A BEAM-SYNCHRONOUS GATED PEAK-DETECTOR FOR THE LHC BEAM OBSERVATION SYSTEM

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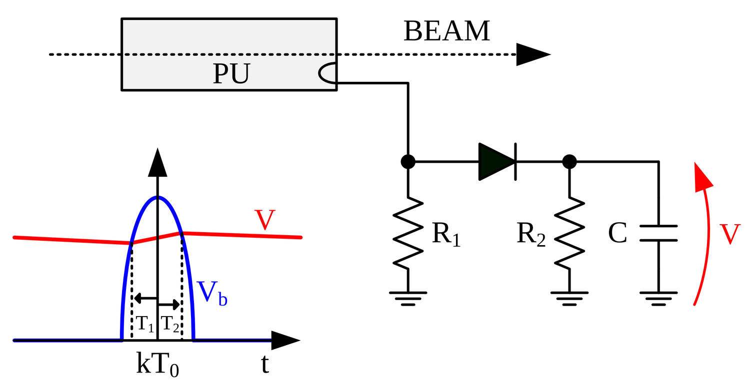
ABSTRACT

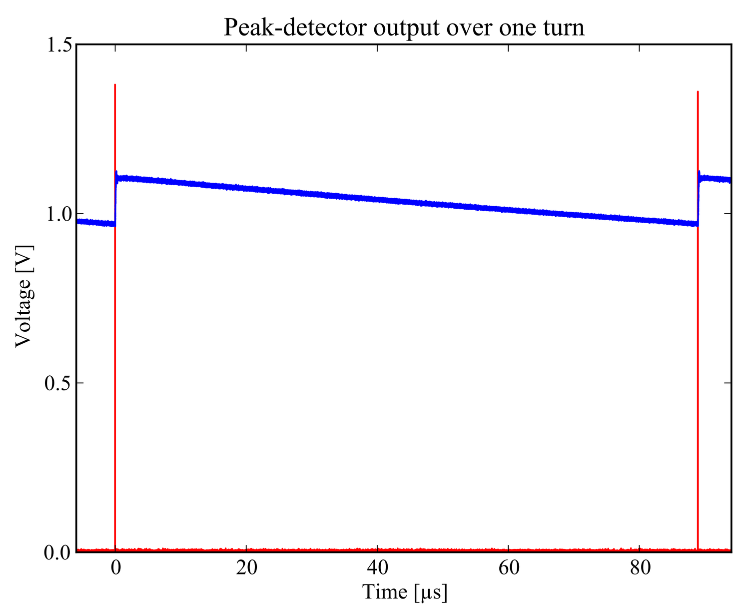
Measurements of the bunch peak amplitude using the longitudinal wideband wall-current monitor are a vital tool used in the Large Hadron Collider (LHC) beam observation system. These peak-detected measurements can be used to diagnose bunch shape oscillations, for example coherent quadrupole oscillations, that occur at injection and during beam manipulations. Peak-detected Schottky diagnostics can also be used to obtain the synchrotron frequency distribution and other parameters from a bunched beam under stable conditions. For the LHC a beam-synchronous gated peak detector has been developed to allow individual bunches to be monitored without the influence of other bunches circulating in the machine. The requirement for the observation of both low intensity pilot bunches and high intensity bunches for physics requires a detector front-end with a high bandwidth and a large dynamic range while the usage for Schottky measurements requires low noise electronics. This paper will present the design of this detector system as well as initial results obtained during the 2012-2013 LHC run.

PEAK-DETECTOR

- Vital tool in the LHC & SPS RF beam observation systems.
- Essentially a fast diode detector, connected to the APWL longitudinal wideband wall-current monitor.
- Detects the peak value of the Gaussian bunch signal on each turn and has a long decay time of approx. 10 turns.
- Can be used to diagnose bunch shape oscillations, such as coherent quadrupole oscillations, that can occur at injection or during beam manipulations.
- After a transient period, the only variations in value are due to Schottky noise.
- Peak-detected Schottky measurements can provide information about the particle distribution in synchrotron frequency.



A simplified schematic of the peak-detector.



- Adapted peak detector from SPS used during first LHC run. However, a lack of sensitivity was observed in 2010 when comparing detector to turn-by-turn acquisitions made with a 2.5 GHz oscilloscope.
- Measurements and simulations were performed and led to an alteration of the resistance and capacitance values in the diode detector, while maintaining the time constant.
- New circuit values show much better sensitivity. The DC working point was also modified to maximise sensitivity.

CONCLUSION

A new peak-detector for the LHC beam-observation system has been designed. The new VME card offers a number of additional features the most important of which is gating to allow observation of individual bunches circulating in the machine without the influence of others. Full remote control and readout will enable automatic diagnostic measurements. Initial results obtained at the end of the first LHC run look promising, both for measuring injection oscillations and for peak-detected Schottky.

