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

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on behalf of the ATLAS HGTD Group

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- BPOL12V performance study at low temperature
  - Test setup
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- BPOL12V performance study in magnetic field
  - Magnetic field in PEB region
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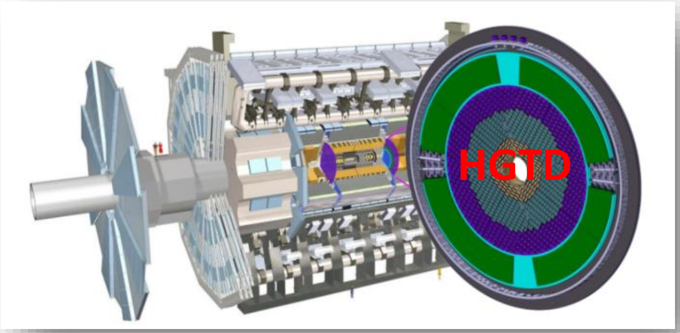
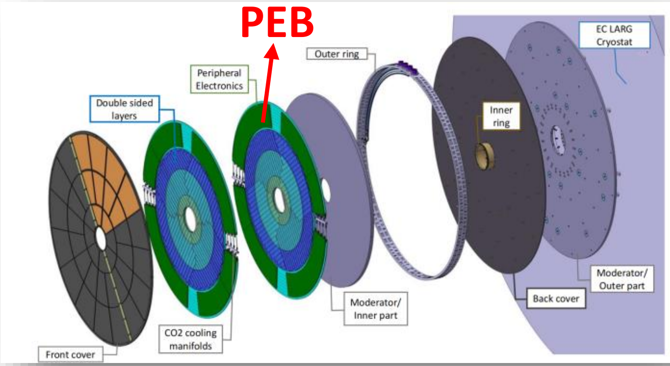
Introduction

- 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.**

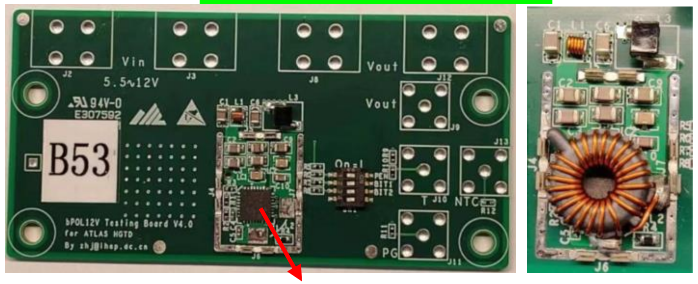
HGTD position



HGTD structure



BPOL12V test board



BPOL12V

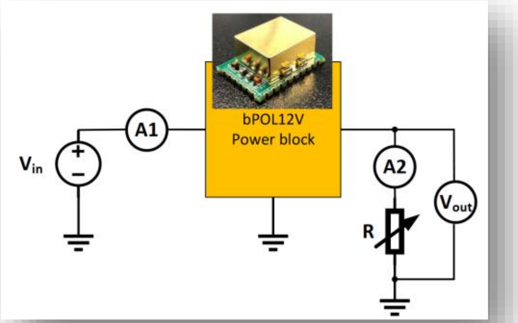
BPOL12V performance study at low temperature

Test setup

- BPOL12V used for test：
  - Power block version 3 (Vout = 1.2V/2.5V)
  - Power block version 4 (Vout = 1.2V/2.5V)

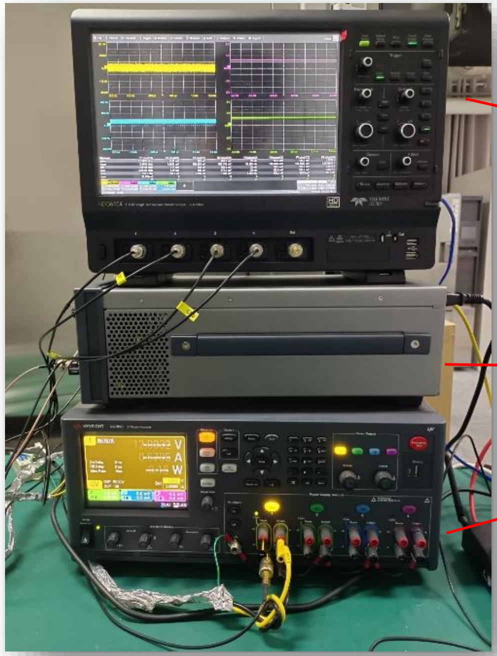
P3

P4



- 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



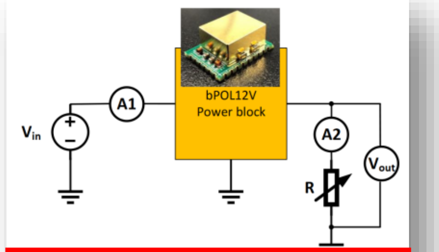
Oscilloscope

Load

Source Meter

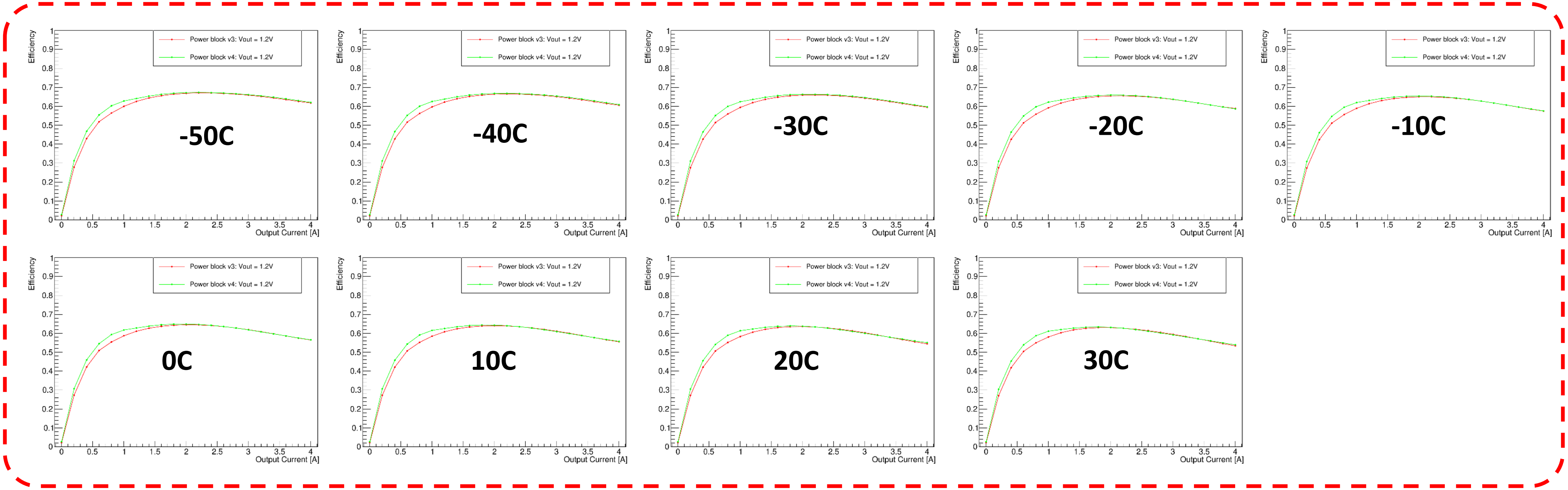
Efficiency

- 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 V_{in} (9->12V), I_{out} (0->4A) and T(-50 ->30℃)**.



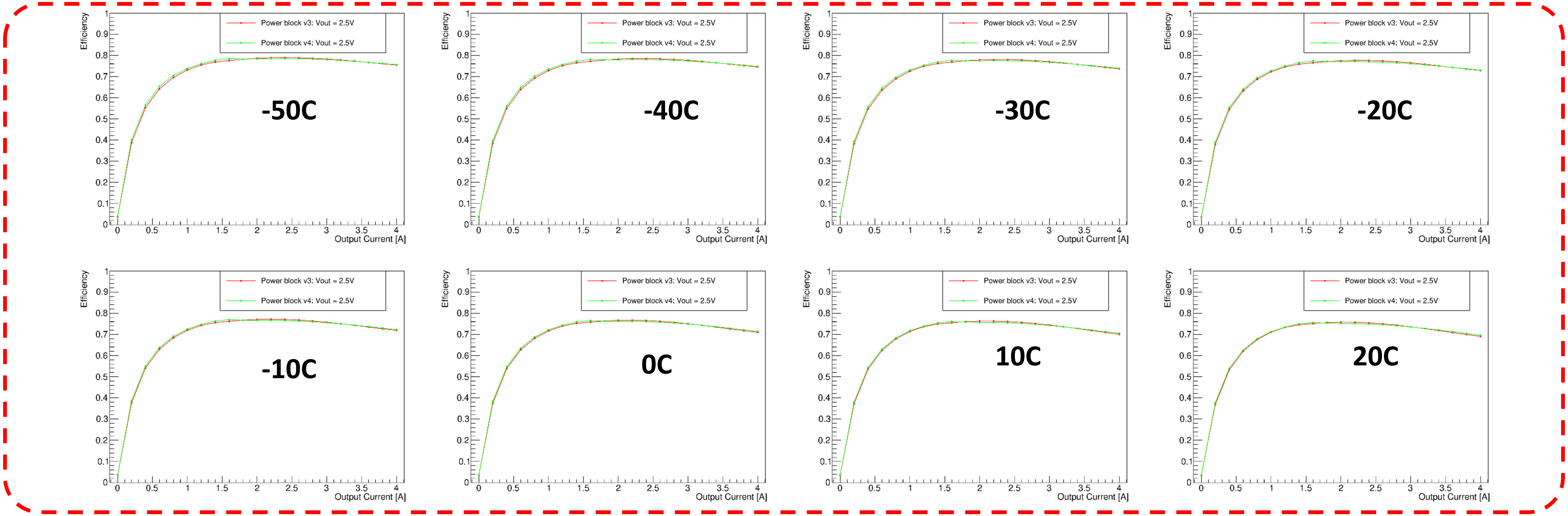
- Power efficiency $= \frac{V_{out} \times I_{A2}}{V_{in} \times I_{A1}}$

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



Efficiency

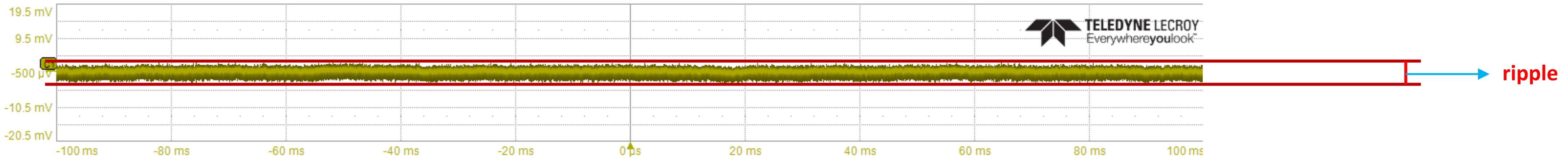
Efficiency (Vout = 2.5V, Vin = 11V)



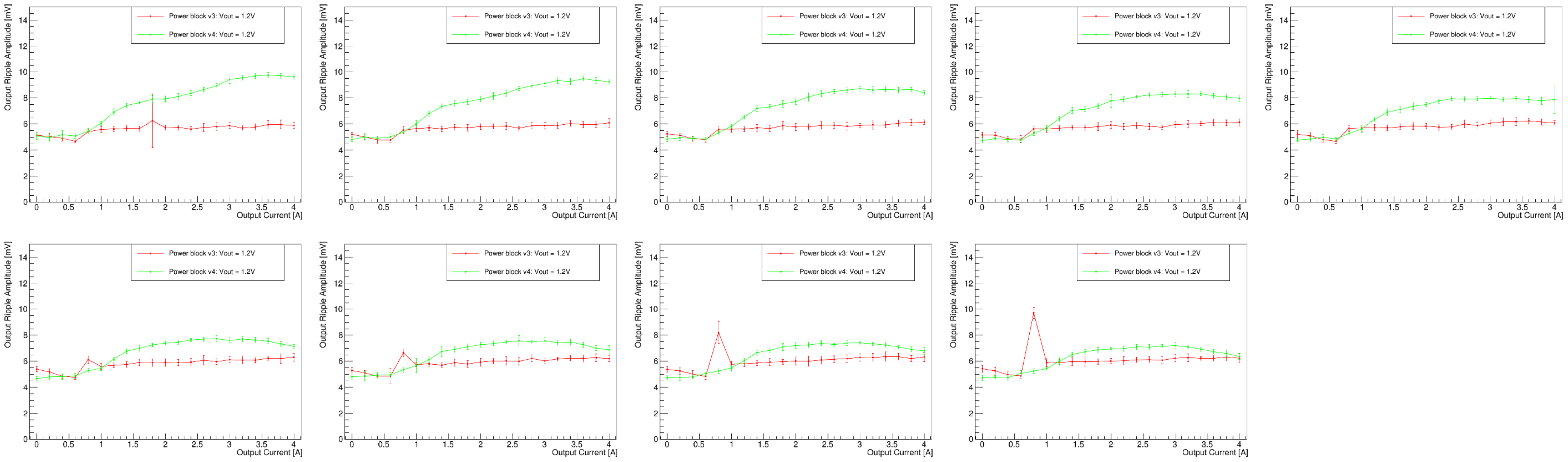
- ✓ Taking Vin = 11V as an example, for both Vout = 1.2V and Vout = 2.5V cases:
  - ✓ In low Iout region: P4 has better efficiency than p3.
  - ✓ In high Iout region: P4 has similar efficiency as p3.
- ✓ More results for other Vin can be seen in backup. -> Conclusions are similar.

Output ripple

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

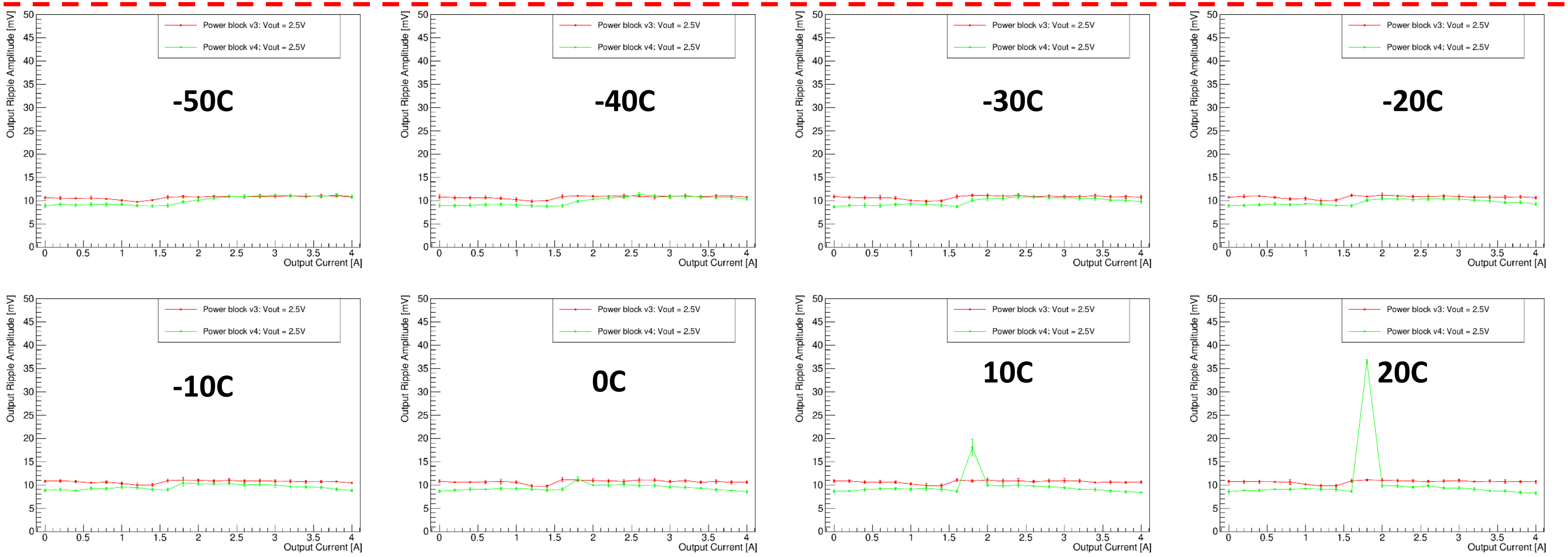


Efficiency (Vout = 1.2V, Vin = 11V)



Output ripple

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

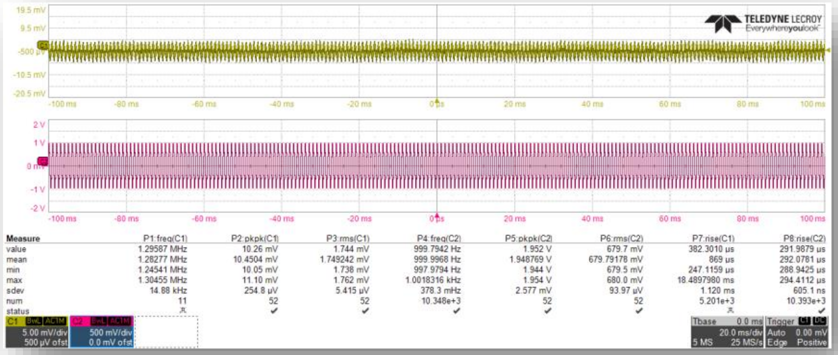


- ✓ For Vout = 1.2V:
  - ✓ In general, p4 has worse ripple than p3.
  - ✓ p3 has peak at Iout = 0.8A for some cases.
- ✓ For Vout = 2.5V:
  - ✓ In general, p4 has better ripple than p3.
  - ✓ p4 has peak at Iout = 1.8A for some cases.

