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HGTD DC/DC Converter in Low Temperature and Magnetic Field Operation

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Abstract: The BPOL12V is a DC/DC converter designed to supply power to the High Granularity Timing Detector (HGTD) as part of the ATLAS Phase II upgrade project. The HGTD operates in an environment characterized by low temperatures and a magnetic field. Ensuring the reliable functionality of the BPOL12V under such conditions is of utmost importance. This paper outlines a series of functionality tests for the BPOL12V, including efficiency, ripple, and rise/fall edge assessments across various operational scenarios. The performance of the BPOL12V consistently meets the requirements of the HGTD, whether it operates in low temperatures down to -30 °C or in the presence of a 0.4 T magnetic field.

Keywords: Analogue electronic circuits; Timing detectors; Voltage distributions

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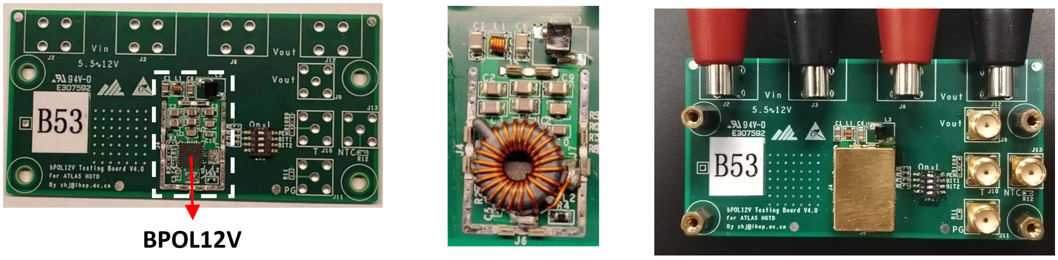
Contents

1 Introduction

The ATLAS Phase II upgrade will employ the High Granularity Timing Detector (HGTD), which provides a time measurement per end-cap track with a resolution of approximately 30 ps in the High Luminosity Large Hadron Collider (HL-LHC). Positioned between the barrel and the end-cap calorimeter, the HGTD is situated at a radial distance ranging from 110 to 1000 mm and at a z-distance of about 3.5 m from the interaction point [1]. The Peripheral Electronics Board (PEB), located at the outer radius of the HGTD, fulfills various functions, including control, monitoring, data transmission, power-supply distribution, and routing temperature sensors for the interlock system [2]. As the voltage converter in PEB, the BPOL12V [3] is responsible for converting an input voltage of around 11 V to an output voltage of 1.2 V or 2.5 V and supplying power to ATLAS Timing Read-Out Chip (ALTIROC) [4] and other PEB components. The operational conditions of the HGTD necessitate exposure to low temperatures, approximately -30 °C. PEB operates within a magnetic field ranging from 0.38 T to 0.43 T, with the angle of incidence falling between 57° and 67° [5, 6]. It is crucial to ensuring the functionality of the BPOL12V under these conditions.
In this paper, Section 2 describes the details of test setup. Sections 3 - 5 discuss the test results, including efficiency, ripple and rise/fall edge. Section 6 presents the conclusion.

2 Test setup

BPOL12V test board Photos of the BPOL12V test board are shown in Figure 1. Figure 1(a) shows a photo of the full BPOL12V test board without inductor, prior to shielding and wiring terminal installation. The marked black square represents the BPOL12V. For a closer look at the setup, refer to Figure 1(b), which features an enlarged view of the white-dotted box in Figure 1(a), with the inductor added atop the BPOL12V. Figure 1(c) shows the complete BPOL12V test board with inductor, as well as the shielding and wiring terminal.



(a) (b) (c)

Figure 1: Photos of the BPOL12V as described in text.

Test setup at low temperature To assess the BPOL12V's performance under low temperature conditions, the test system is set up as illustrated in Figure 2. The system comprises a climate chamber for temperature control, a source meter for supplying and measuring input voltage and current, a load for providing and measuring output voltage and current, and an oscilloscope for scrutinizing ripple and transient behavior. Four-wire measurement is used to eliminate the impact of input/output cables resistance. No magnetic field is applied during the low temperature test.

