CONSTRUCTION AND CHARACTERIZATION OF THE INDUCTIVE PICK-UP SERIES FOR BEAM POSITION MONITORING IN THE TBL LINE OF THE CTF3 AT CERN*

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Abstract

A set of two Inductive Pick-Up (IPU) prototypes with its associated electronics for Beam Position Monitoring (BPM) in the Test Beam Line (TBL) in the 3^{rd} Compact Linear Collider (CLIC) Test Facility (CTF3) at CERN were designed, constructed, characterized and tested by the IFIC team. One of this two prototypes is already mounted in the first module of the TBL line. In the first part of the paper we described the complete characterization of these two prototypes and the first tests performed with beam. The second part of this paper is dedicated to the description of the construction and performance characterization of a series of 15 units including its respective mechanical supports. The description of the low-frequency set-up used for the characterization tests is also included.

INTRODUCTION

The CLIC Test Facility will demonstrate the essential parts of the CLIC drive beam generation scheme consisting of a fully loaded linac, a delay loop and a combiner ring. The final CTF3 drive beam is delivered to the CLIC Experimental Area (CLEX) comprising the TBL and a two beam test stand. The TBL is designed to study and validate the drive beam stability during deceleration. The TBL consists of a series of FODO lattice cells and a diagnostic section at the beginning and end of the line to determine the relevant beam parameters. Each cell is comprised of a quadrupole, a BPM (labeled as BPS) and a Power Extraction and Transfer Structure (PETS) [1]. A 3D view of a TBL cell is shown in Fig. 1. The available space in CLEX allows the construction of up 16 cells with a length of 1.4 m per cell. The BPS's are IPU type and the expected performances for a TBL beam type (current range 1-32 A, energy 150 MeV, emittance 150 μm, bunch train duration 20-140 ns, microbunch spacing 83ps (12GHz), microbunch duration 4-20 ps, microbunch charge 0.6-2.7 nC) are summarized in Tab. 1.

BPS PROTOTYPES

A set of two prototypes of the BPS's labeled as BPS1 and BPS2 with its associated electronics has been designed, constructed and characterized by the IFIC team with the collaboration of the CTF3 team at CERN. A detailed description of the mechanics, electrical model and the electronics of this two prototypes could be found in [2]. The

* Work supported by FPA2007-31124-E

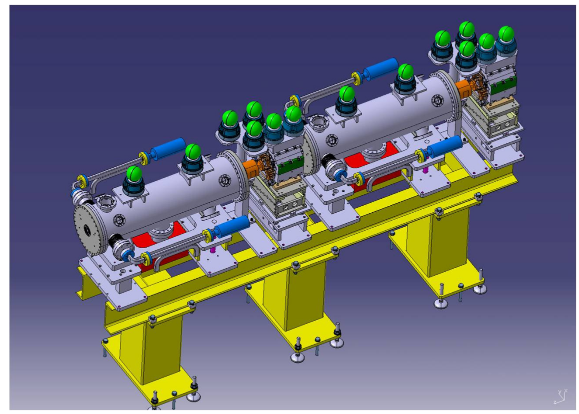

Figure 1: 3D view of a TBL cell with the PETS tanks, the BPS's and the quadrupoles.

Table 1: Expected BPS Characteristics

Analog bandwidth	10 kHz-100 MHz
Beam position range	±5 mm (H/V)
Beam aperture diameter	24 mm
Overall mechanical length	126 mm
Number of BPS's	16
Resolution at maximum current	≤5 μm
Overall precision $\sigma_{H/V}$	≤50 μm

electric model and characterization parameters: sensitivity, overall precision (accuracy), electrical offset and cut-off frequencies with its associated time constants; has been determined with the wire method in the BI-PI labs at CERN. This test is based on a test bench setup that allows moving the BPS with respect to a current wire that simulates the beam passing trough the BPS under test. From the point of view of the electronics two different versions of the PCB's, differing in the secondary output resistors used for the adjustment of the low-frequency cut-off, has been also tested. The BPS1 performance with the PCB version giving lower low-frequency cut-off are summarized in the Tab. 2. The performed tests in the wire setup yield good linearity results and reasonably low electrical offsets from the mechanical center. From the linearity errors analysis can be stated that the overall precision results have to be ameliorated, considering the effect of the very low excitation current in the wire (13 mA) and the misalignment for the horizontal plane electrodes. Concerning the frequency response measurements, the low cut-off frequencies for the difference (Δ) signals are equal for the vertical