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

Ripple suppression ability

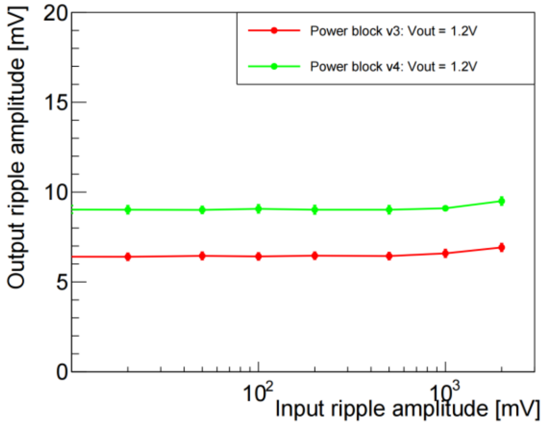
- To test ripple suppression ability for BPOL12V, we provide input ripple using KEYSIGHT N6705C source meter and measure output ripple.
- Test setup: T=-30C, Iout = 3A, based voltage = 11V, sine ripple frequency = 50HZ/1000HZ.

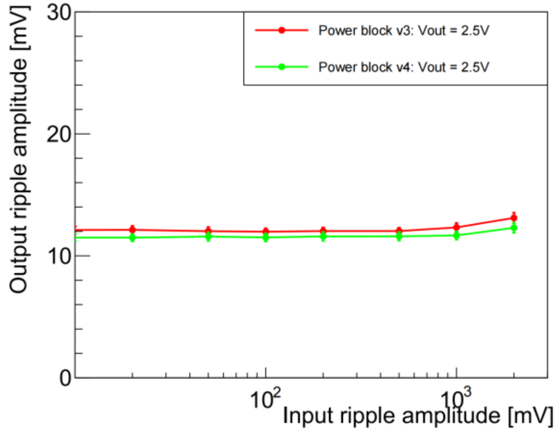


Output ripple

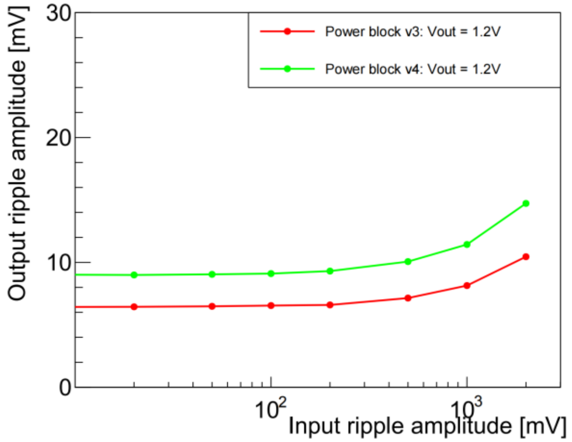
Input ripple

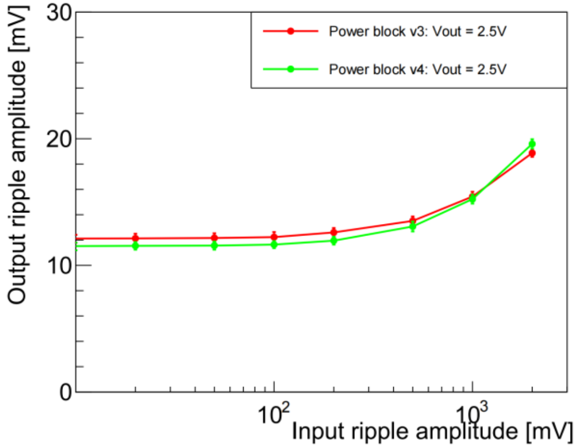
Input ripple frequency = 50HZ





Input ripple frequency = 1000HZ

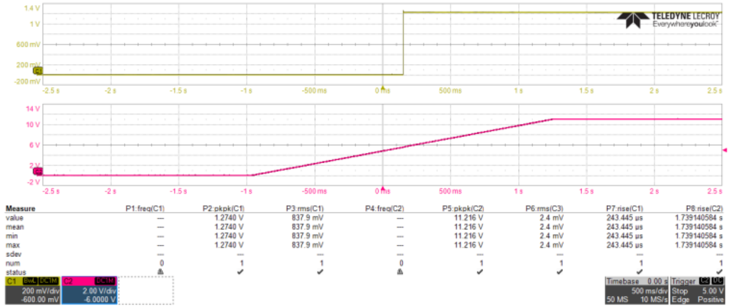




✓ For all BPOL12V, input ripple below 100mV has negligible effect on the output ripple.

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%).

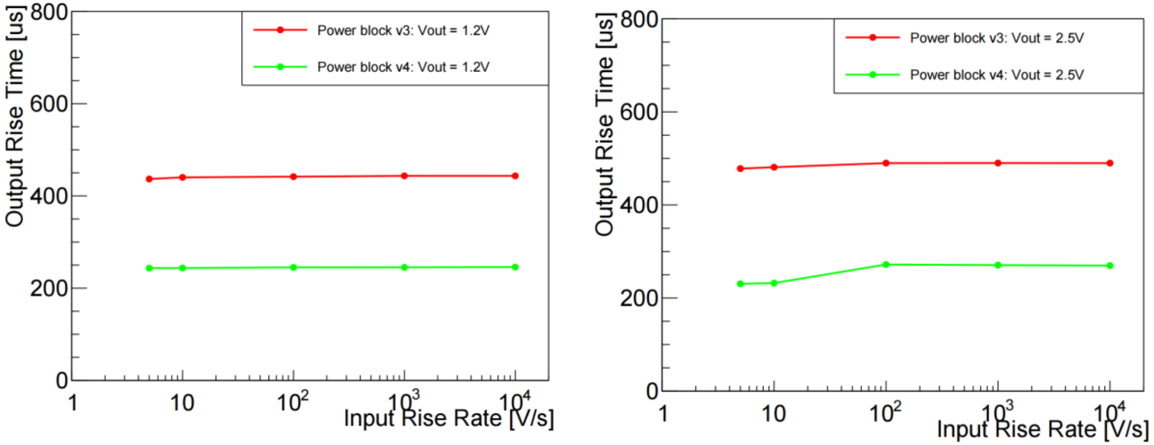


output rising time

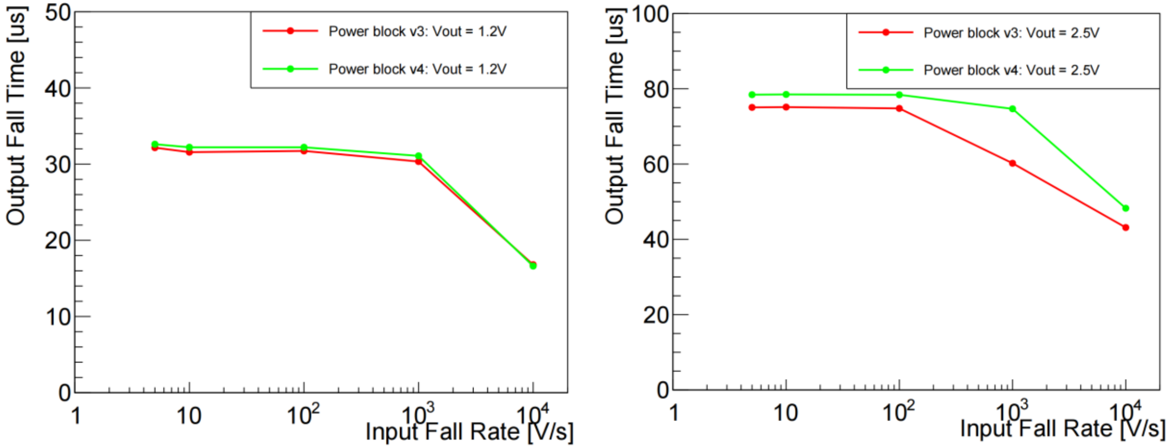
Input rising time

- Test setup: T=-30C, Iout = 3A, target input voltage = 12V

Rising time test



Falling time test



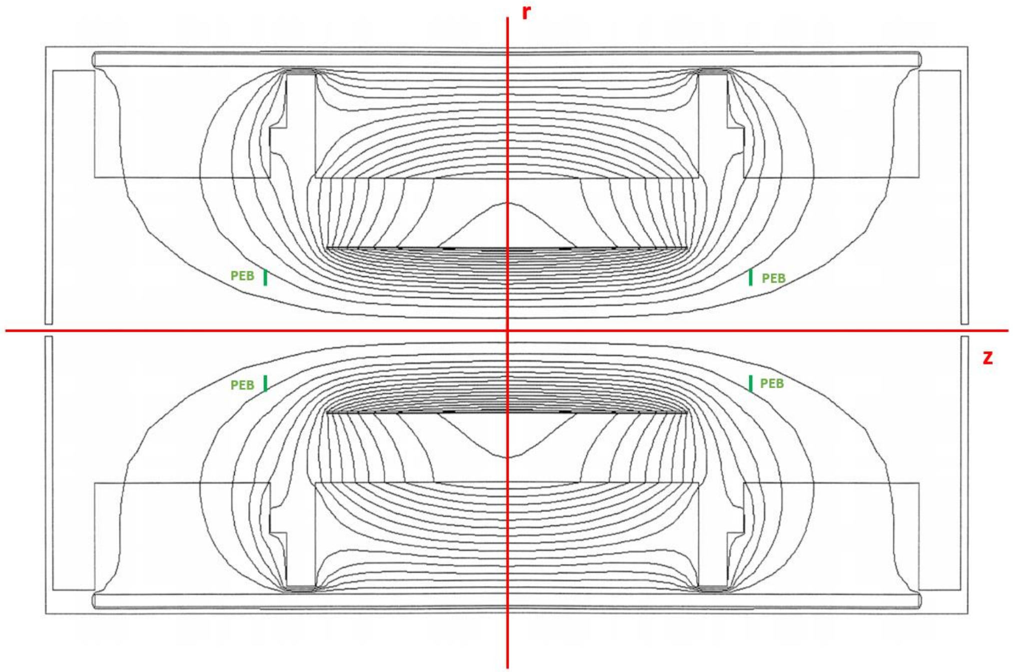
✓ Input rising rate has negligible impact on output rising time.

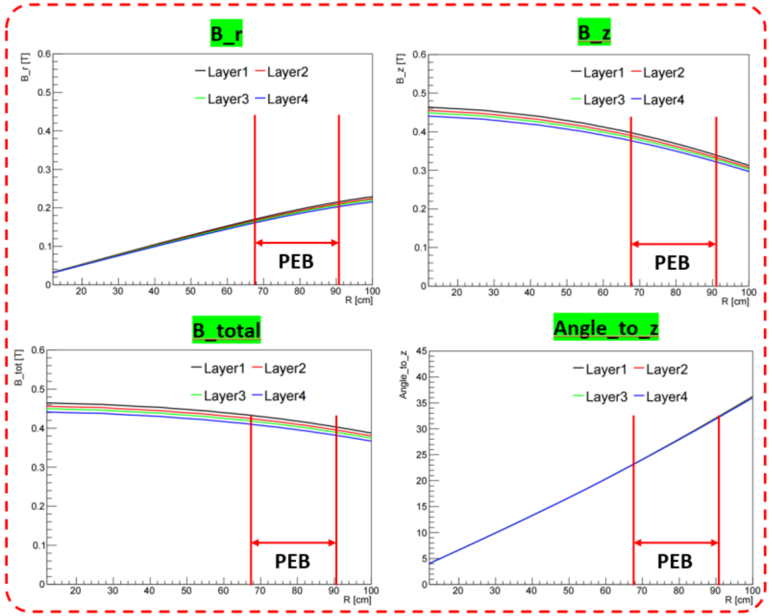
✓ Input falling rate has some impact on output falling time. But in overall, falling time is smaller than 100us.

BPOL12V performance study in magnetic field

Magnetic field in PEB region

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





	Value
B_r	0.161 - 0.215 T
B_z	0.323 - 0.398 T
B_tot	0.382 - 0.433 T
Angle to z	23.1 – 32.3°

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

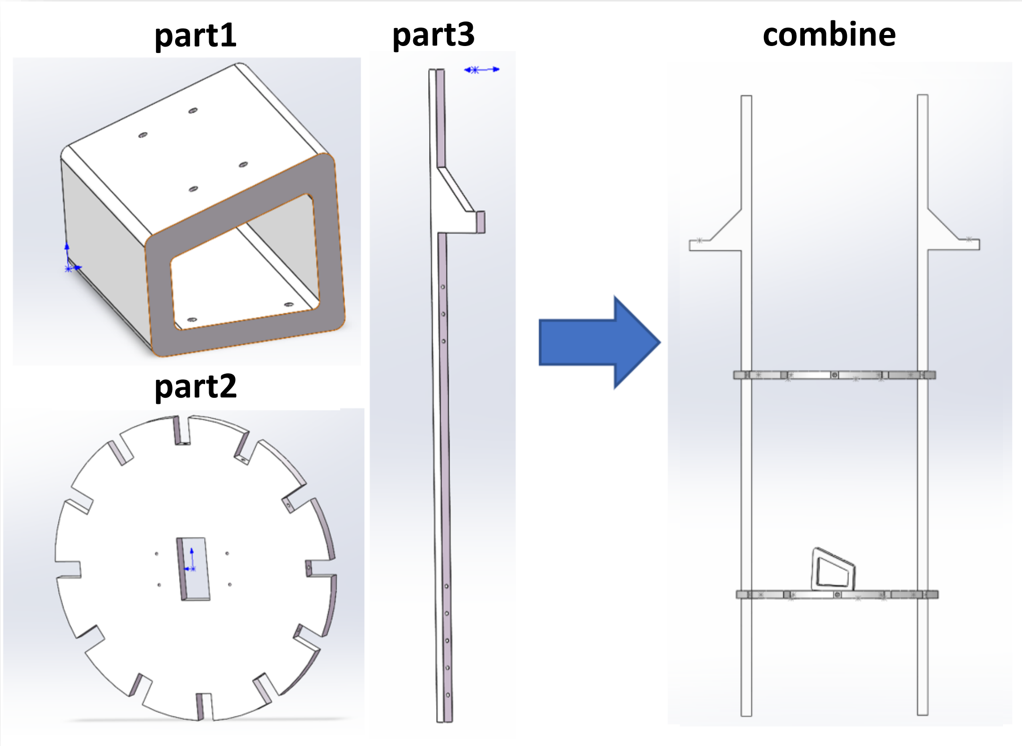
Test plan

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°**.