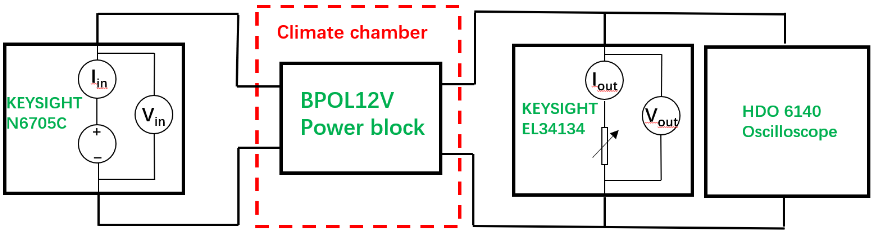


Figure 2: The diagram of the BPOL12V test system at low temperature.

Test setup in magnetic field To evaluate the BPOL12V's performance in the presence of magnetic fields, a setup involving a barrel with a magnetic field generated by a superconducting solenoid is employed. Additionally, support materials are used to secure the BPOL12V at the center of the magnetic field and control the angle between the BPOL12V and the magnetic field (see Figure 3). This testing is conducted exclusively at room temperature.

3 Efficiency

Efficiency at low temperature The efficiency of the BPOL12V, defined as $(V_{out} * I_{out})/(V_{in} * I_{in})$, is vital for understanding HGTD power supply and heat dissipation. The efficiency is tested as a function of I_{out}, and the results are presented in Figure 4. The BPOL12V can achieve an efficiency of approximately 65% (75%) when V_{out} is 1.2 V (2.5 V), meeting the HGTD requirements.

Efficiency in magnetic field The impact of magnetic field on the efficiency is investigated at room temperature. Figure 5(a) displays efficiency measurements for various magnetic field strengths at

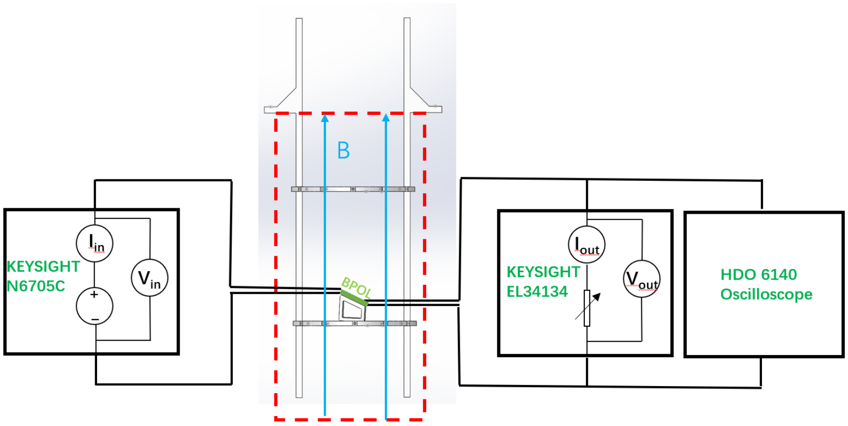
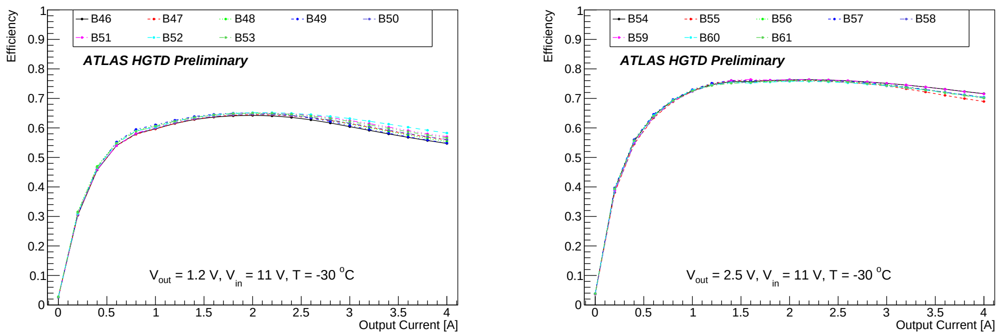


Figure 3: The diagram of the BPOL12V test system in magnetic field.