Table 2: BPS1 Prototype Performance

BPS1 Sensitivity and Linearity Parameters	
V Sensitivity S_V	$41.09\,\mathrm{m}^{-1}$
H Sensitivity S_H	$41.43\,\mathrm{m}^{-1}$
V Electric Offset EOS_V	0.03 mm
H Electric Offset EOS_H	0.15 mm
V Overall precision σ_V (± 5 mm)	78 μm
H Overall precision σ_H (± 5 mm)	109 μm
BPS1 Characteristic Output Levels	
Sum signal level Σ	16.5 V
Diff signals levels $\|\Delta V/H\|_{max}$	8.25 V
Centered beam level, $V_{sec}(x_{V/H} = 0)$	4.125 V
BPS1 Frequency Response (Bandwidth) Parameters	
Σ low cut-off freq f_{l_Σ}	1.76 kHz
Δ low cut-off freq f_{l_Δ}	282 kHz
Σ [Cal] low cut-off freq $f_{l_{\Sigma[Cal]}}$	1.76 kHz
Δ [Cal] low cut-off freq $f_{l_{\Delta[Cal]}}$	180 kHz
High cut-off freq f_h	>100 MHz
High cut-off freq [Cal] $f_{h[Cal]}$	>100 MHz
BPS1 Pulse-Time Response Parameters	
Σ droop time const τ_{droop_Σ}	90 μs
Δ droop time const τ_{droop_Δ}	564 ns
Σ[Cal] droop time const $\tau_{droop_{\Sigma[Cal]}}$	90 μs
Δ[Cal] droop time const $\tau_{droop_{\Delta[Cal]}}$	884 ns
Rise time const τ_{rise}	<1.6 ns
Rise time const [Cal]$\tau_{rise[Cal]}$	<1.6 ns

and horizontal planes, and they are given for performing the compensation of droop time constants with the external amplifier, but they show a difference of around 100 kHz between the low cut-off frequencies for the wire/beam and the calibration excitations. This effect never seen before must be investigated in a future work. The low cut-off frequencies for the sum (Σ) signals, corresponding also to each electrode output frequency response, are the same for both cases wire/beam and calibration excitation, and they are under specifications (below 10 kHz), as well as, the high cut-off frequency that we could determine to be above the required 100 MHz.

The BPS1 and its support is already installed in the TBL line as it is shown in Fig. 2. After the installation in December 2008 some preliminary test with beam losses has been performed. In the first series of measurements with beam we have observed a ringing problem with calibration pulses. Ringing problem has been investigated and solved in a collaborative effort. The results of the second series of measurements after solving the initial ringing problem are shown in Fig. 3.

The BPS2 remained at the IFIC labs for testing and implementing the issues for improvements signaled above.

BPS SERIES PRODUCTION

The series production of the 15 unit (BPS1 + 15) have been started at the IFIC labs in November 2008.

Figure 2: BPS1 and its support installed in the TBL line.

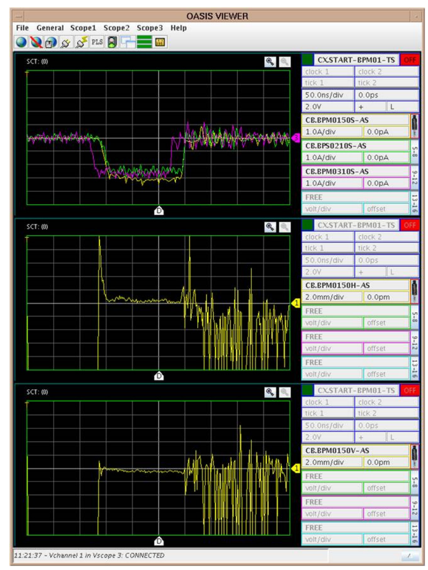

Figure 3: Measurements of the BPS1 with beam in the TBL line.

Mechanics

From the point of view of the BPS mechanics there are no major changes compared with the prototypes. The production of the different parts, described in detail in [2], is finished. The assembly of the series is foreseen at the end of May 2009. The supports are also in production and they will finished at the same time. The metrology of the supports will be made at CERN prior the installation foreseen in the first part of June 2009.

One complete unit of the series: BPS3 was already assembled. After the characterization test made at IFIC labs in a new wire low-frequency setup, it was shipped to CERN jointly with BPS2 and its corresponding supports. These two units are being installed in the TBL line. All the characterization details are described in the following section.

Electronics

In the final version of the PCB design, boarded on the new units of the BPS's series (BPS2 and BPS3), some improvements was made from the first prototype version (BPS1). Mainly, the redesign of the PCB was focused on trying to diminish the high coupling effects that exists between the BPS strip electrodes. The PCB final version production is started and it will be finished mid May 2009.

BPS SERIES CHARACTERIZATION

The BPS series characterization is already started at the IFIC labs. We have characterized two units: a refurbished version of the BPS2 (PCB final version) and a new unit labeled as BPS3.