Magnetic barrel

Supporting meterail

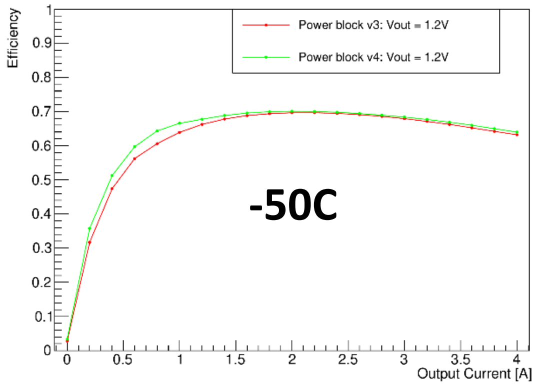


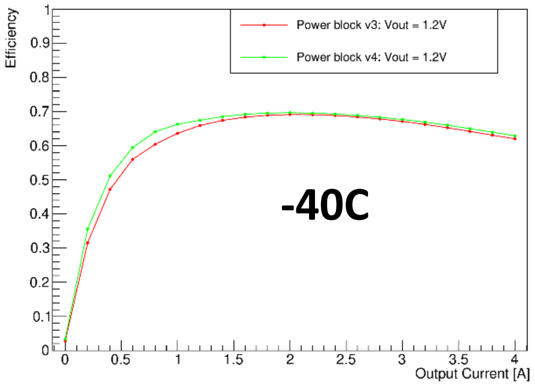
Summary and plan

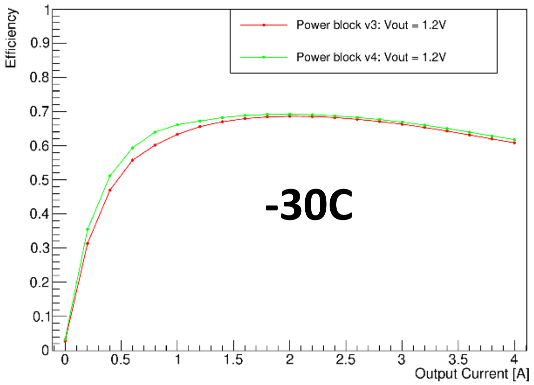
- Summary:
  - The BPOL12V will work in low temperature (around -30C) and magnetic field (around 0.4T) conditions during operation, so a comprehensive study of its performance is essential.
  - We have performed some study for BPOL12V at low temperature, including efficiency, output ripple, ripple suppression 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.

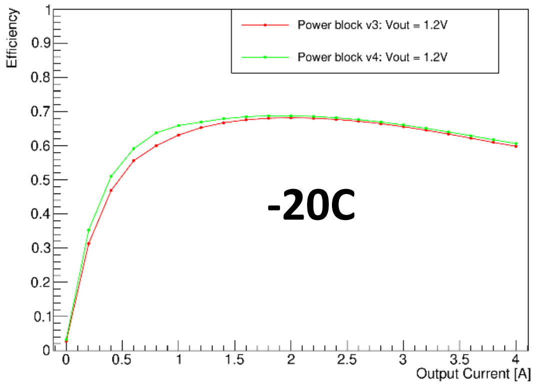
Backup

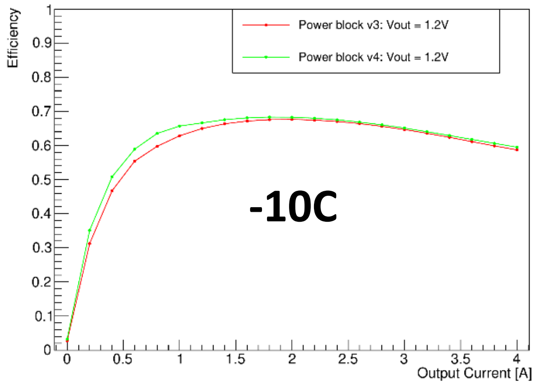
Efficiency (Vout = 1.2V, Vin = 9V)

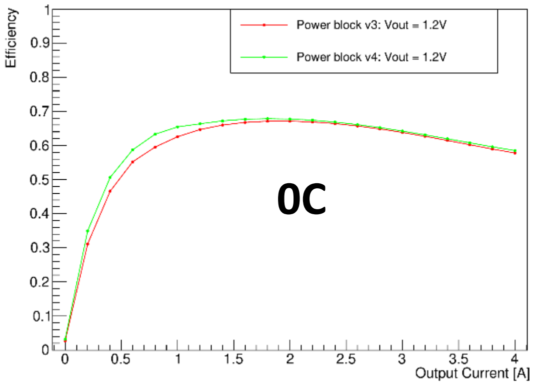


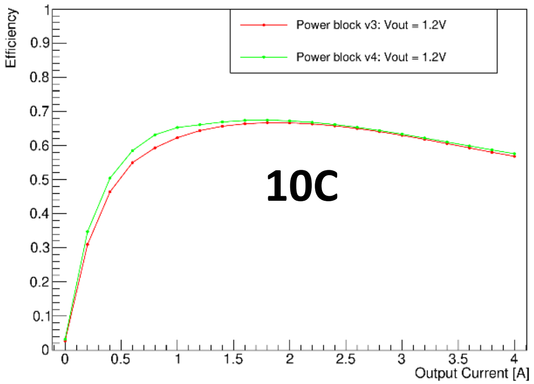


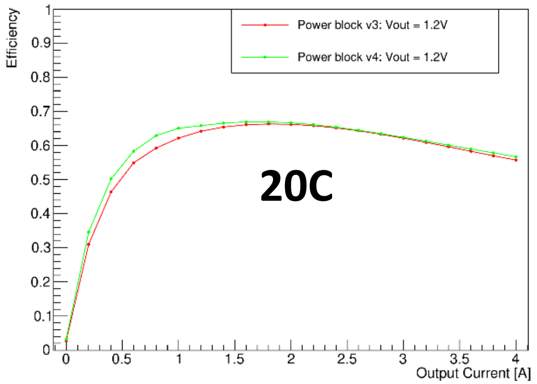


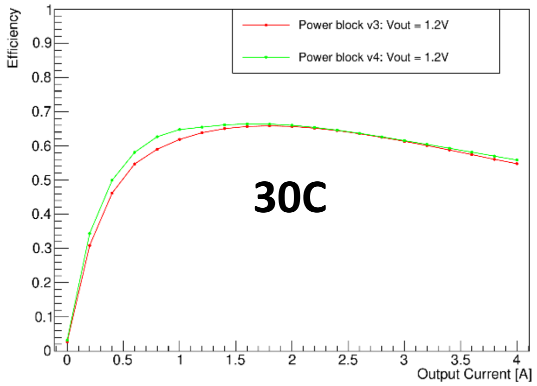




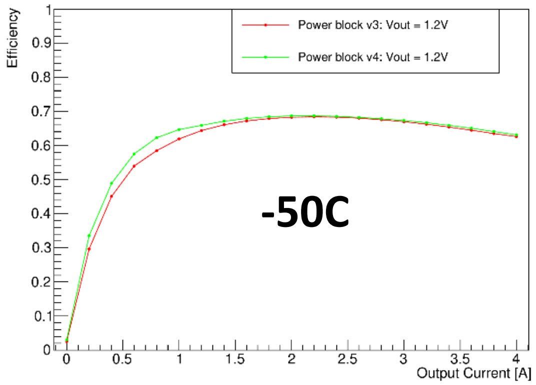


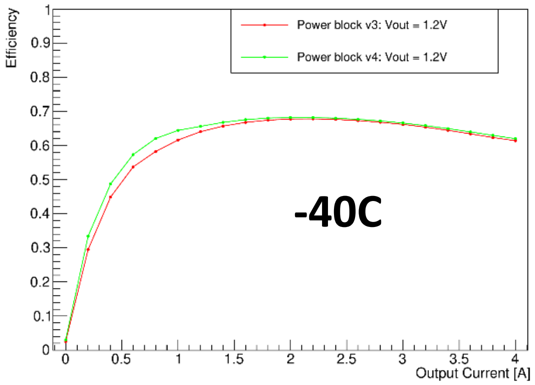


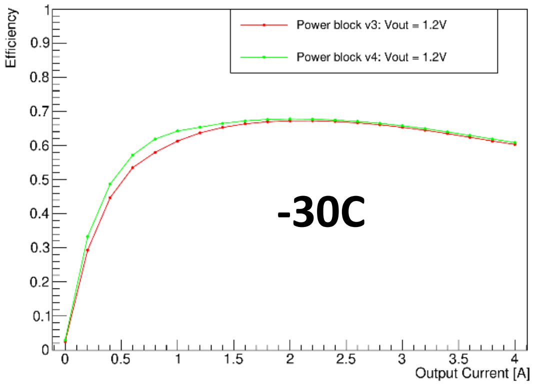


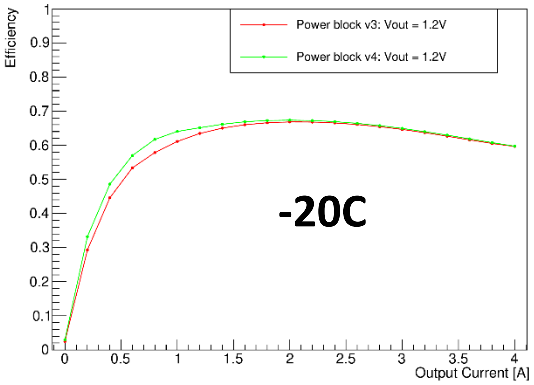


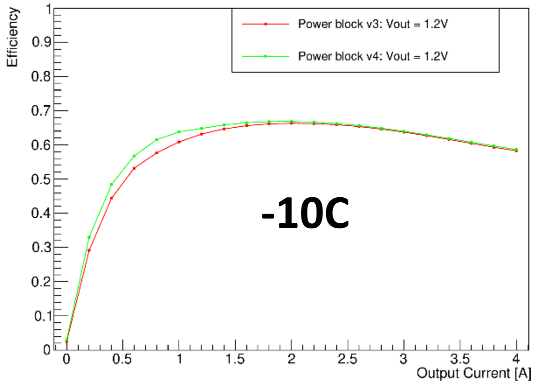
Efficiency (Vout = 1.2V, Vin = 10V)

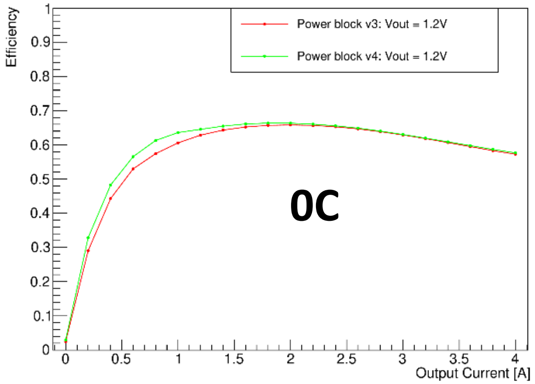


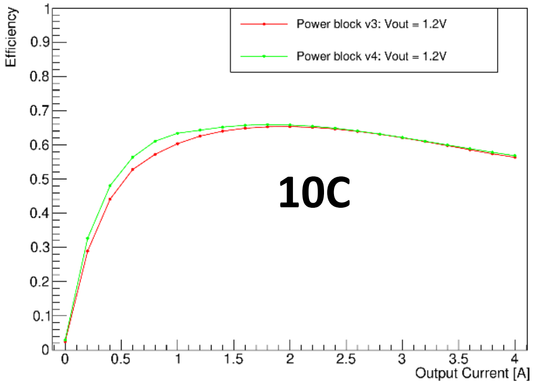


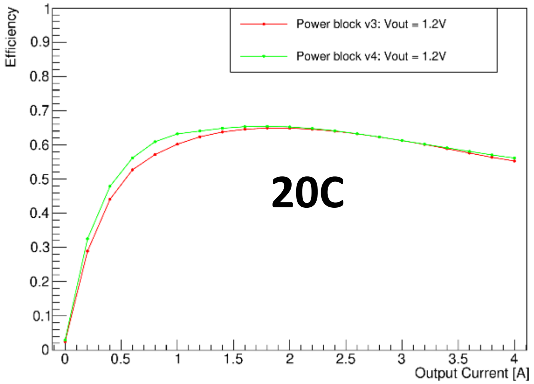


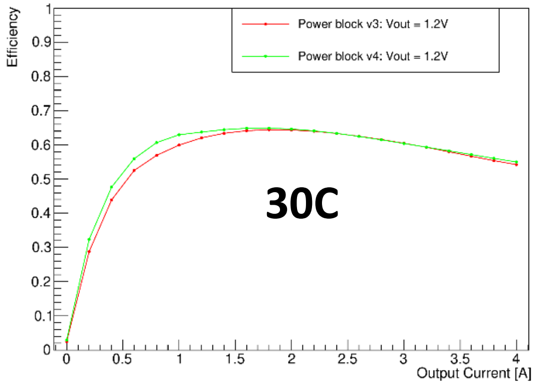




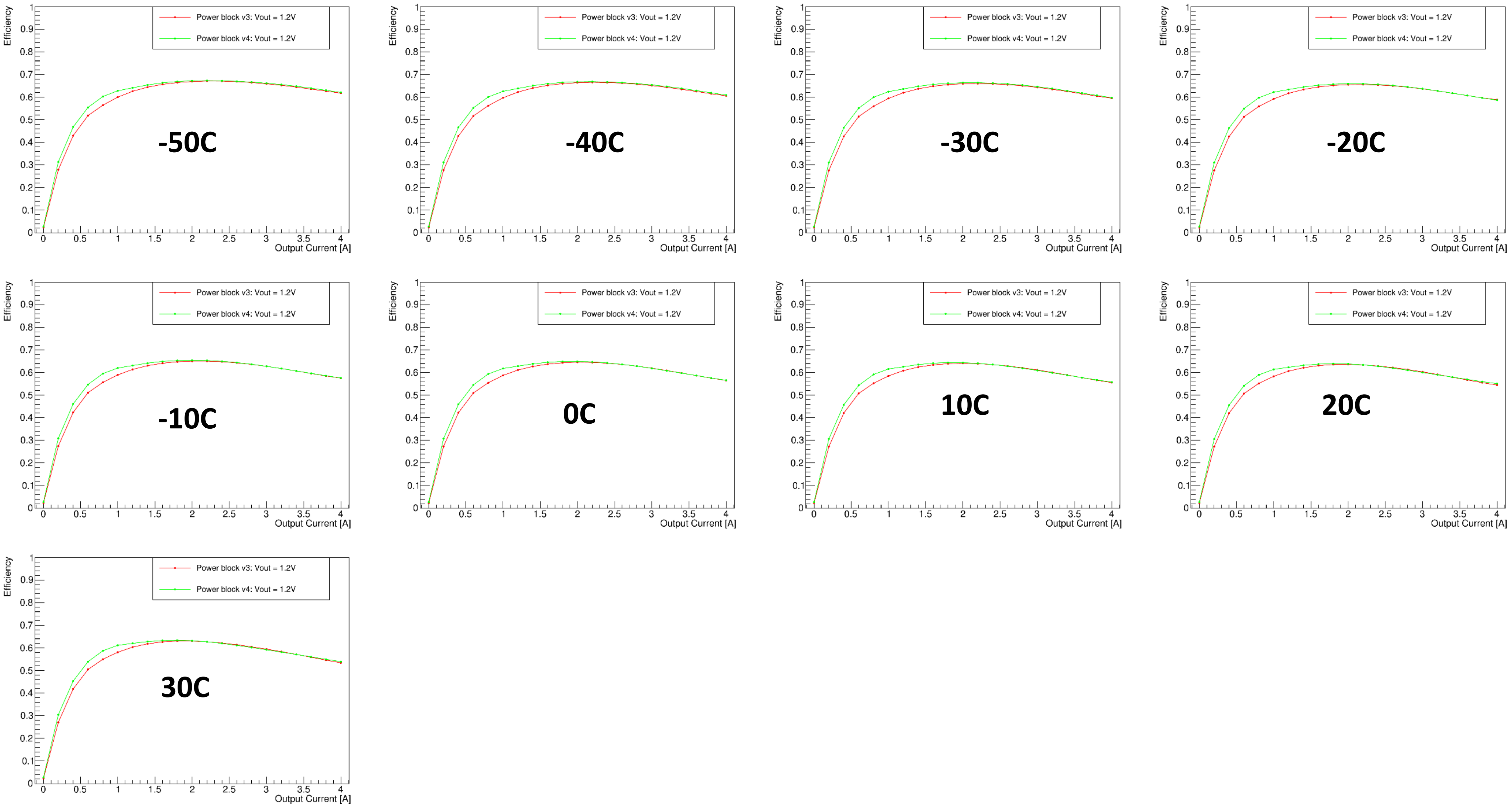




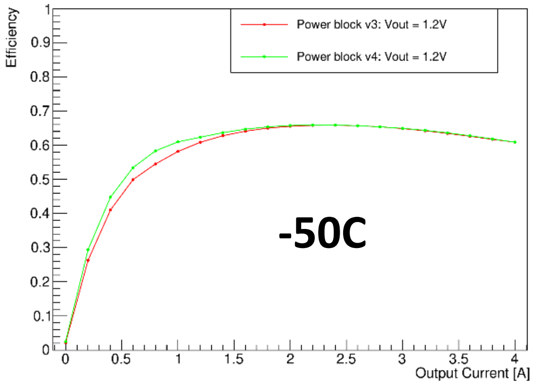


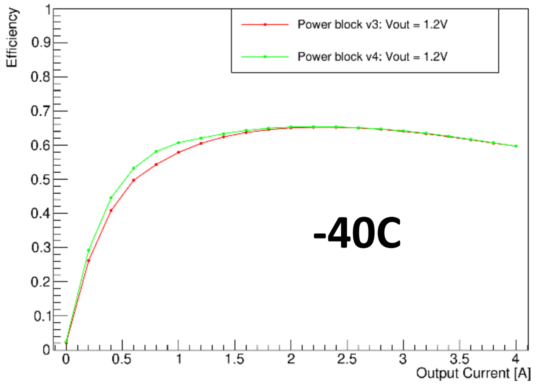


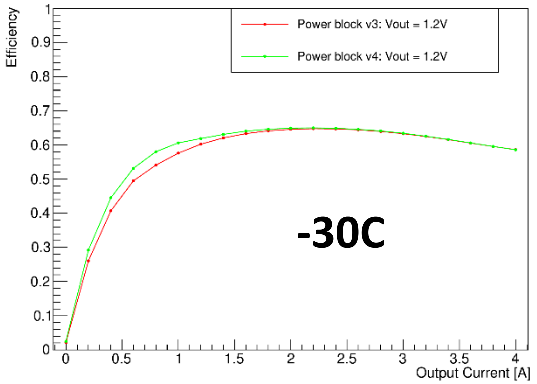
Efficiency (Vout = 1.2V, Vin = 11V)

