPROM Daughter boards: • WorldFIP interface • Dual ADC filter • 20bit DAC	• Reset watchdog • Runcode registers • RS232 connector • FIFO connector • Analogue displays • Digital displays • Runcode displays • WorldFIP ID display • Vsource type display

Backplane

Defining the Reference 1



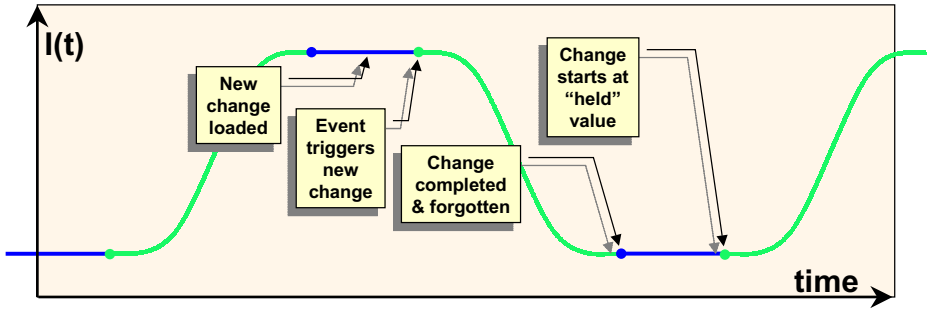
Defining the Reference 2

1. The current reference can be completely predefined: $I_{ref} = I(t)$
2. The current reference can be the sum of predefined and real-time parts: $I_{ref} = I(t) + \Delta I_{rt}$
3. The current reference can be the product of predefined and real-time parts: $I_{ref} = I(t).G_{rt}$
4. The current reference can be completely defined in real-time: $I_{ref} = I_{rt}$

Defining the Reference 3

The predefined contribution to the reference has only two basic states:

1. **HOLDING**
2. **CHANGING**



Function Generation 1

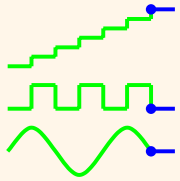
- A ramp or squeeze is defined by sets of machine optics, associated with energies. For each optics, the normalised magnetic strengths are calculated for all the machine elements.
- Normalised strengths are interpolated between optics with a defined rate function.
- The interpolated normalised strength function is then converted into the equivalent field strength against time: $B_m(t)$
- The field strengths are translated into circuit currents via the circuit calibration database(!)
- Finally, for each circuit we have a table of current against time: (I_0,t_0), (I_1,t_1), (I_2,t_2), …, (I_n,t_n)
- Question: How do we join the dots?

Function Generation 2

There will be three different types of change function:

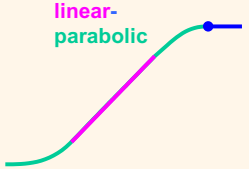
Test Functions:

- steps
- square
- sine



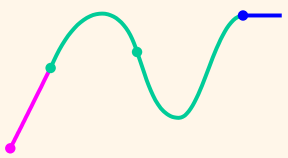
Pre-programmed functions:

- Parabolic-exponential-linear-parabolic



Interpolated functions:

- linear
- spline



Function Generation 3

Linear Interpolation

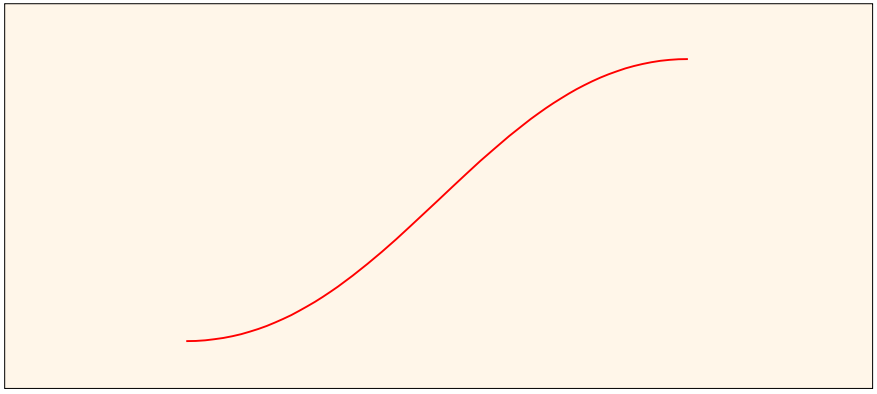
- Linear is simple and easy to compute.
- Derivative is discontinuous, which is hard for the algorithm to follow - risk of undershoot/over shoot.
- Lots of points needed if error is to be very small, I.e. ~1ppm.

Smooth Splines

- Spines are more difficult to define and calculate.
- Derivative is continuous.
- Fewer points are needed so download times will be faster and storage requirements reduced.

Function Generation 4

The Choice of Spine Function needs to be studied!



Function Generation 5

- Requirement for smoothness may be difficult to meet with linear interpolation without needing very large numbers of points.
- Choice of spline type should be made collectively, based upon the way ramps will be defined and the way the circuits will respond.
- Thus there should be an LHC standard for interpolating between points.
- Cubic splines are probably not ideal due to unwanted points of inflexion.