

HGTD PEB DC/DC Power Block in Low Temperature and Magnetic Field Operation

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Introduction

• The ATLAS Phase II upgrade will employ the High Granularity Timing Detector (HGTD), which provide a time measurement per end-cap track with a resolution of about 30ps in the High Luminosity LHC.

• Peripheral Electronics Boards (PEB), at the outer radius of the HGTD, contains various functions such as control, monitoring, data transmission, power-supply distribution, and temperature sensor routing for interlock system.

• As a part of PEB, the DC/DC converters, BPOL12V, will be used to generate 1.2V and 2.5V for the ALTIROC ASIC and other components of PEB. **The BPOL12V will work in low temperature (around -30C) and magnetic field (around 0.4T) conditions during operation, so a comprehensive study of its performance is essential.**

BPOL12V performance study at low temperature

Test setup

- BPOL12V used for test:
	- Power block version 3 (Vout = 1.2V/2.5V)
	- Power block version 4 (Vout = 1.2V/2.5V)
- Test system:
	- Climate chamber: Control the temperature
	- Source meter: Supply and measure the input voltage and current
	- Load: Provide and measure the output current and voltage
	- Oscilloscope: Examine the ripple and transient behavior. **Climate chamber**

Efficiency

- The power efficiency for BPOL12V is relevant to **output current (I_{out}), input voltage (V_{in}) and temperature (T)**. It is important to simulate the total power consumption.
- **Tests** are performed based on **3D scan of Vin (9->12V), Iout (0->4A) and T(-50 ->30℃)**.

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Efficiency (Vout = 1.2V, Vin = 11V)

Efficiency

Efficiency (Vout = 2.5V, Vin = 11V)

 \checkmark Taking Vin = 11V as an example, for both Vout = 1.2V and Vout = 2.5V cases:

- \checkmark In low lout region: P4 has better efficiency than p3.
- \checkmark In high Iout region: P4 has similar efficiency as p3.
- \checkmark More results for other Vin can be seen in backup. -> Conclusions are similar.

Output ripple

• The output ripple can be tested using oscilloscope. It is calculated peak to peak.

Output ripple

Efficiency (Vout = 2.5V, Vin = 11V)

- \checkmark For Vout = 1.2V:
	- \checkmark In general, p4 has worse ripple than p3.
	- \checkmark p3 has peak at lout = 0.8A for some cases.
- \checkmark For Vout = 2.5V:
	- \checkmark In general, p4 has better ripple than p3.
	- \checkmark p4 has peak at lout = 1.8A for some cases.

More results for other Vin can be seen in backup. -> Conclusions are similar.

Ripple suppression ability

- To test ripple suppression ability for BPOL12V, we provide input ripple using KEYSIGHT N6705C source meter and measure output ripple.
- Test setup: T=-30C, lout = 3A, based voltage = 11V, sine ripple $frequency = 50$ HZ/1000HZ.

 $\begin{array}{r} \n 10.26 \text{ mV} \\
10.26 \text{ mV} \\
10.4504 \text{ mV} \\
10.05 \text{ mV} \\
11.10 \text{ mV} \\
254.8 \text{ mV} \\
52 \text{ mV} \n \end{array}$

2007 MHz
28277 MHz
24541 MHz
30455 MHz
14.88 kHz

999.7942 Hz
999.9968 Hz
997.9794 Hz
997.9794 Hz
378.3 mHz
10.348e+3

 $1.744 \text{ mV}
\n1.749242 \text{ mV}
\n1.738 \text{ mV}
\n1.762 \text{ mV}
\n5.415 \text{ mV}
\n52$

1.952 V
1.948769 V
1.944 V
1.954 V
2.577 mV
52

679.7 mV
679.7 mV
679.79178 mV
680.0 mV
93.97 uV

8.4897980 ms
8.4897980 ms
1.120 ms
5.201e+3

 \checkmark For all BPOL12V, input ripple below 100mV has negligible effect on the output ripple.