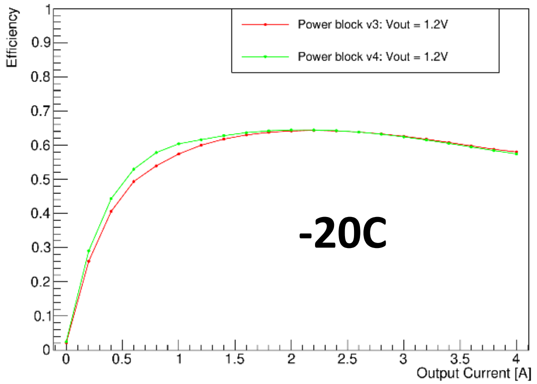


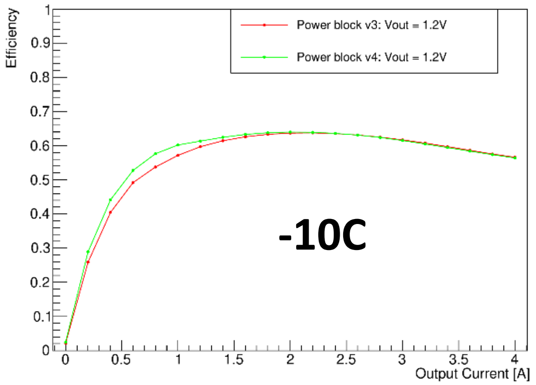
Efficiency (Vout = 1.2V, Vin = 12V)

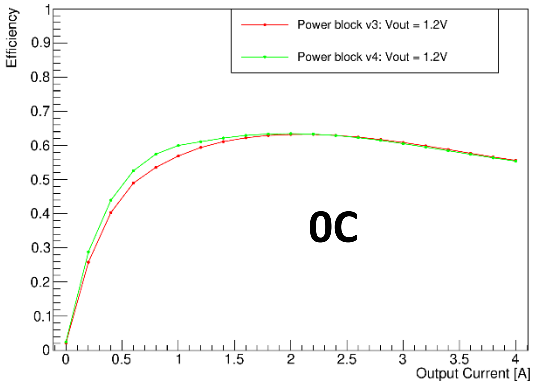


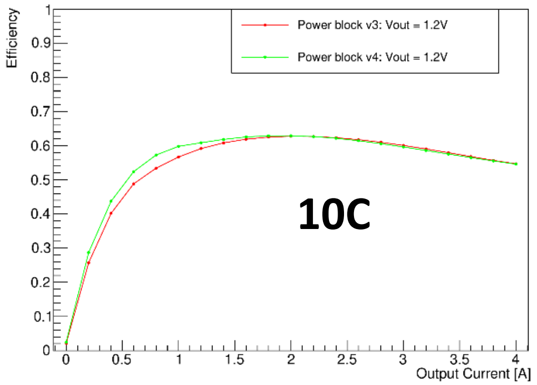


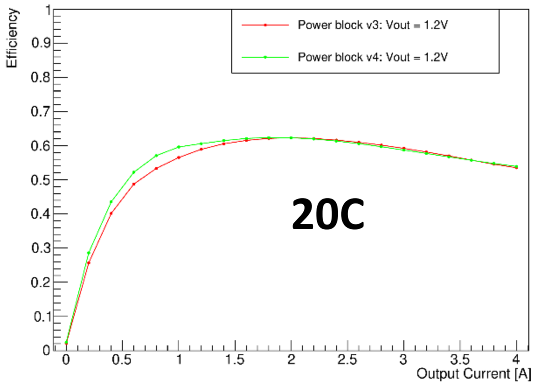


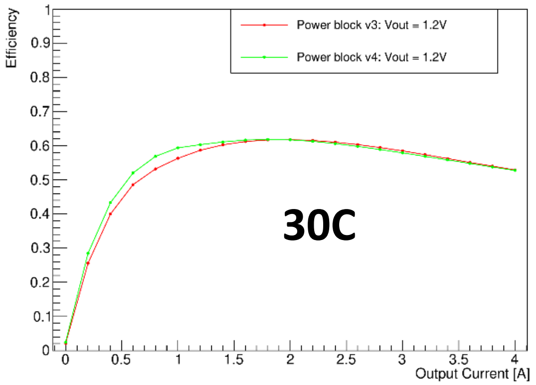




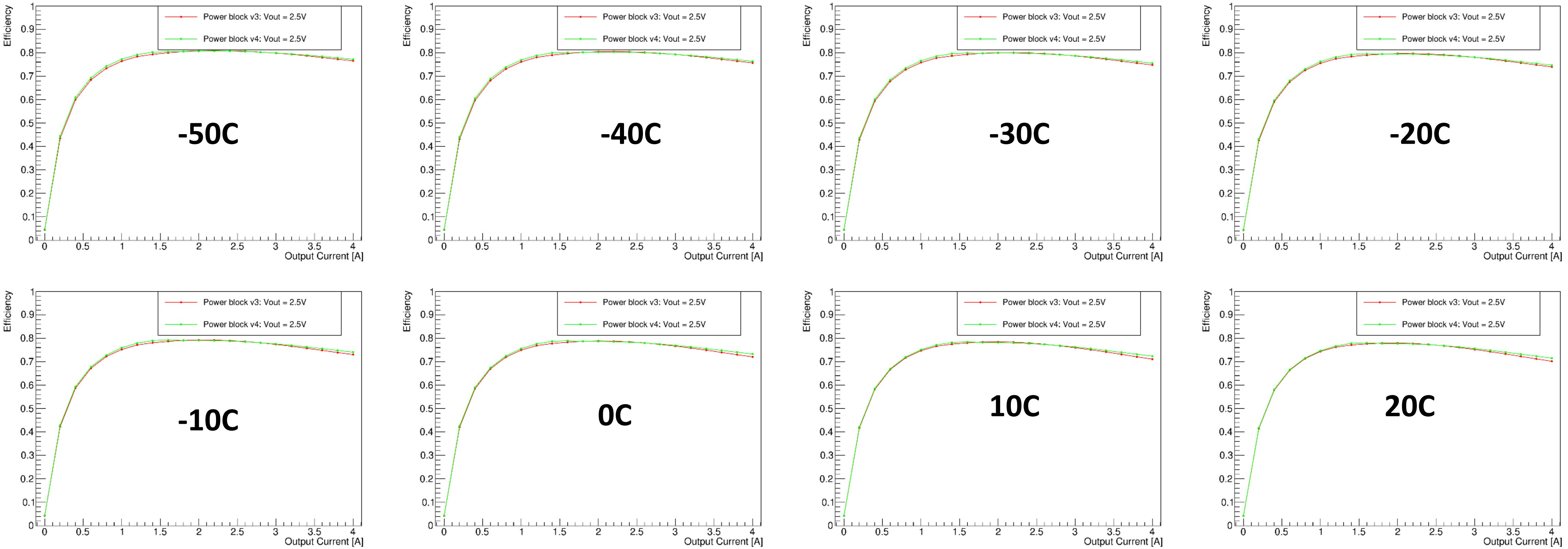




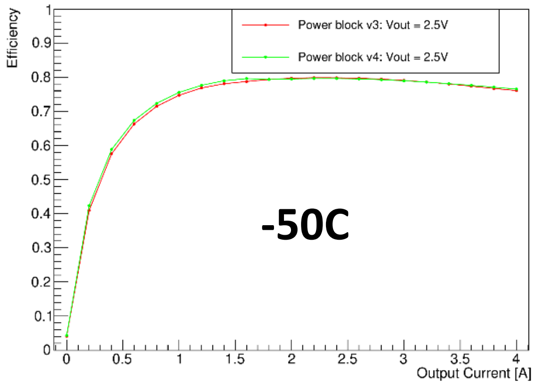


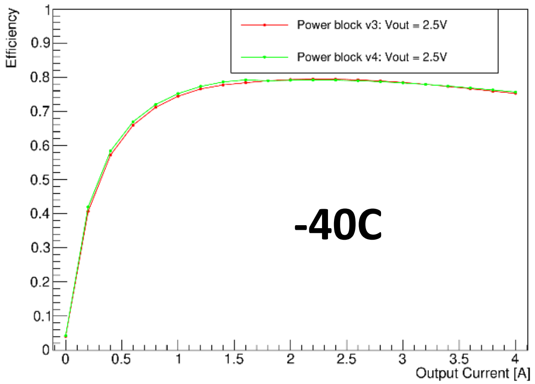


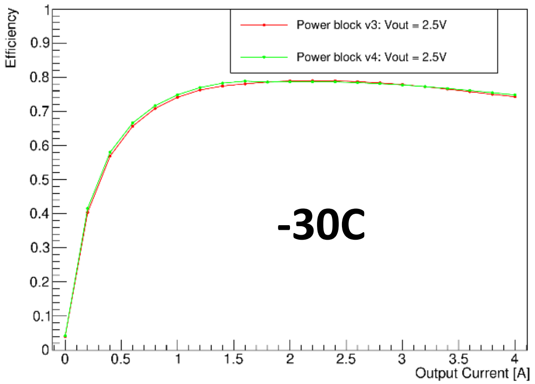
Efficiency (Vout = 2.5V, Vin = 9V)

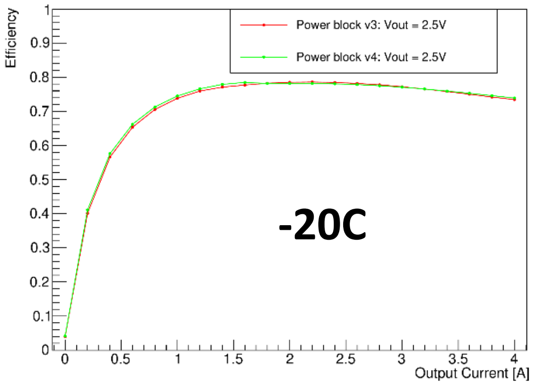


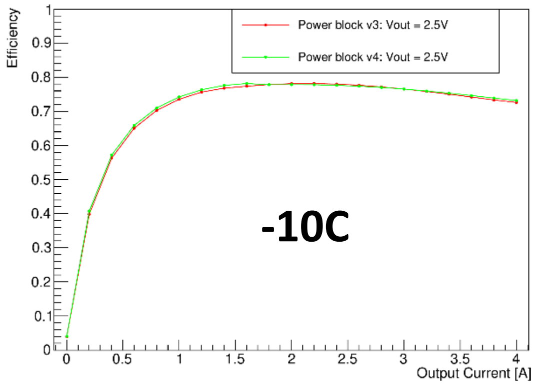
Efficiency (Vout = 2.5V, Vin = 10V)