Low-Frequency Set-Up

To carry out the characterization test of the series a new improved setup has been built. Fig. 4 shows the new wire low-frequency setup in the IFIC labs. This wire test bench setup is inspired in the one at BI-PI labs at CERN, used for the characterization of the prototypes BPS1 and BPS2. The main features of this new test bench setup is that the BPS under test will be moved by a motorized XY and rotatory micromovers to change the relative wire position with respect to the BPS, and, moreover, the wire will be fed with a higher current (> 250 mA) to avoid the low current effects in the test measurements. The wire positioning system will allow to fully automatize the measurements and, due to its high resolution (precision/resolution: XY 2/0.2 μm, rotatory 0.2/0.009 μrad), we will also be able to estimate the minimum position resolution down to 5 μm according to TBL specifications, with enough accuracy.

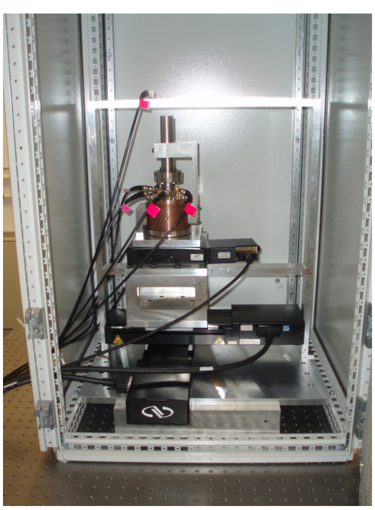

Figure 4: Low-frequency wire test setup in the IFIC labs.

The characterization results for refurbished BPS2 and BPS3 are shown in Tab. 3

Table 3: BPS2/3 Series Performance

BPS2/3 Sensitivity and Linearity Parameters	
V Sensitivity S_V	43.16/43.70 m^{-1}
H Sensitivity S_H	42.60/42.10 m^{-1}
V Electric Offset EOS_V	-0.67/-0.84 mm
H Electric Offset EOS_H	0.50/0.52 mm
V overall precision σ_V ($\pm$5 mm)	89/94 μm
H overall precision σ_H ($\pm$5 mm)	90/98 μm
BPS2/3 Characteristic Output Levels	
Sum signal level Σ	16.5/16.5 V
Diff signals levels $\|\Delta V/H\|_{max}$	8.25/8.25 V
Centered beam level, $V_{sec}(x_{V/H}=0)$	4.125/4.125 V
BPS2/3 Frequency Response (Bandwidth) Parameters	
Σ low cut-off freq f_{l_Σ}	2.90/1.70 kHz
Δ low cut-off freq f_{l_Δ}	271/275 kHz
Σ[Cal] low cut-off freq $f_{l_{\Sigma[Cal]}}$	2.80/1.70 kHz
Δ[Cal] low cut-off freq $f_{l_{\Delta[Cal]}}$	163/171 kHz
High cut-off freq f_h	>100/100 MHz
High cut-off freq [Cal] $f_{h[Cal]}$	>100/100 MHz
BPS2/3 Pulse-Time Response Parameters	
Σ droop time const τ_{droop_Σ}	55/93 μs
Δ droop time const τ_{droop_Δ}	587/579 ns
Σ[Cal] droop time const $\tau_{droop_{\Sigma[Cal]}}$	57/93 μs
Δ[Cal] droop time const $\tau_{droop_{\Delta[Cal]}}$	976/931 ns
Rise time const τ_{rise}	<1.6/1.6 ns
Rise time const [Cal] $\tau_{rise[Cal]}$	<1.6/1.6 ns

CONCLUSION AND FUTURE TASKS

The series production of 15 units has already started. The production of the different parts is finished. One unit of the series: BPS3 was assembled. After the characterization test made at IFIC labs in a new wire low-frequency setup, it was shipped to CERN jointly with BPS2 and its corresponding supports. These two units are being installed in the TBL line. The rest of the series will be installed in June 2009. Furthermore a high frequency setup for measuring the longitudinal impedance is being constructed at IFIC. The measurements will be made during May with some of the units of the series.

ACKNOWLEDGMENTS

We would like to thank all members of the CTF3 team at CERN for their continuous help, especially to G. Geschonke, S. Döebert, L. Søby and F. Guillot. Thanks also to Trinos Vacuum Projects and Lemar for the participation in the BPS's manufacturing.

REFERENCES

[1] S. Doebert, et al "Status report of the CTF3 Test Beam Line", CTF3 Note 076.

[2] J.J. Garcia-Garrigos et al "Design and Construction of an Inductive Pick-Up for Beam Position Monitoring in the Test Beam Line of the CTF3", EPAC08.