Output ripple

Input ripple

291.9879
292.0781 μ
292.0781 μ
294.4112 μ

Output Rising/Falling time

• we set different input voltage rising/falling rate from 0->12V / 12->0V using KEYSIGHT N6705C source meter and measure output voltage rising time (10%-90%).

 \checkmark Input rising rate has negligible impact on output rising time.

Input falling rate has some impact on output falling time. But in overall, falling time is smaller than 100us.

output rising time

BPOL12V performance study in magnetic field

Magnetic field in PEB region

• Based on ATLAS simulation results, I figured the magnetic fields at PEB region.

- \checkmark Magnetic field only has r and z components, negligible phi component.
- \checkmark Both r and z component of fields are similar at the same z and r.
- \checkmark The magnitude of magnetic field is 0.382 \sim 0.433T.
- \checkmark The angle between magnetic field and z is 23.1 \approx 32.3°.

Test preparation

- We will use a magnetic barrel that can produce adjustable (0 4T) magnetic field using a superconducting solenoid
- We also designed a support material to fix the BPOL12V at the center of the magnetic field and to control the angle between the BPOL12V and the magnetic field. -> 3D print ongoing
- We plan to conduct this test in May.

Test plan

First, we will test BPOL12V efficiency and ripple based on the magnetic field at PEB position. Later, we can extend our test.

- Magnitude: 0.38T, 0.41T, 0.44T, 0.5T
- Angle between BPOL and fields: 18°, 23°, 28°, 33°, 38°, 142°, 147°, 152°, 157°, 162°.

Summary and plan

- Summary:
	- The BPOL12V will work in low temperature (around -30C) and magnetic field (around 0.4T) conditions during operation, so a comprehensive study of its performance is essential.
	- We have performed some study for BPOL12V at low temperature, including efficiency, output ripple, ripple suppression ability and rising/falling time.
	- Also, we are preparing all equipment and material for BPOL12V performance study in magnetic field.
- Plan:
	- Plan to test BPOL12V performance in magnetic field in May.
	- Plan to test more BPOL12V with different PCB boards.
	- Plan to perform 3D fit for efficiency w.r.t Vin, Iout and T.

Backup

Efficiency (Vout = 1.2V, Vin = 9V)

Efficiency (Vout = 1.2V, Vin = 10V)

Efficiency (Vout = $1.2V$, Vin = $11V$)

Efficiency (Vout = 1.2V, Vin = 12V)

Efficiency (Vout = 2.5V, Vin = 9V)

Efficiency (Vout = 2.5V, Vin = 10V)

Efficiency (Vout = 2.5V, Vin = 11V)

Efficiency (Vout = 2.5V, Vin = 12V)

Output ripple (Vout = 1.2V, Vin = 9V)

Output Current [A]

Output ripple (Vout = 1.2V, Vin = 10V)

-⊟ ⊡ 4 $2 -$

Output ripple (Vout = 1.2V, Vin = 11V)

Output ripple (Vout = 1.2V, Vin = 12V)

Output ripple (Vout = 2.5V, Vin = 9V)

Output ripple (Vout = 2.5V, Vin = 10V)

Output ripple (Vout = 2.5V, Vin = 11V)

Output ripple (Vout = 2.5V, Vin = 12V)

Ripple suppression test (p3, Vout =1.2V, input ripple 50HZ)

Ripple suppression test (p3 , Vout =1.2V, input ripple 1000HZ)

TELEDYNE LECROY P6:rise(C2)
195.7066 us
194.762 us
120.1560 us
219.4240 us
7.221 us
10.388e+3 P3:ms(C1)
722 uV
728.911 uV
718 uV
744 uV
5.716 uV
5.716 uV P5: pkpk(C2)
129 mV
131.519 mV
127 mV
136 mV
2.024 mV
62 P6 mms(C2)
33.9 mV
33.94325 mV
33.9 mV
34.0 mV
33.73 uV
52 $\begin{array}{r} \text{P7}.\text{rise}(\text{C1})\\ 15.0653481\,\text{ms}\\ 3.741\,\text{ms}\\ 6.7105\,\text{us}\\ 49.3993040\,\text{ms}\\ 5.451\,\text{ms}\\ 1.170\,\text{e-3}\\ \text{x} \end{array}$ P2 pkpk(Cf)
6.88 mV
6.5367 mV
6.18 mV
6.88 mV
171.3 µV
52 1.31210 MHz
1.27186 MHz
1.04379 MHz
1.68314 MHz
38.31 kHz
1.824463e+6 nggar **an 1993**
Wilo 0,00 mV