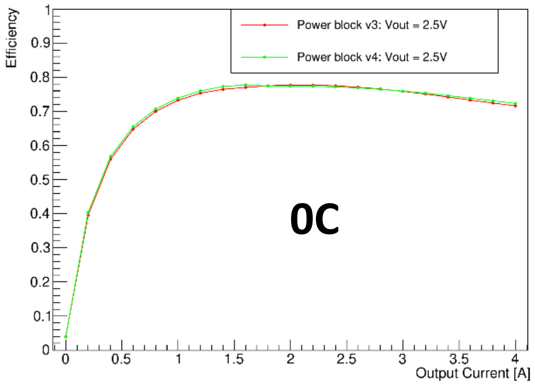


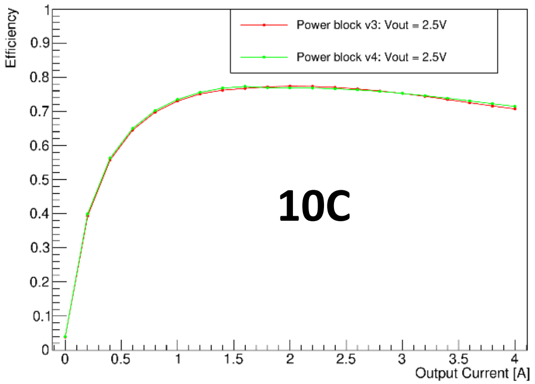


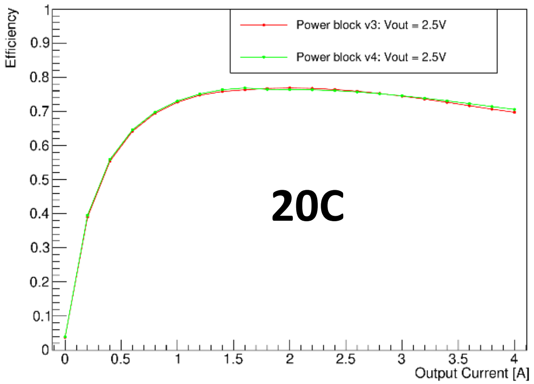




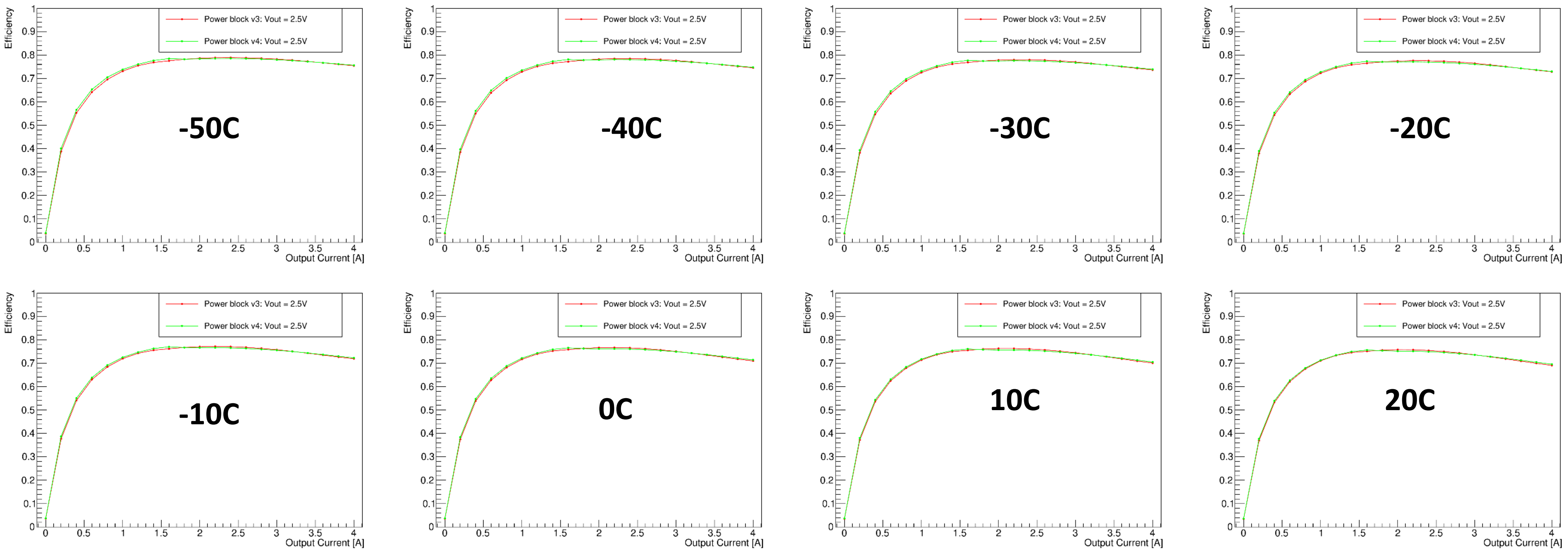




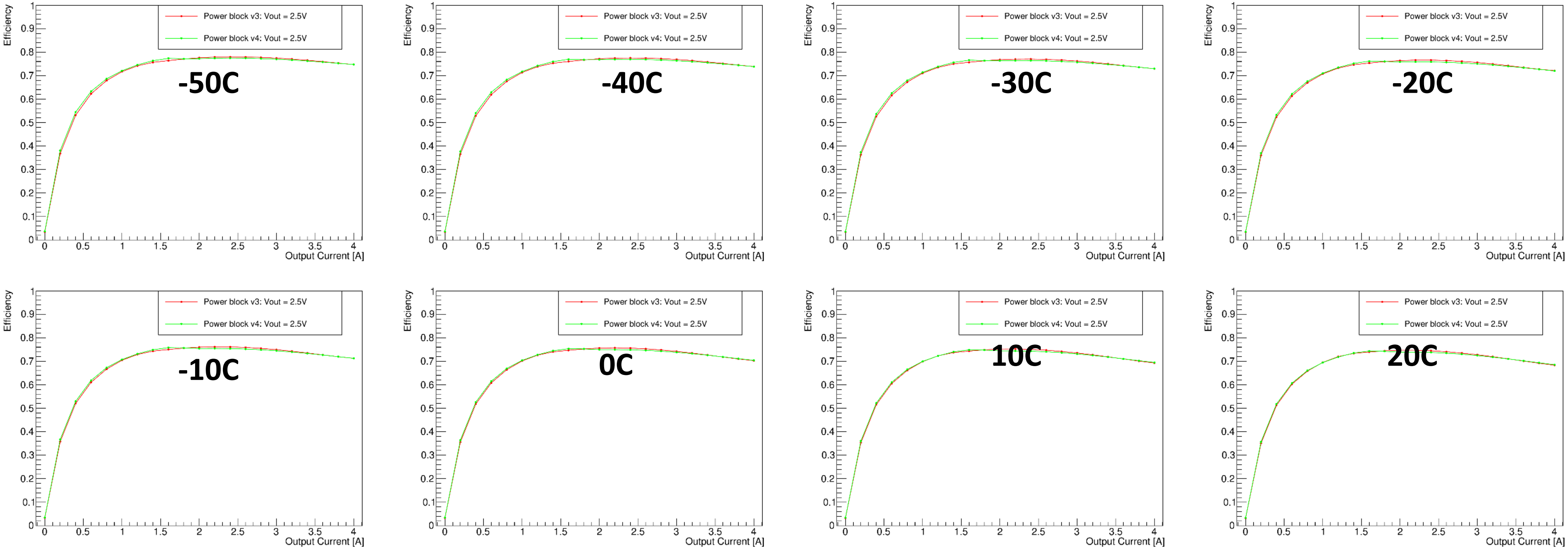




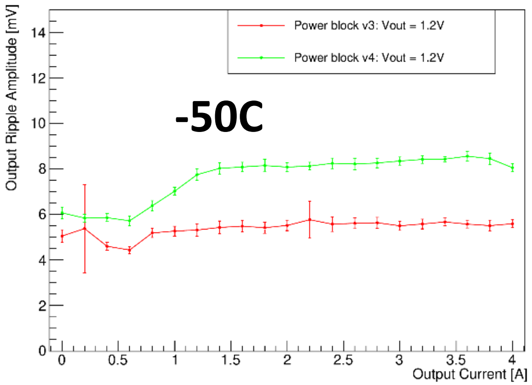
Efficiency (Vout = 2.5V, Vin = 11V)

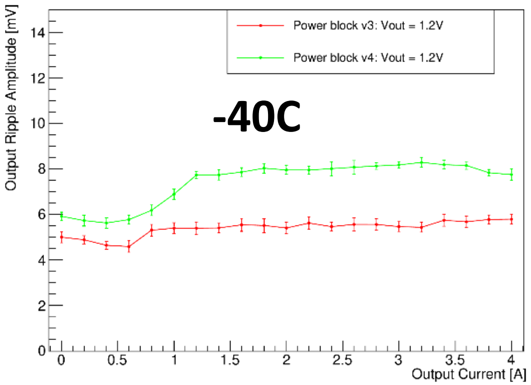


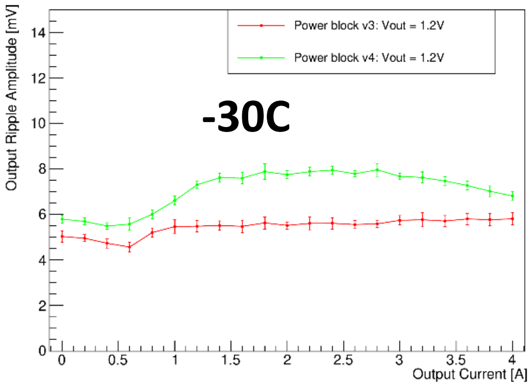
Efficiency (Vout = 2.5V, Vin = 12V)

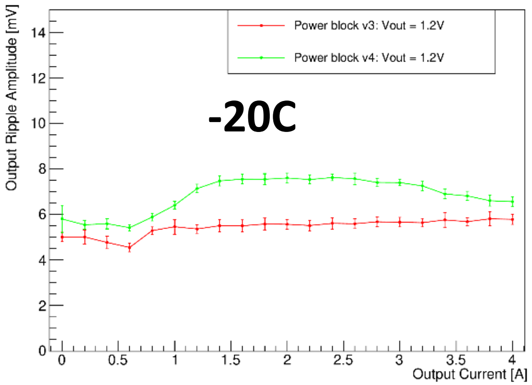


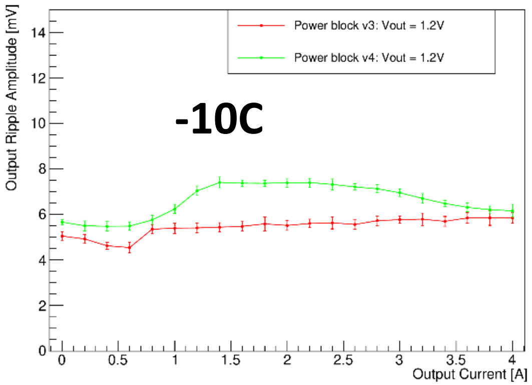
Output ripple (Vout = 1.2V, Vin = 9V)

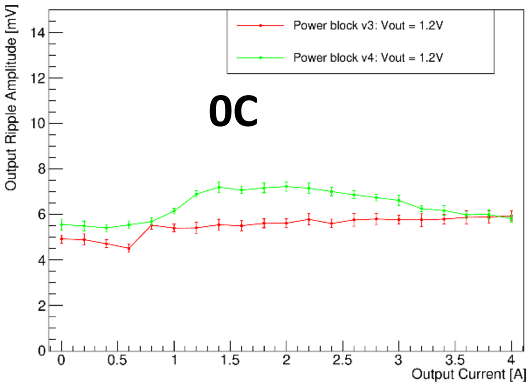


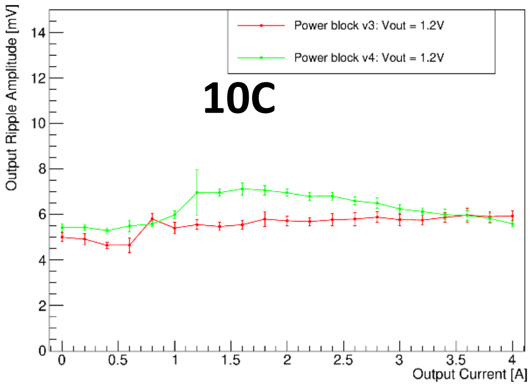


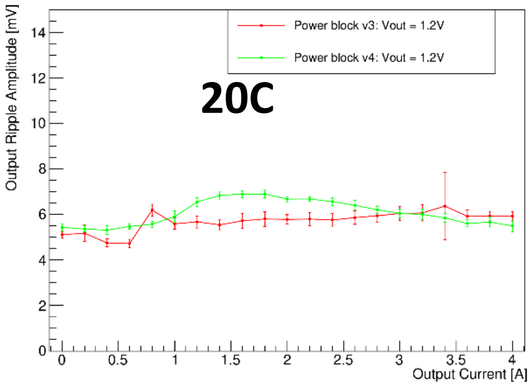


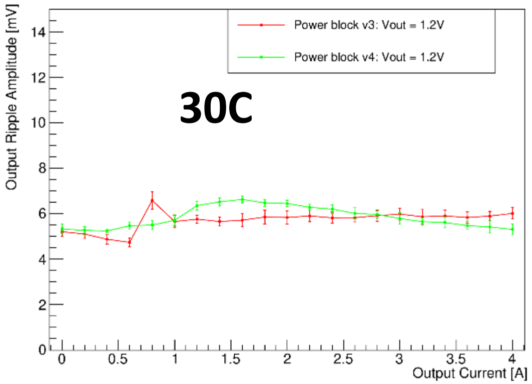




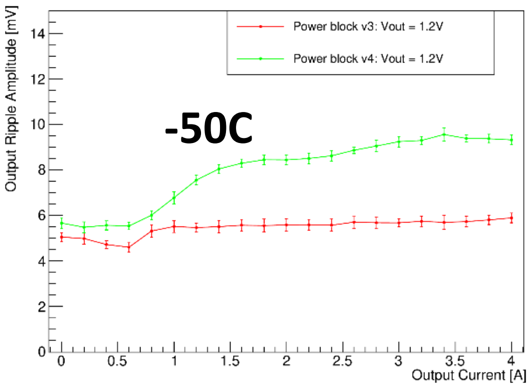


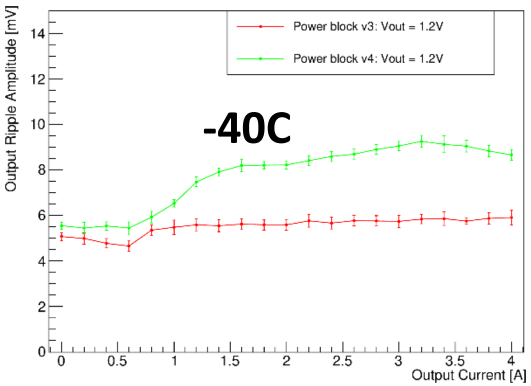


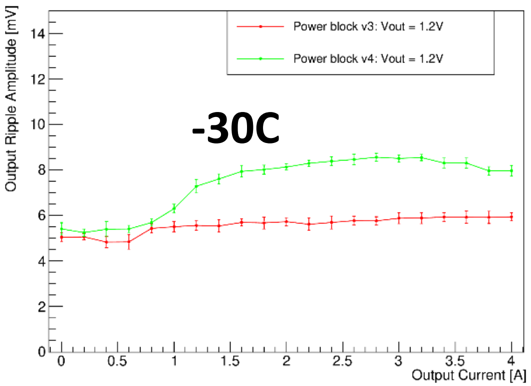


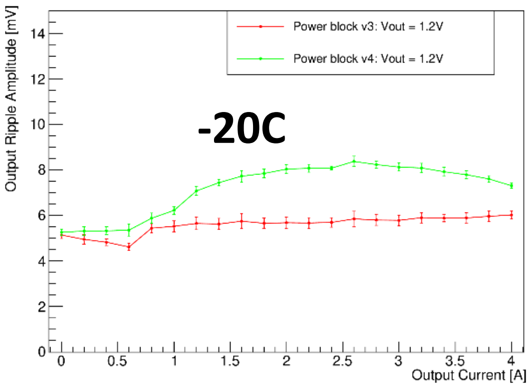


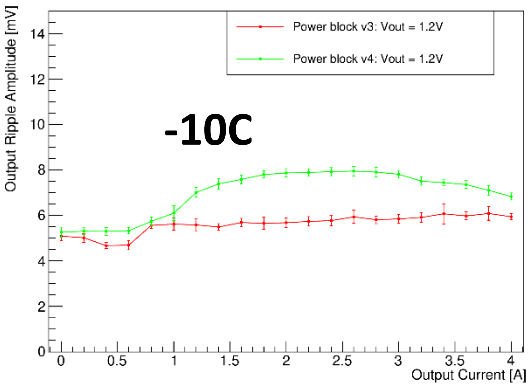
Output ripple (Vout = 1.2V, Vin = 10V)