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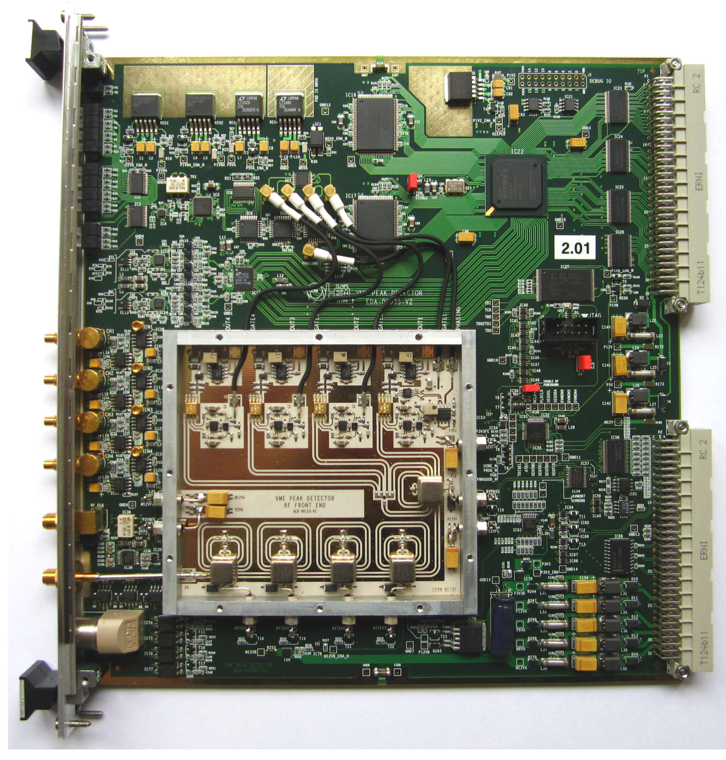
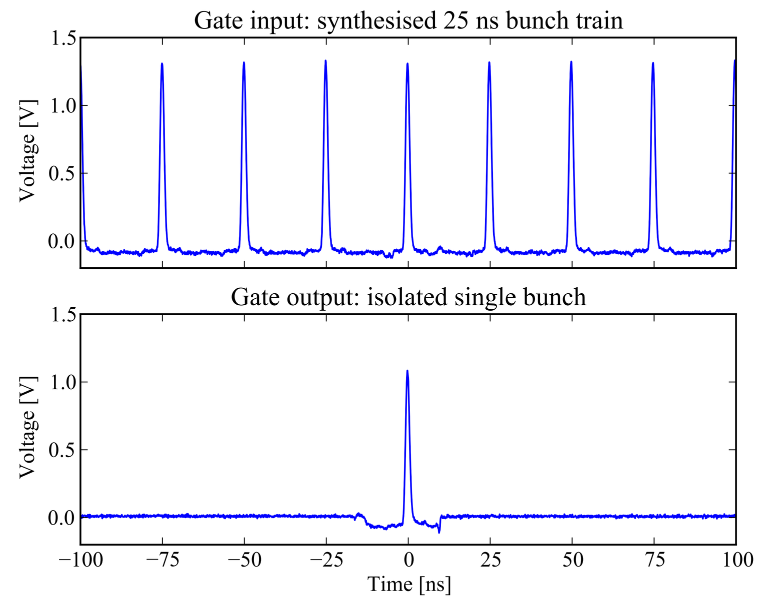
HARDWARE

- APWL pick-up has a usable bandwidth of 80 kHz to 3.5 GHz.
- We require a high bandwidth RF front end to avoid pulse shape distortion.
- Due to large intensity difference between probe and physics bunches, the front end must be able to handle > 34 dB difference in signal level and 8 W peak RF power.
- The diode detector requires a constant DC working point.
- Multiple switched attenuator stages:
  - 6 dB, 10 dB and 20 dB (10 W)
  - 1 dB, 2 dB, 4 dB and 8 dB (1W)
- Switched, high bandwidth, amplifier for extremely low intensity bunches.
- Four peak detector channels for concurrent observation of different bunches.
- Bunch synchronous gate to isolate individual bunches out of trains.
- FPGA based LLRF VME acquisition and control card.
- ADC sampling at a multiple of f_{rev} to avoid added noise due to jitter of sampling point against input signal.
- 46.7 second record length, double buffered to provide longer sampling periods for Schottky measurements.



