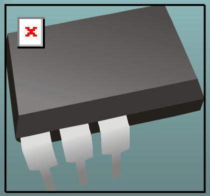
LLRF Functionality

Stefan Simrock



Outline

- Purpose of Catalog with LLRF Functions
- Function Descriptions with breakdown of options
  - Level of Complexity
  - Benefits
  - Cost
- Table of Functions
- Examples of Function descriptions

Purpose of Catalog of LLRF Functions

- Provides structured overview over LLRF functionality
- Describes all possible functions with options
- Describes when the functions and options are needed
- Describes benefits of functions and individual options
- Can be used to decide at which stages which functions and options are needed
- Allows to estimate total cost and is used to decide on priorities.

Idea

	Function	Option	Description	Phase	Benefit	Cost
x	F_01	Basic	…	P0	T++, O+…	3
	…	O_01	…	P1	…	1
	…	O_02	…	P3	…	4
x	F_02	Basic	…	P0	…	6
	…	O_01	…	P2	…	1
x	…	O_02	…	P1	…	2
x	…	O_03	…	P1	…	1
	…	O_04	…	P3	…	3
	F_03	Basic	…	P0	…	2

Phase and Level Complexity

- P_0 : Commissioning (2012-2013)
  - Basic needs relevant for commissioning of accelerator subsystems
- P_1 : Initial Operation (2014-2015)
  - Mainly manual operation
  - Applications supporting operator
- P_2 : Upgrades (2016-2017)
  - Semi-automated operation
  - Advanced exception handling by operator
- P_3 : Future Needs (> 2018)
  - Fully automated operation
  - Complex exception handling

Benefits

- T: Technical
  - Field regulation, Robustness against parameter variations, Resonance control, Good performance close to limit.
- O: Operational
  - Automation, Application tools for operators,
- A: Availability
  - Redundancy, automation, …
- Diagnostics
  - Software, hardware, performance monitors …
- M: Maintainability
- U: Upgradeability
  - (Modular Design, sufficient resources, ...)
- Well understood

Cost

- Cost based on function points (or use case point)
  - Estimate in person-month of work
  - Costing of basic function and all options
  - Includes all work from requirements to commissioning
  - Calibration against existing work
  - Some functions require other function as pre-requisite

Grouping of Functions

- Measurements
- RF System Calibration
- RF Field Control
- Cavity Resonance Control
- Subsystem Control
- Subsystem Characterization
- Exception Detection
- Exception Handling
- LLRF Diagnostics
- RF Global Control

1.0 Measurements

- Vector-Sum Measurement
- Incident and reflected Wave Measurement
- QL and Detuning
- Beam Phase and Beam Current
- Gamma Dose Rate
- Neutron Flux

2.0 RF System Calibration

- Vector-sum with single bunch
- Vector-sum with moderate current
- Vector-sum with high current
- Incident and reflected wave
- Loop gain and loop phase
- Gradient and phase
- Gamma Dosimetry
- Neutron Dosimetry

3.0 Field Control

- Simple Feedforward
- Adaptive Feedforward
- Redundant Feedforward
- Universal Controller
- Optimal Controller

4.0 Cavity Resonance Control

- Slow resonance control
- Lorentz force compensation
- Microphonics control
- Wide range cavity tuning

5.0 Subsystem Control

- Klystron linearization
- Timing control
- Klystron overhead management
- Adjust incident phase
- Adjust loaded Q

6.0 Subsystem Characterization

- Klystron (drive chain)
- Downconverter characterization
- Cavity operational limits
- System identification

7.0 Exception Detection

- Cavity Quench
- SEU Hang-up
- Signal Integrity Violation
- Cavity operational limit exceeded
- Klystron overhead low

8.0 Exception Handling

- Recover from cavity quench
- Recover from SEU hangup
- Adjust klystron overhead

9.0 LLRF Diagnostic

- Configuration status
- Calibration status
- Field regulation performance monitor
- Event generation
- Alarm generation
- Warning generation
- Fault statistics

10.0 Accelerator Section Global Control

- Momentum management
- Beam energy feedback
- Beam arrival time feedback
- Bunch compression feedback

Example: 1.1 Vector-Sum Measurement (1)

- The measured vector-sum is the necessary pre-requisite for the field stabilization. Both - feedback and feedforward algorithms - will attempt to control the measured vector-sum to the vector-sum setpoint table.
- Basic
  - individual cavity field measurements (non-IQ)
  - filter and decimate signal
  - calibrate individual cavity fields (rotation matrix)
  - Calculate vector-sum
  - Save data in buffer (ind. Cavities and VS)
- O1: save raw data at full sampling rate
  - B(D++,T+,W++): Useful for diagnostic purposes

Example: 1.1 Vector-Sum Measurement (2)

- O2: phase drift compensation of field measurement
  - B(T+++): Guarantees long term field stability
- O3: linearization of downconverter
  - B(T++): better vector-sum regulation
  - B(T+,O++): larger dynamic range
- O4: measure level of non-linearity (gen. exception flag)
  - Provide warning if non-linearity error large
- O5: RF Level adjustment at downconverter input
- O6: Amplitude drift correction of field measurements

Example: 3.4 Universal Controller

- The universal controller supports different modes of operation (SEL,GDR,VCO). It can be used for field control but supports also wide range cavity tuning, cavity/coupler conditioning etc.
- Basic
  - Feedback and feedforward
  - GDR and SEL mode incl. mixture
  - IQ, AP and AQ control
  - PI controller filter
- O1: VCO mode
- O2: Coupler conditioning mode
- O3: MIMO controller

Conclusion

- The LLRF Function Catalog will be an important tool to understand the functional needs of the LLRF system
- It will help to understand the trade-offs between performance and cost.
- It will help to define the acceptance tests for LLRF deliverables.

- I will need everyones help to fill the function catalog with live.