Abstract
Since the dismantling of LEP no storage rings, making lifetime measurements necessary are operated at CERN. Nevertheless beam intensity measurements are extensively used in the transfer lines between the different accelerators as well as in the accelerators themselves. The operations crew has provided information on where they see performance limitations of the current measurement systems, possible improvements and requests for additional resources.
The paper first gives an overview of the different types of beam current measurements available in the PS and SPS complex today and then describes shortcomings that have been observed.

SYSTEM OVERVIEW
Figure 1 shows all beam current measurements available in the machines of the PS complex. Depending on the beam type different transformer types and readout electronics is used.

In the transfer lines from Linac-2, (proton Linac) to the PS Booster (PSB) and from Linac-3 (lead ion Linac) to LEIR the beam has a length of several hundred µs (~200 µs in the case of Linac-2 and up to 500 µs in the case Linac-3) and fast sampling ADCs followed digital signal treatment a integration are used (transformers shown in magenta). Beam intensities have typical values of 180 mA for Linac-2 and 20 µA for Linac-3.

After multi-turn injection into the Booster, bunching and acceleration, the bunches have a typically lengths of several tens of ns and analogue integrators are used.

Figure 1: Overview of Beam Current Transformers in the PS complex
Since many of the transformers see vastly different intensities depending on the accelerator cycle (e.g. proton vs ion cycles) a multi-gain amplification system is used (transformers marked in red).

In the circular machines the beams stays for 1-2 s which makes DC current detection necessary (transformers marked in green).

**TRANSFORMERS IN THE LINACS**

The main problem seen on the Linac-3 transformers is due to the very low intensity ion current resulting in very high amplifications needed in the preamplifier chain. The transformer signal sits on low frequency noise induced by nearby pulsed elements. In order to reduce these effects an analogue baseline restoration is performed by subtracting a ramp signal whose slope must be manually adjusted. In addition a precise current pulse for calibration purposes is injected just before the arrival of the beam.

As can be seen from the trace, the baseline restoration is not perfect and measuring the baseline with subsequent baseline subtraction would be preferable. Unfortunately this would however need a bigger dynamic range for the ADC which is currently limited to 8 bits with only 2kBytes of associated memory. In the near future we foresee to replace the ADCs by 12 bit models having bigger attached memories.

For very low intensity beams electromagnetic interference constitutes a big problem which can only be resolved through very careful shielding and great care in the use of ground connections.

**DC CURRENT TRANSFORMERS**

There is at least one DC current transformer (DCCT) in each of the circular machines measuring the intensity of the circulating beams. This transformer is used to observe losses down to the percent level.

When producing beam for the Antiproton Decelerator (AD) the particle bunches are compressed in time (fig 3).

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![Figure 3: Batch compression of AD beams](image)

When observing this beam in the PS using its DCCT a slight dip in the intensity is observed, this is due to an instrument effect. Figure 4 shows the result of the current measurement. The upper trace represents the plot seen on the control system while the lower trace is zooming in to the critical area.

Changing the distance between bunches and leaving a bigger hole between each batch of 4 bunches modifies the frequency content of the transformer signal. The revolution frequency becomes more visible. This upsets the low frequency amplifier used in the feedback chain of the DCCT electronics.

![Figure 2:](image)

a) typical oscilloscope trace from a Linac-3 transformer

b) additional signals used for intensity calculations
RELATIVE MEASUREMENTS

When increasing the beam intensities for high current operations like CERN’s new neutrino program (CNGS) it becomes more and more important to control possible losses. Relative current measurements allow pinning down the location where such losses occur.

CONCLUSIONS

- Generally low intensity beams cause more problems to the instruments but are less interesting to operation. (low freq. EM problems)
- Problems of relative calibration of transformers for loss measurements
- Lack of a transformer measuring many turns at injection. The DCCT sees the injected beam only after around 100 ms due to bandwidth limitations.