Ripple suppression test (p4 , Vout =1.2V, input ripple 50HZ)

Ripple suppression test (p4 , Vout =1.2V, input ripple 1000HZ)

1000mV 2000mV

Ripple suppression test (p3, Vout =2.5V, input ripple 50HZ)

TELEDYNE LECROY

value
mean
min
max
sdev
num

Ripple suppression test (p3 , Vout =2.5V, input ripple 1000HZ)

TELEDYNE LECROY

PointerC21
7.5713055 ms
8.49 ms
338.8208 us 76.4470778 ms
10.88 ms
854

TELEDYNE LECROY

P8:rise(C2)
269.4211 us
269.734 us
255.3893 us
276.5235 us
2.044 us
10.387e+3

P7:nse(C1)
256.2328 us
1.987 ms
5.9498 us
58.5955121 ms
3.520 ms
2.445e+3

 $\begin{array}{r} \text{PT:rise(C1)}\\ 2.6084605\ \text{ms} \\ \text{1.975 ms} \\ \text{142.1304 }\ \text{us}\\ 80.5430964\ \text{ms} \\ \text{3.466 ms} \\ 2.641\text{e} + 3.7\ \text{cm} \end{array}$

Ripple suppression test (p4 , Vout =2.5V, input ripple 50HZ)

TELEDYNE LECROY

P8.1all(CZ)
5.9923230 ms
5.992513 ms
5.9986919 ms
6.9986919 ms
4.030 µs
648

29.6007025 ms
7.325 ms
7.325 ms
26.7960 us
87.8205108 ms
7.486 ms

49.9994992 Hz
49.9994992 Hz
49.999898 Hz
49.993252 Hz
50.0076822 Hz
2.300 mHz
648

0 GHz
0 GHz
0 GHz
0 GHz
0 GHz
397.0 kHz
3.550703e+6

P2 pkpk(Cf)
11.70 mV
11.5776 mV
10.97 mV
12.52 mV
348.4 pV

P1.treg(C1)
0 GHz
2.6639 MHz
0 GHz
0 GHz
265.2 kHz
3.863755e+6

P3:msiC1)
1.264 mV
1.253336 mV
1.229 mV
1.276 mV
8.113 µV

P5: pkpk(C2)
71 mV
70.353 mV
65 mV
65 mV
79 mV
3.092 mV

P6.mm(C2)
18.0 mV
17.95082 mV
17.9 mV
18.1 mV
46.06 µV
51

 $\begin{array}{r} \text{P7:fall(C1)}\\ \text{189.1159} \text{~us}\\ \text{2.895} \text{~ms}\\ \text{26.7846} \text{~us}\\ \text{6.2707158} \text{~ms}\\ \text{4.344} \text{~ms}\\ \text{1.428e+3} \end{array}$

 $\begin{array}{r} 5.9899586 \text{ ms} \\ 5.6877687 \text{ ms} \\ 1.7683822 \text{ ms} \\ 10.1829122 \text{ ms} \\ 2.129 \text{ ms} \\ 485 \text{ s} \end{array}$

TELEDYNE LECROY

Ripple suppression test (p4 , Vout =2.5V, input ripple 1000HZ)

Output Rising time (p3, Vout = 1.2V)

Output Rising time (p4, Vout = 1.2V)

Output falling time (p3, Vout = 1.2V)

Output falling time (p4, Vout = 1.2V)

Output Rising time (p3, Vout = 2.5V)

Output Rising time (p4, Vout = 2.5V)

5V/s 10V/s 100V/s

Output falling time (p3, Vout = 2.5V)

5V/s 10V/s 100V/s

Output falling time (p4, Vout = 2.5V)