(a) (b)

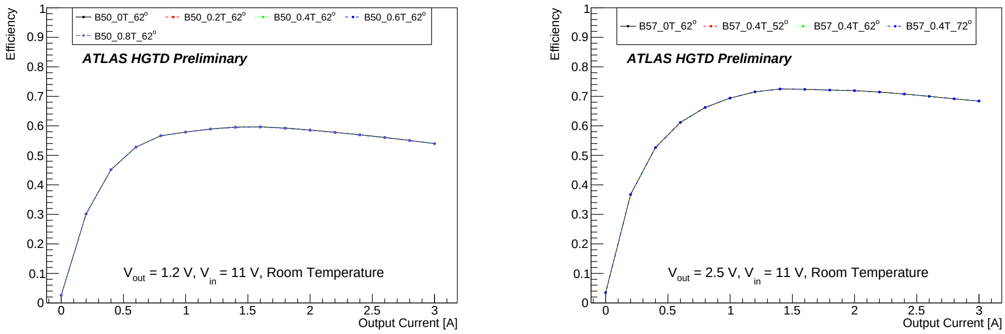
Figure 4: The BPOL12V efficiency with respect to I_{out} , with different colors standing for different boards (e.g, B44, B45). Measurements are performed at V_{out} = 1.2 V (a) / 2.5 V (b), V_{in} = 11 V and T = -30 °C.

a fixed angle of 62^o. Figure 5(b) presents efficiency data for different angles of the magnetic field at a constant value of 0.4 T. With tested magnetic field values (0 - 0.8 T) and angles (52° - 72°), negligible impact can be observed on efficiency, thus satisfying the HGTD requirement (around 0.4 T, 62°). In addition, the efficiency is further tested in a magnetic field of 4 T and little impact is observed.

4 Ripple

Ripple at low temperature Output ripple, defined as the peak-to-peak value of the output voltage, can influence the performance of devices connected to the BPOL12V. Therefore, it is crucial to measure and minimize ripple. In Figure 6(a), one can observe the distribution of ripple concerning I_{out} at -30 °C. The results presented are specific to V_{out} = 1.2 V, with ripple values less than 7 mV, in compliance with HGTD requirements.

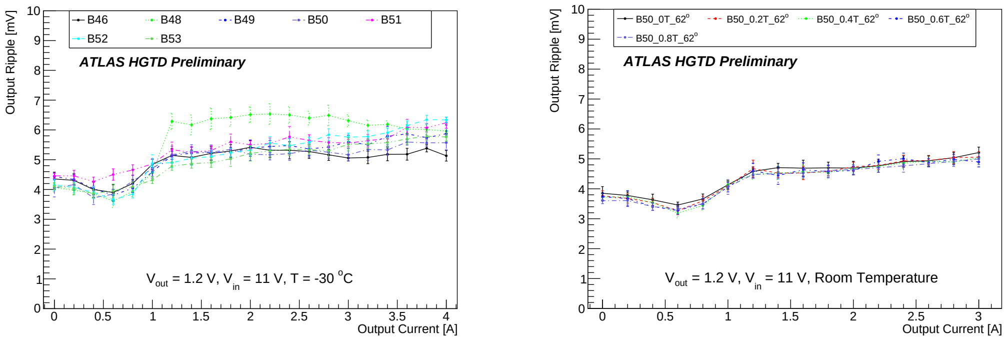
Ripple in magnetic field The impact of magnetic fields on ripple is studied at room temperature. Figure 6(b) illustrates ripple measurements at different magnetic field strengths (0 - 0.8 T) with a



(a) (b)

Figure 5: The BPOL12V efficiency with respect to I_{out} in magnetic field. Measurements are performed at V_{out} = 1.2 V (a) / 2.5 V (b), V_{in} = 11 V and room temperature. Magnetic field with different values (a) or angles (b) are applied in the measurements.

fixed angle of 62°, for V_{out} = 1.2 V. Our findings reveal negligible impact on ripple, even when subjected to magnetic fields, thus meeting the HGTD requirements. Furthermore, the ripple tests are conducted in a 4 T magnetic field, with minimal observed impact.