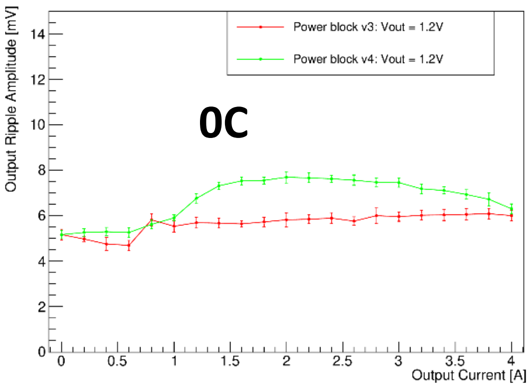


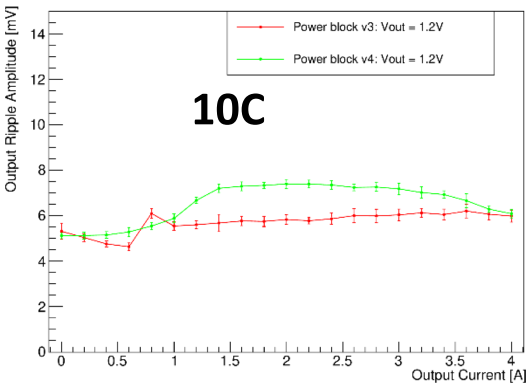


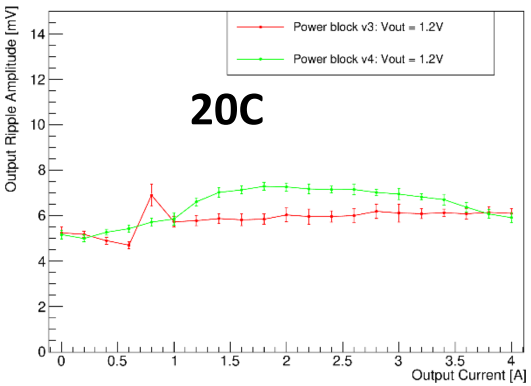


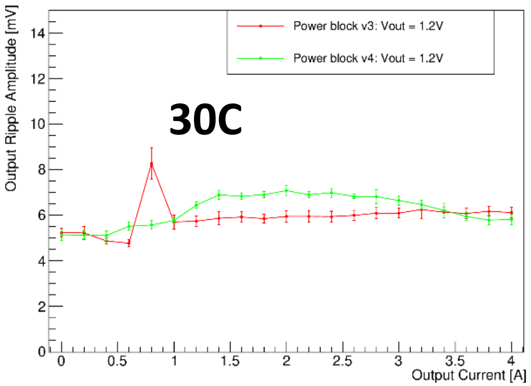




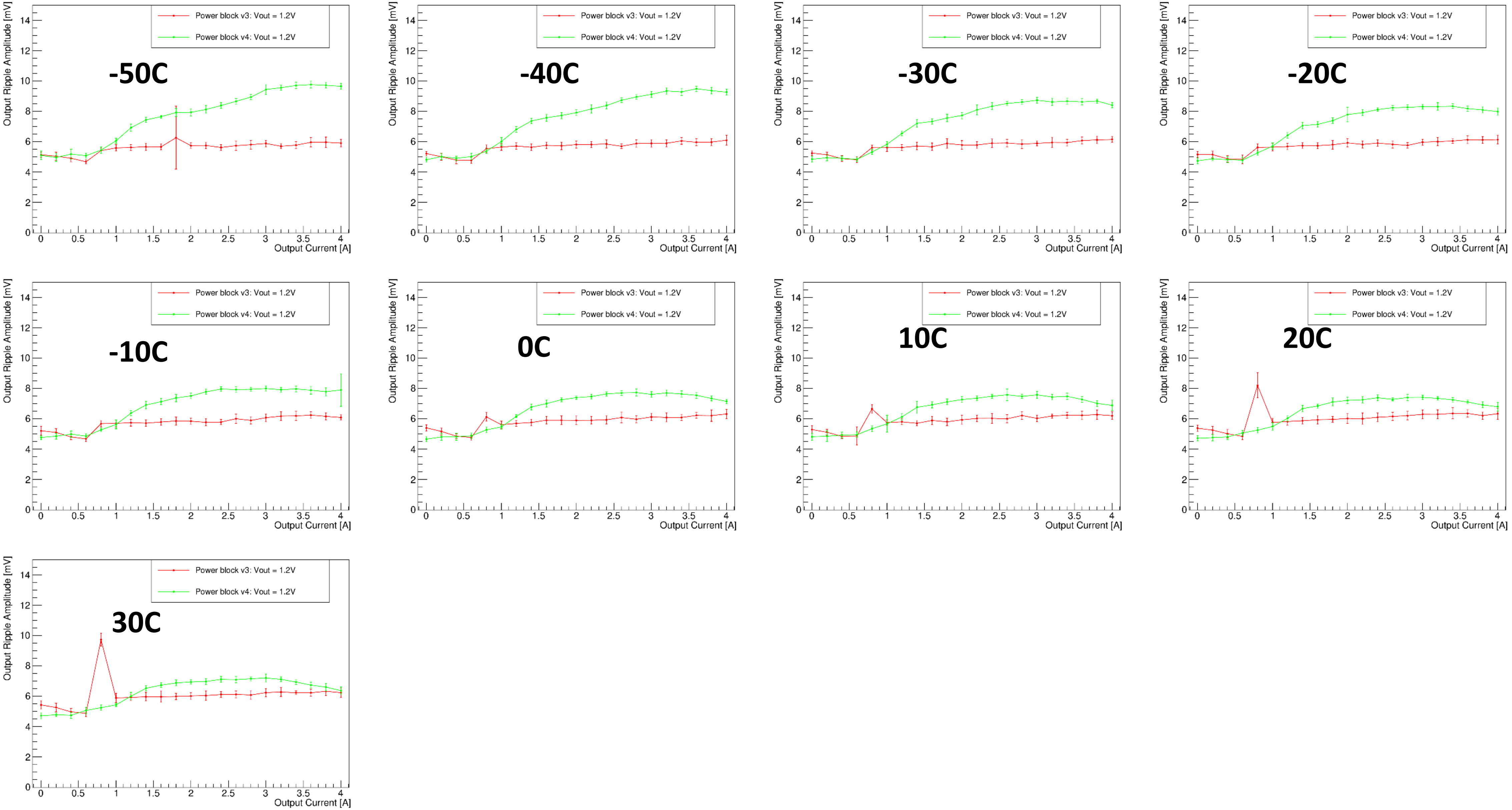




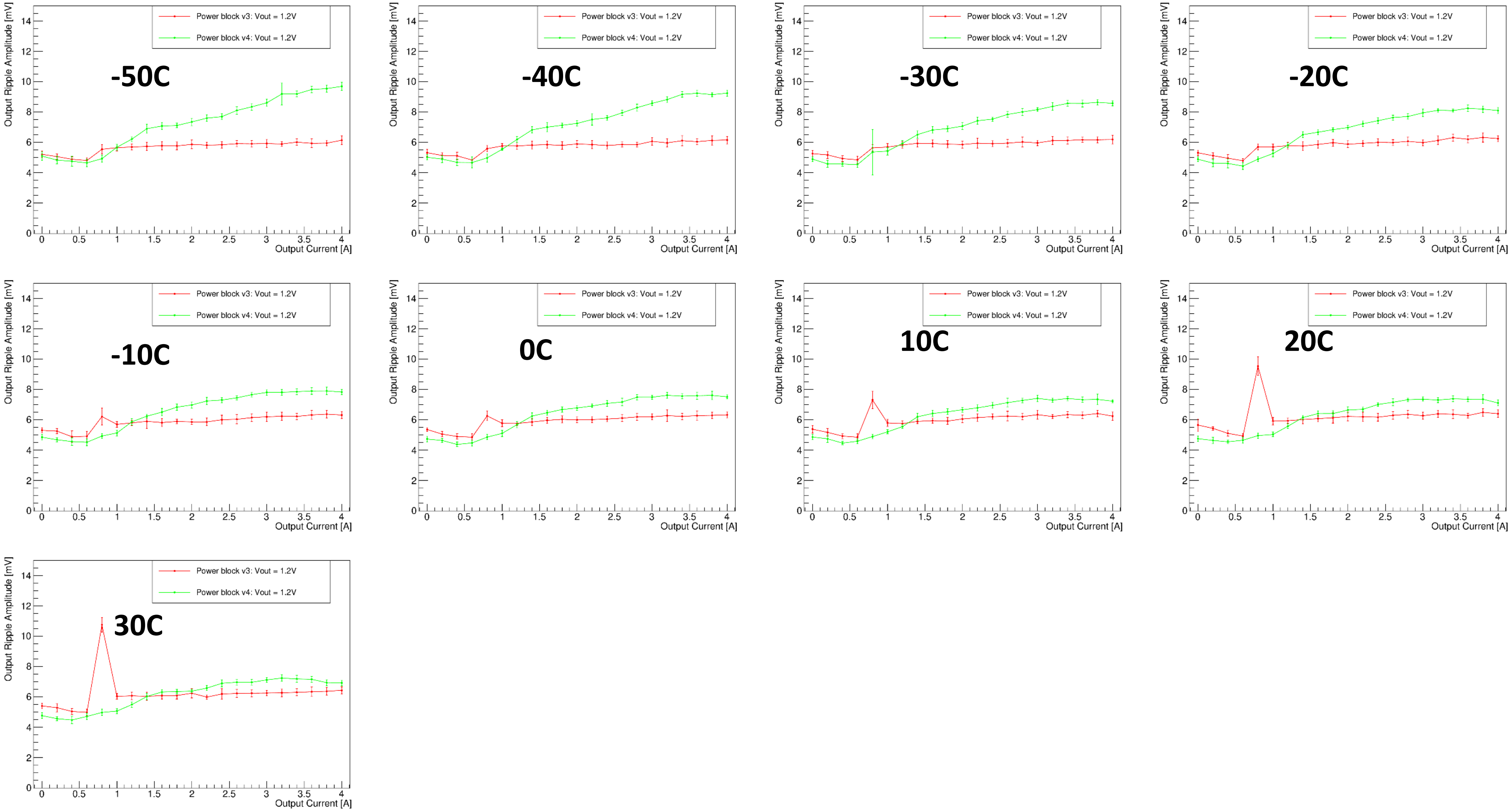




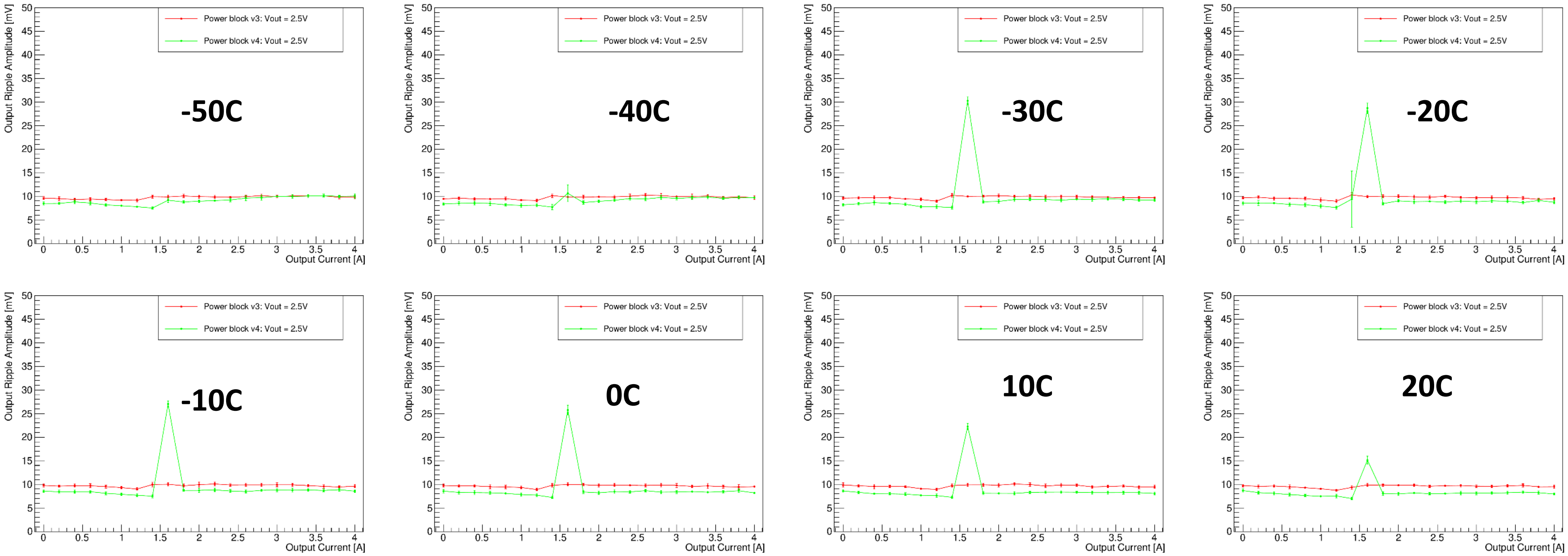
Output ripple (Vout = 1.2V, Vin = 11V)



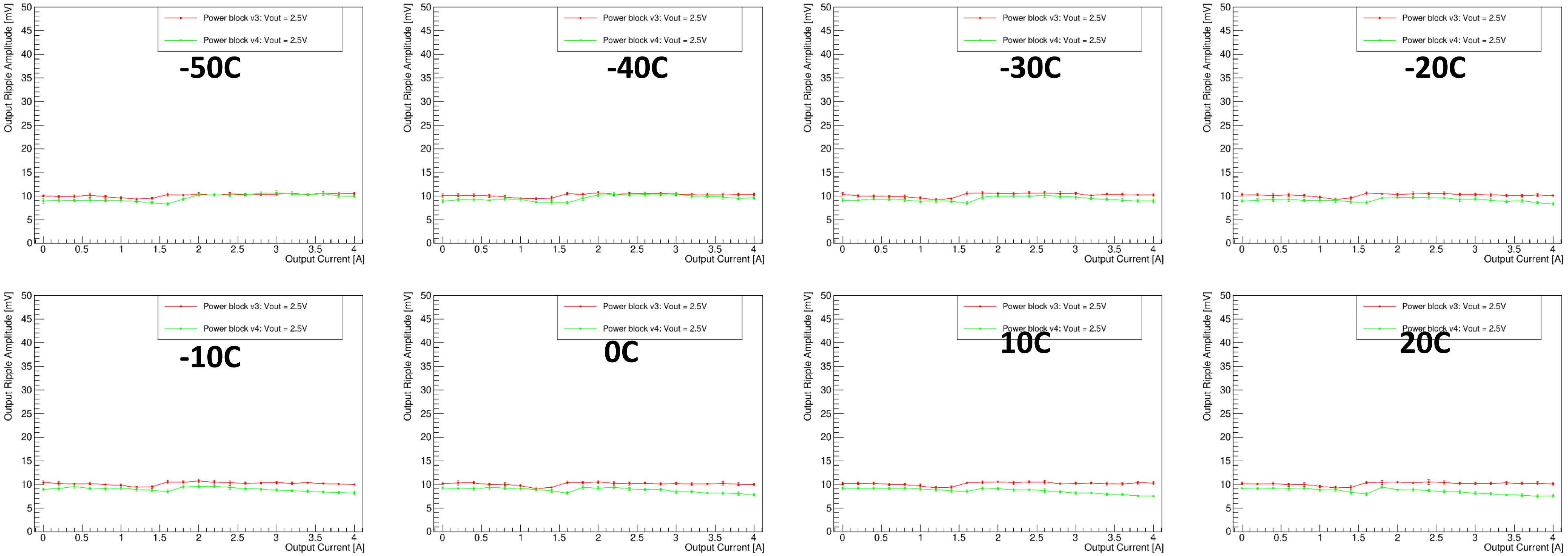
Output ripple (Vout = 1.2V, Vin = 12V)



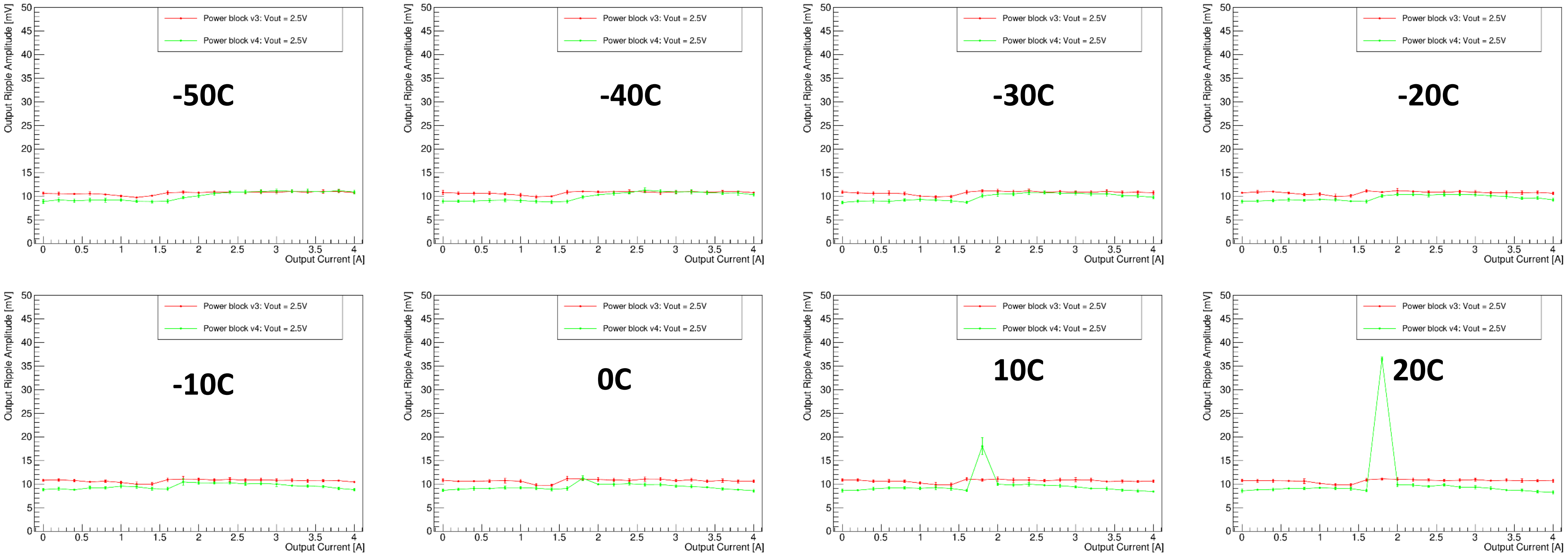
Output ripple (Vout = 2.5V, Vin = 9V)