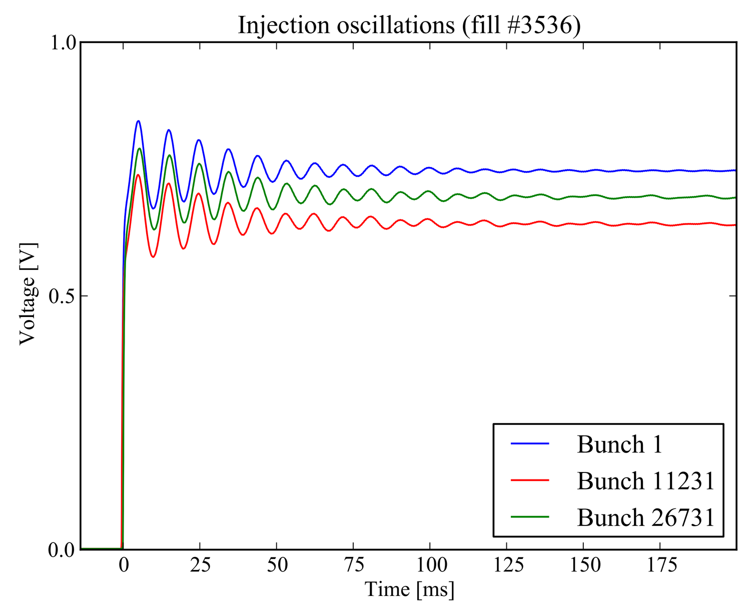
LHC peak-detector card in CERN's custom LLRF VME form factor.



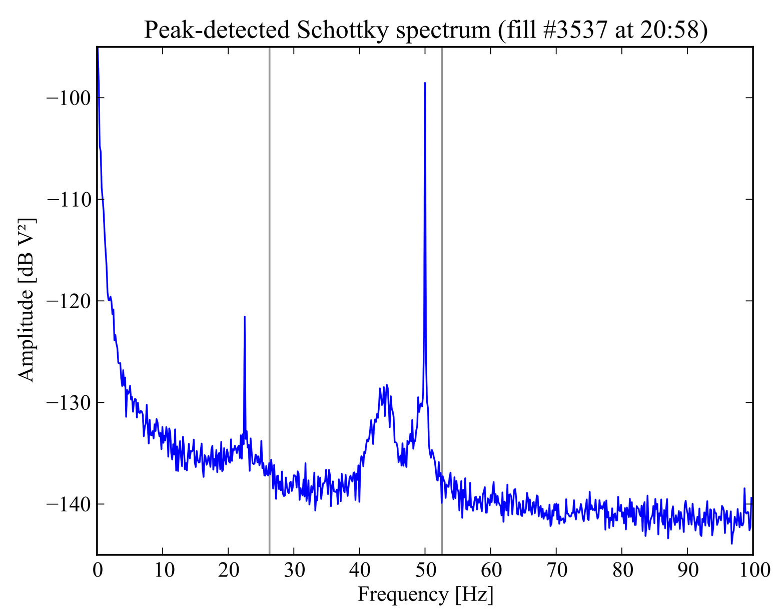
RESULTS

Initial measurements taken during final weeks of LHC run one (2010-2013).

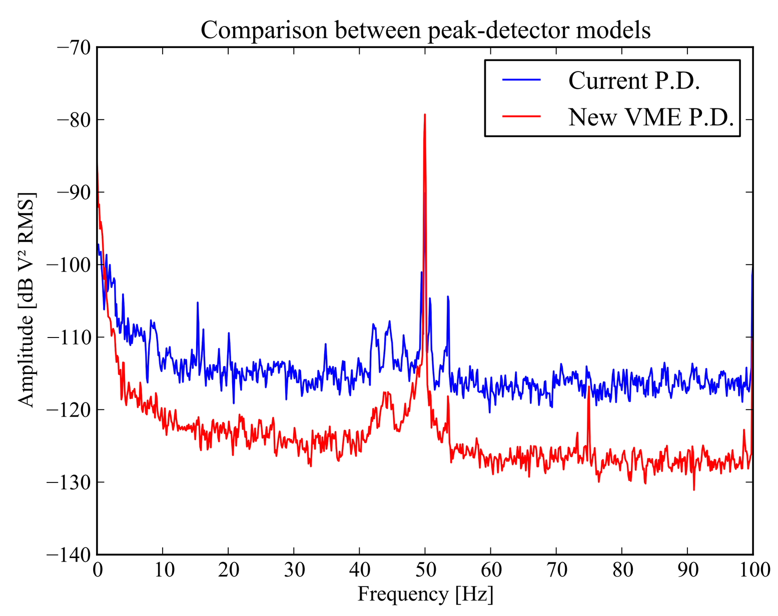
- Injection oscillations measured during LHC fill #3536.
- First bunch of each injected batch was isolated using the gate.
- Selected bunches are shown.
- Measured quadrupole oscillation frequency of 103.5 Hz is slightly lower than the value of $2f_s$ = 110 Hz due to finite bunch length.



- Peak-detected Schottky measurement from a FFT of the sampled data, processed offline.
- Spurious lines at 50 Hz (mains frequency) and 22.5 Hz.
- $2f_s$ distribution clear below the calculated value of 52.6 Hz.
- “Dip” in $2f_s$ spectrum around 46 Hz is not well understood, but is seen regularly in the LHC.
- f_s spectrum visible just above the noise floor below 26.3 Hz.



- Comparison measurement made between current peak-detector and new model using HP3562A spectrum analyser.
- Absolute value of noise floor is non-representative.
- However, details in the $2f_s$ spectrum are more distinct in the new model.
- Again, the “dip” in the $2f_s$ spectrum is visible.



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