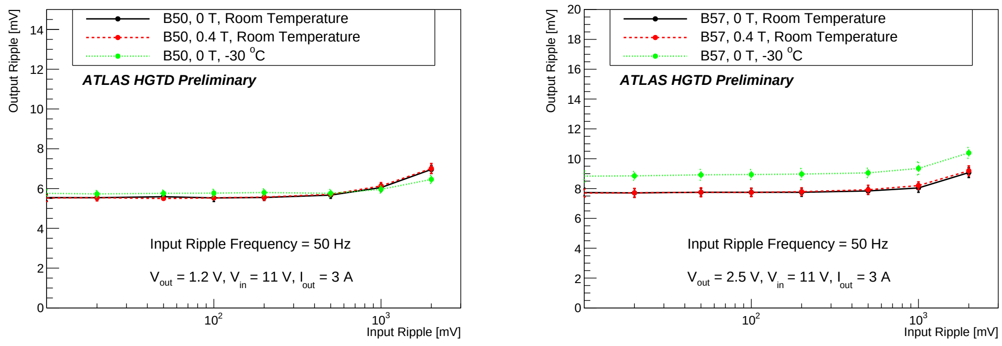
(a) (b)

Figure 6: The BPOL12V output ripple with respect to I_{out}. Measurements are performed at V_{out} = 1.2 V, V_{in} = 11 V, and T = -30 °C without magnetic field (a) or room temperature with different values of magnetic fields (b).

Ripple suppression ability Given the inherent fluctuations in input voltage during operation, it is crucial for the BPOL12V to exhibit effective ripple suppression. Three conditions are considered: no magnetic field at room temperature, no magnetic field at low temperature, and 0.4 T at room temperature. For all conditions, we applied a 50 Hz input ripple. The results presented in Figure 7 indicate that the output ripple remains relatively stable as the input ripple increases.

5 Rise/fall edge

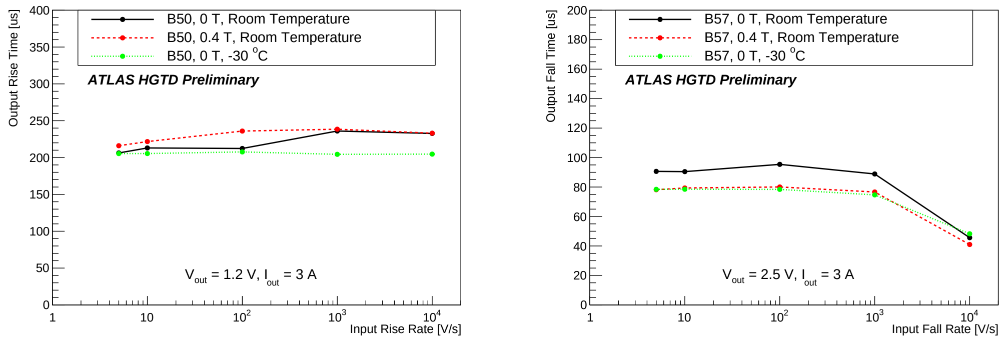
The rise/fall rate of input power can vary during the startup and shutdown of the BPOL12V. It is essential to assess the rise/fall edge of the BPOL12V under various input rise/fall rates. The



(a) (b)

Figure 7: The BPOL12V output ripple with respect to input ripple in different conditions. Measurements are performed at V_{out} = 1.2 V (a) / 2.5 V (b), V_{in} = 11 V and I_{out} = 3 A.

same three conditions are tested as in the ripple suppression study. The results, displayed in Figure 8, demonstrate that the output rise (fall) time is less than 300 (100) μs under the specified test conditions.



(a) (b)

Figure 8: The BPOL12V output rise (a) / fall (b) time with respect to input voltage rise/fall rate in different conditions. Measurements are performed at V_{out} = 1.2 V (a) / 2.5 V (b) and I_{out} = 3 A.

6 Conclusion

The performance of the BPOL12V was thoroughly evaluated under low temperature and magnetic field conditions. Notably, the efficiency can reach up to approximately 65% (75%) for V_{out} = 1.2 V (2.5 V), while the ripple remains below 7 (10) mV for V_{out} = 1.2 V (2.5 V) at -30 °C. Magnetic fields were found to have a negligible impact on both efficiency and ripple, further demonstrating the robustness of the BPOL12V. Moreover, the BPOL12V displayed excellent ripple suppression ability and maintained consistent operation across different input voltage rise/fall rates, even under challenging conditions such as low temperature and a 0.4 T magnetic field. This comprehensive study affirms that the BPOL12V fully meets the requirements of HGTD.

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