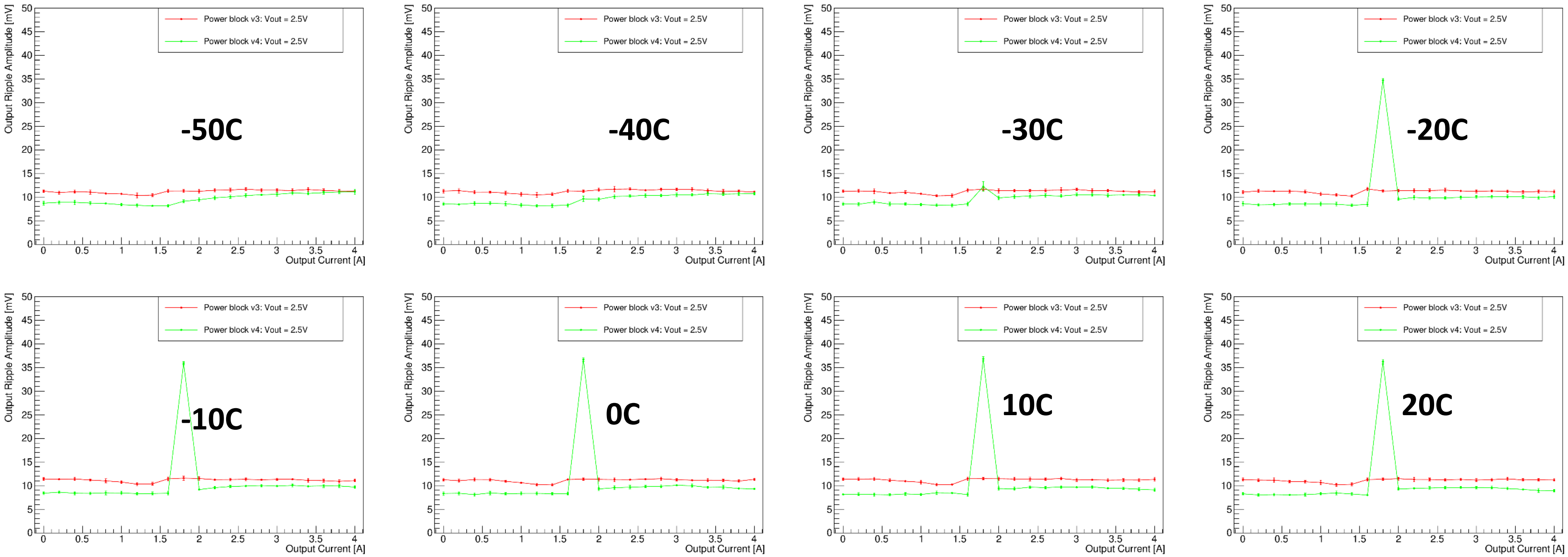
Output ripple (Vout = 2.5V, Vin = 10V)



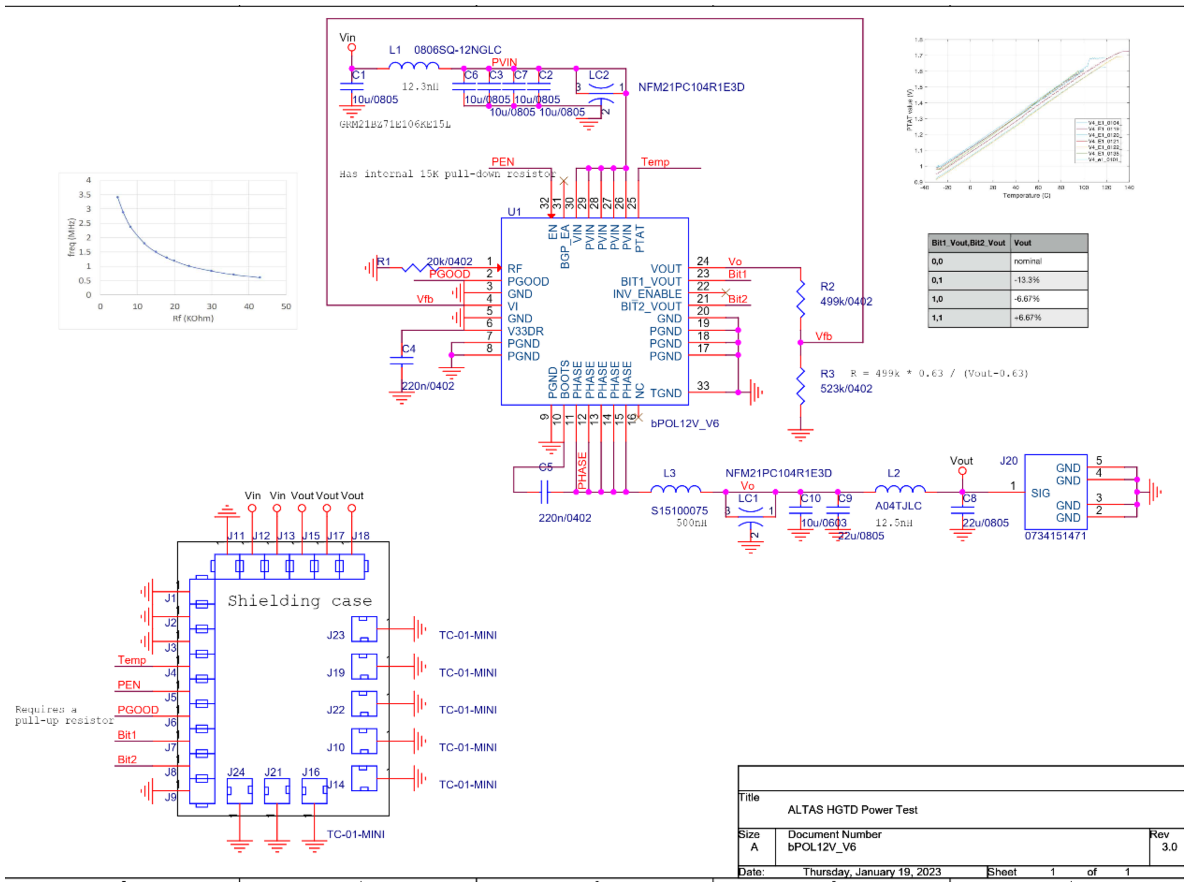
Output ripple (Vout = 2.5V, Vin = 11V)



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

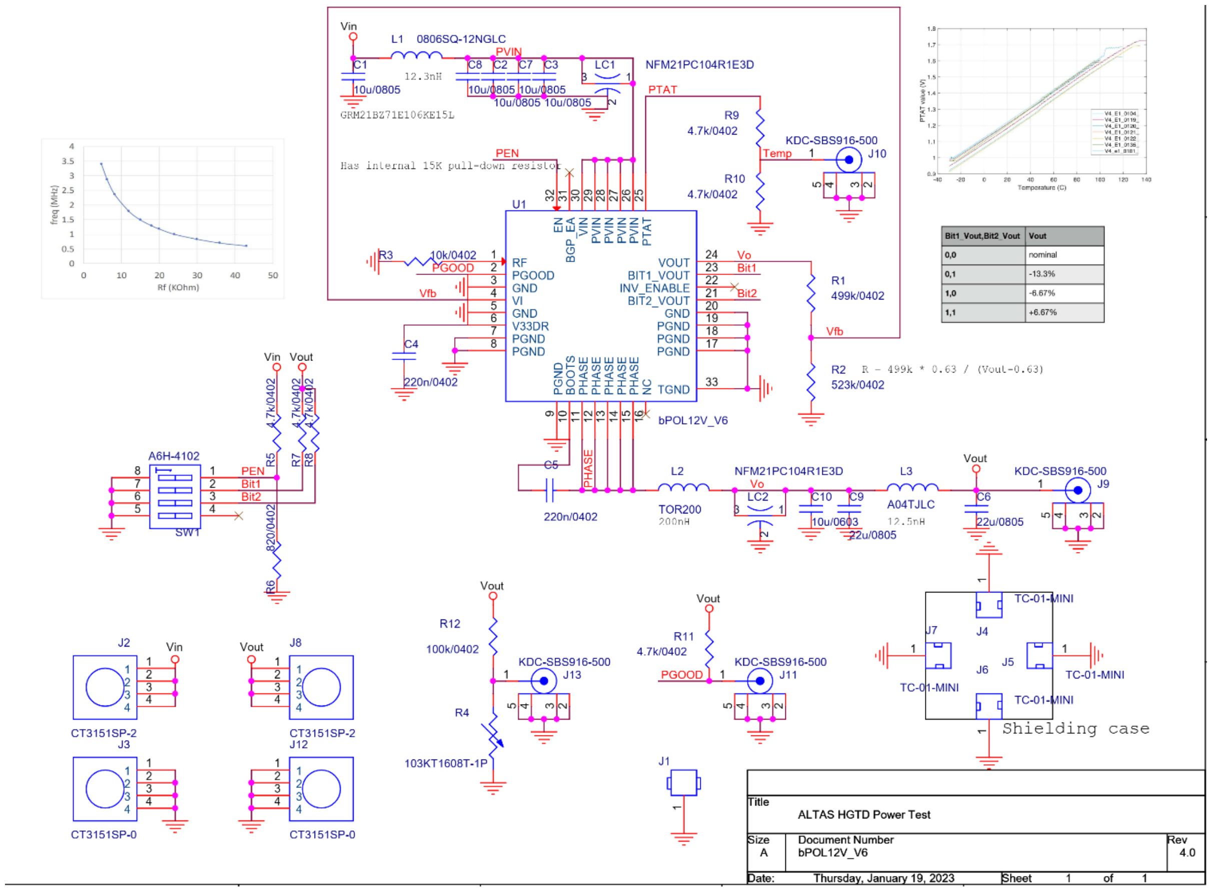


BPOL12V_v3



Bit1_Vout,Bit2_Vout	Vout
0,0	nominal
0,1	-13.3%
1,0	-6.67%
1,1	+6.67%

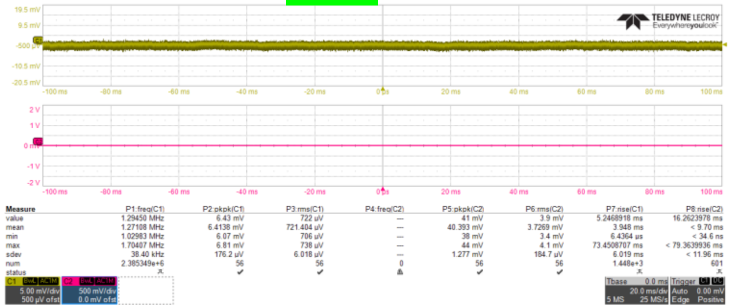
BPOL12V_v4



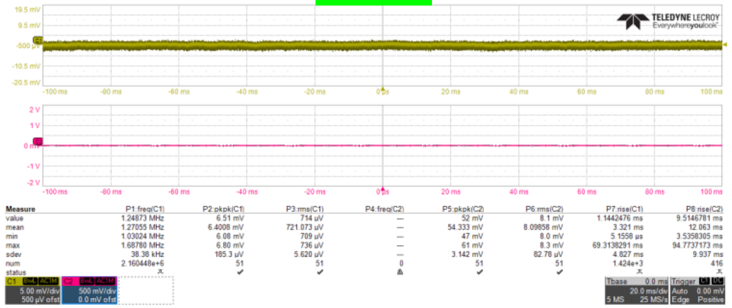
Bit1_Vout,Bit2_Vout	Vout
0,0	nominal
0,1	-13.3%
1,0	-6.67%
1,1	+6.67%

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

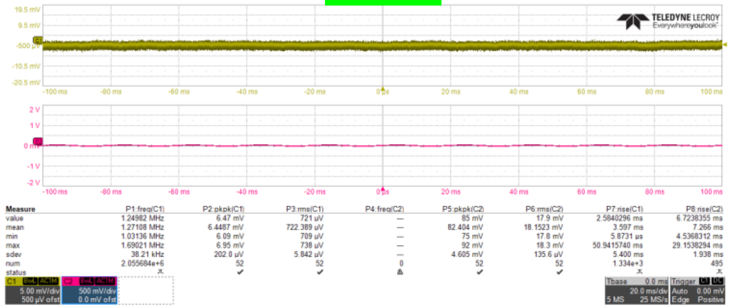
0mV



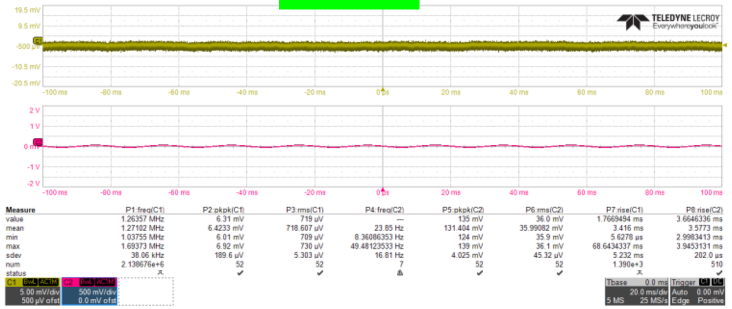
20mV



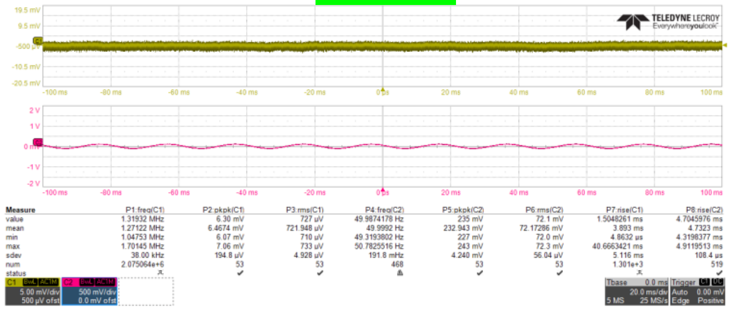
50mV



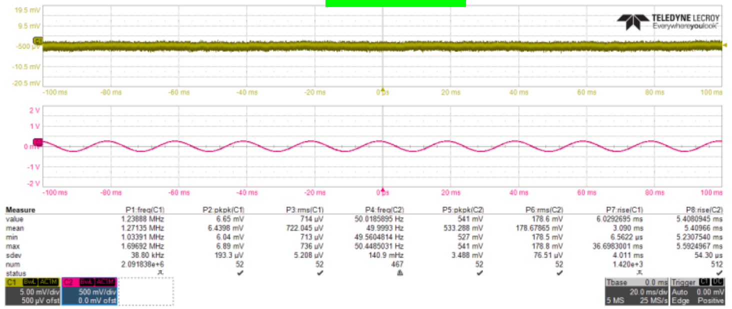
100mV



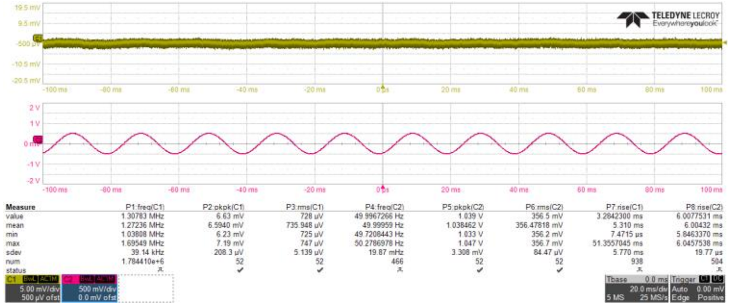
200mV



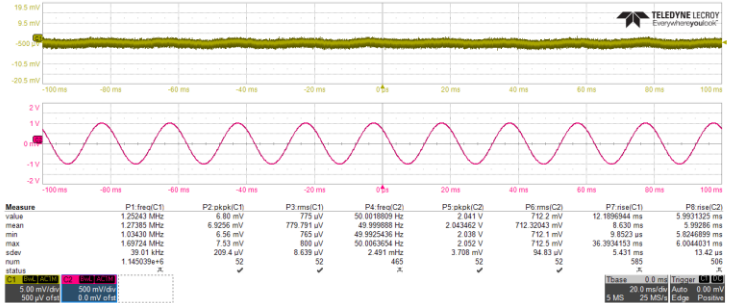
500mV



1000mV

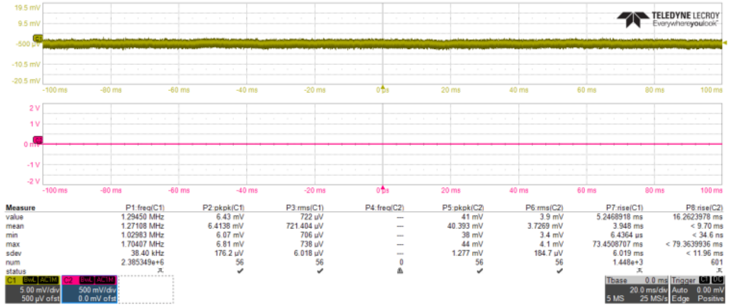


2000mV

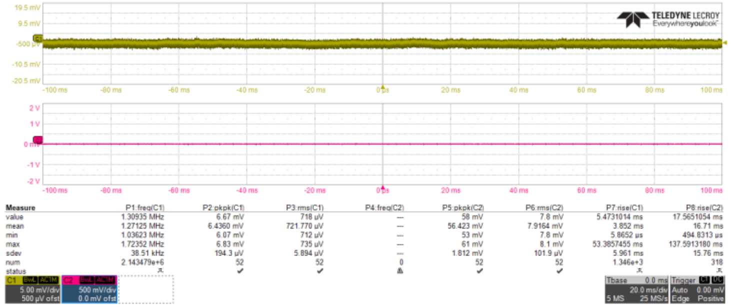


Ripple suppression test (p3 , Vout =1.2V, input ripple 1000HZ)

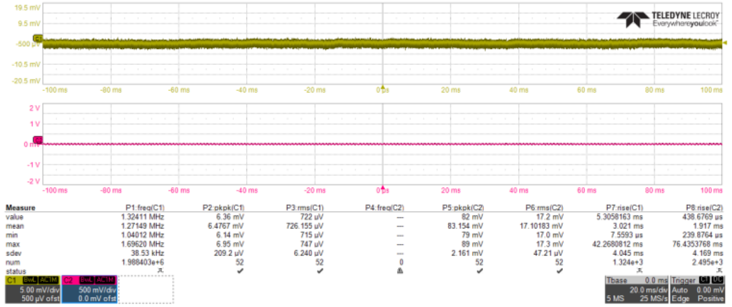
0mV



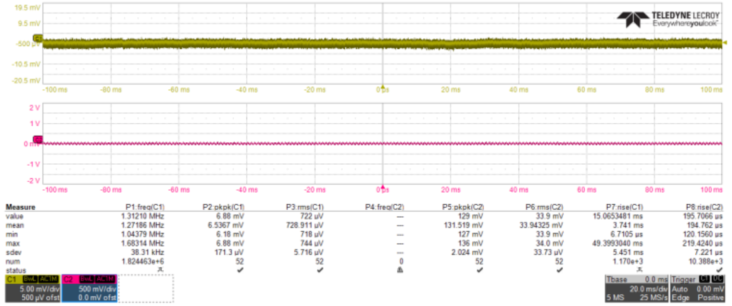
20mV



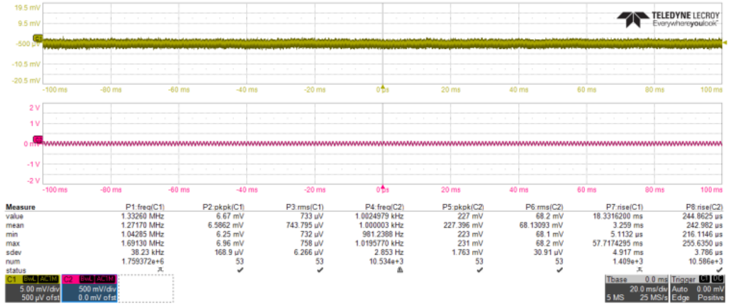
50mV



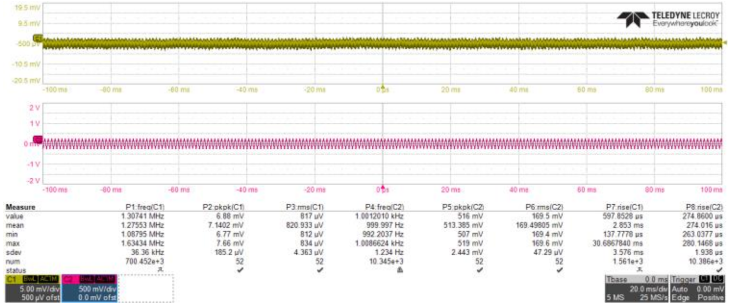
100mV



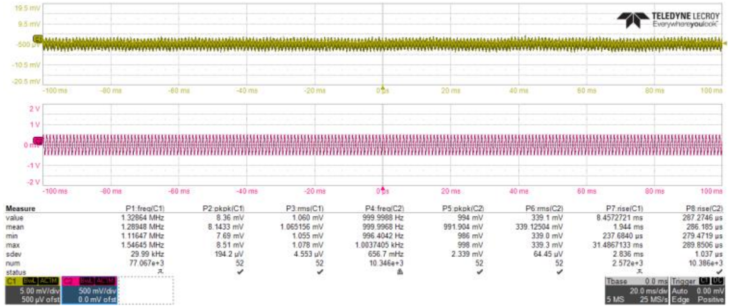
200mV



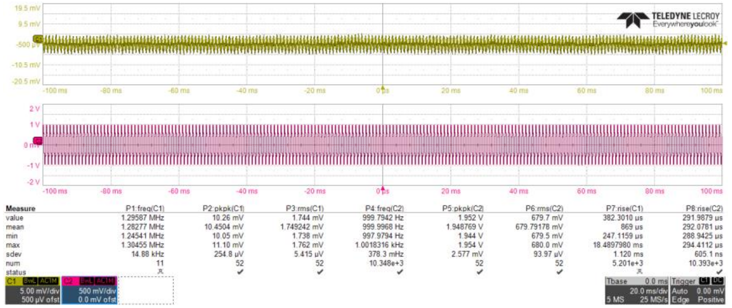
500mV



1000mV

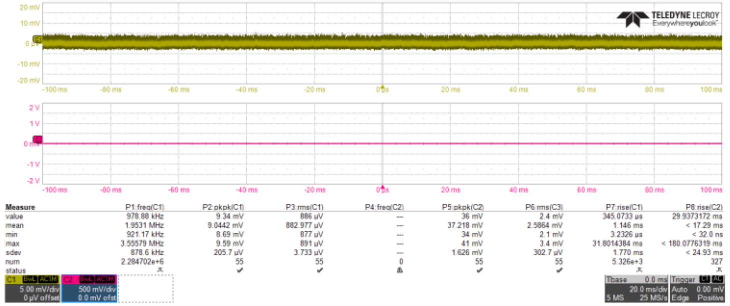


2000mV

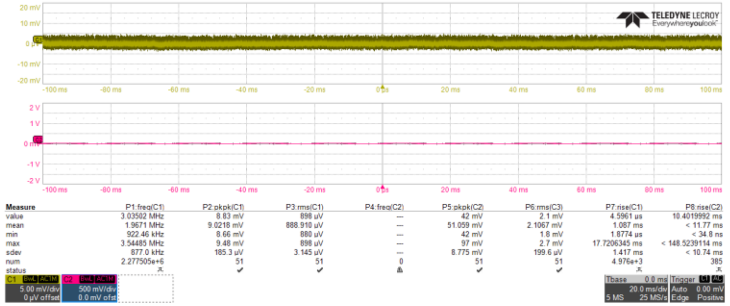


Ripple suppression test (p4 , Vout =1.2V, input ripple 50HZ)

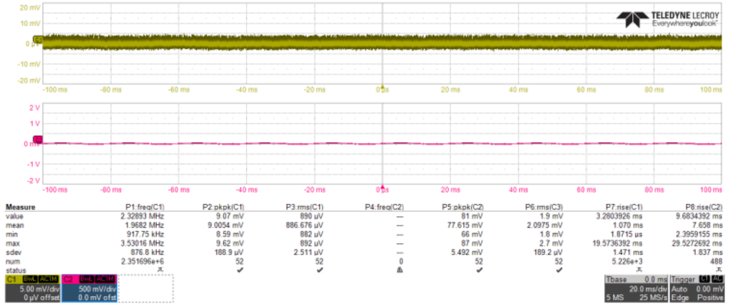
0mV



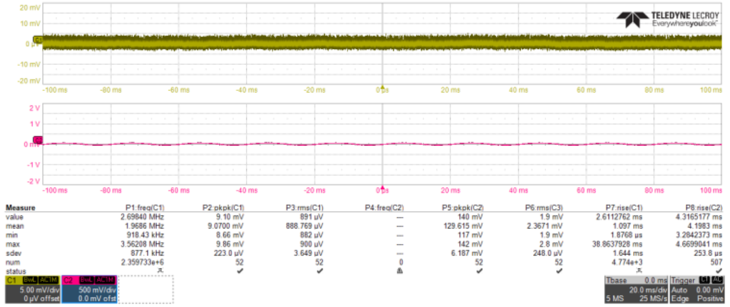
20mV



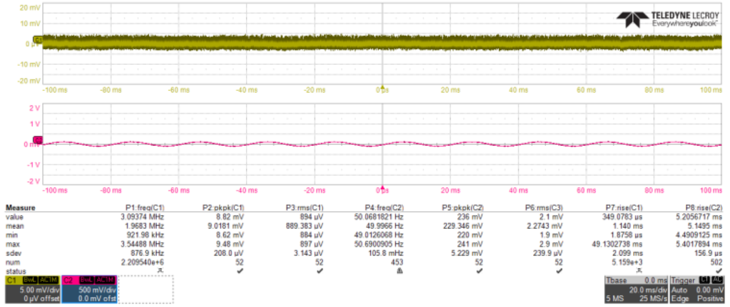
50mV



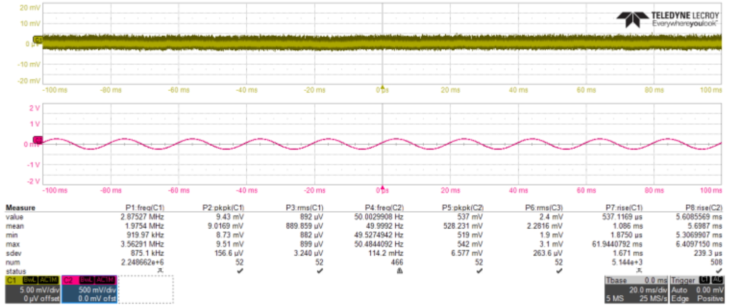
100mV



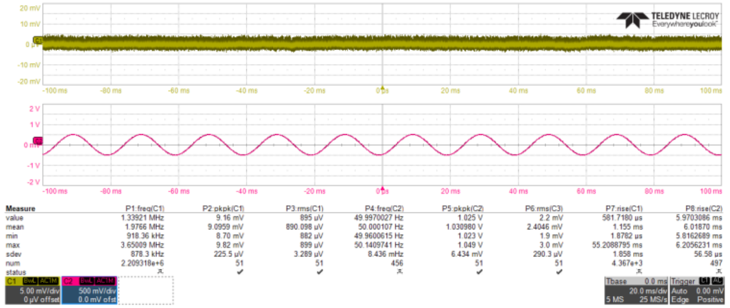
200mV



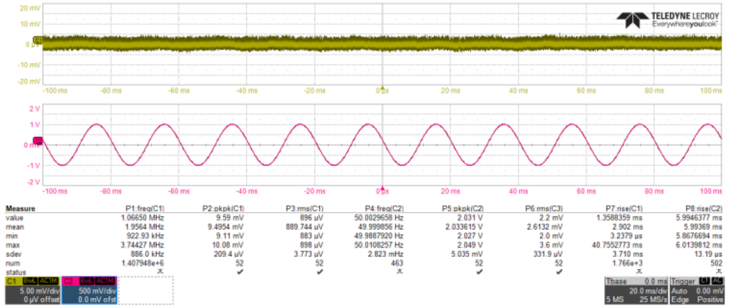
500mV



1000mV

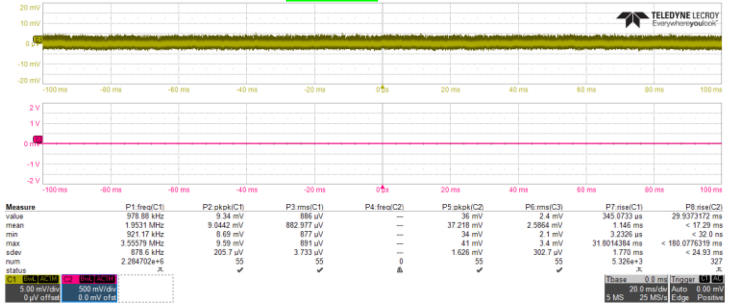


2000mV

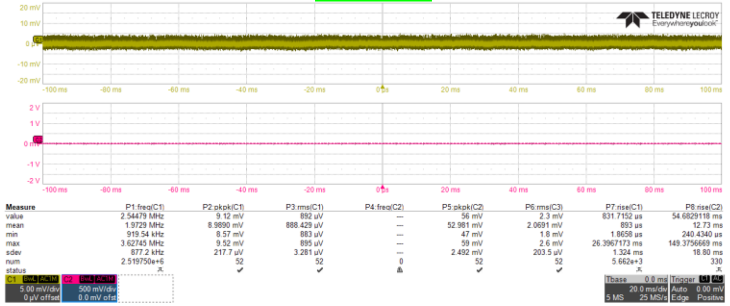


Ripple suppression test (p4 , Vout =1.2V, input ripple 1000HZ)

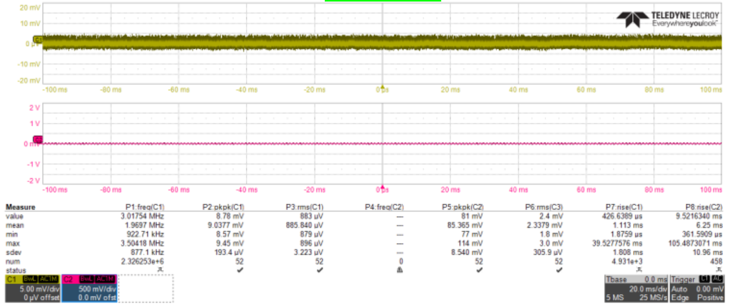
0mV



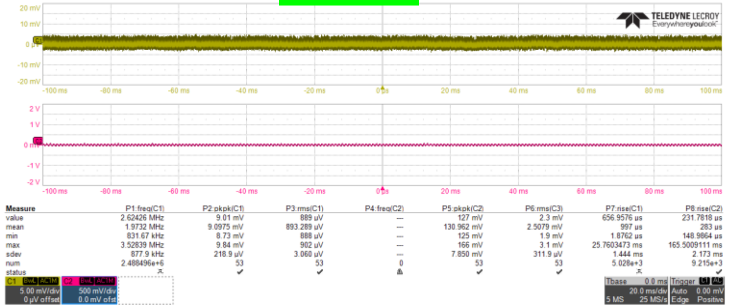
20mV



50mV



100mV

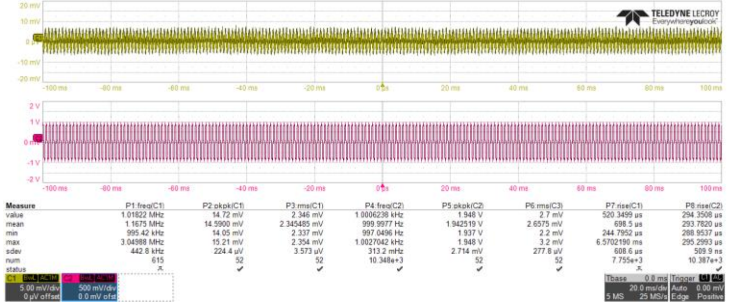


200mV

500mV

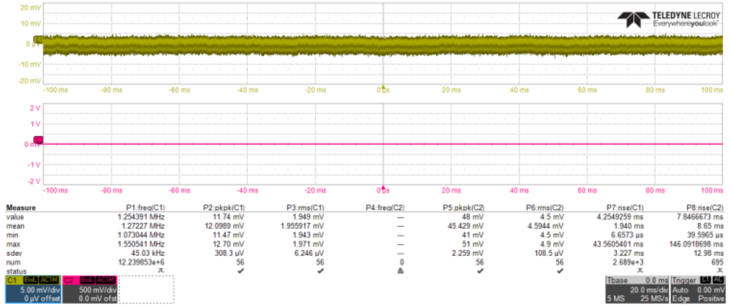
1000mV

2000mV

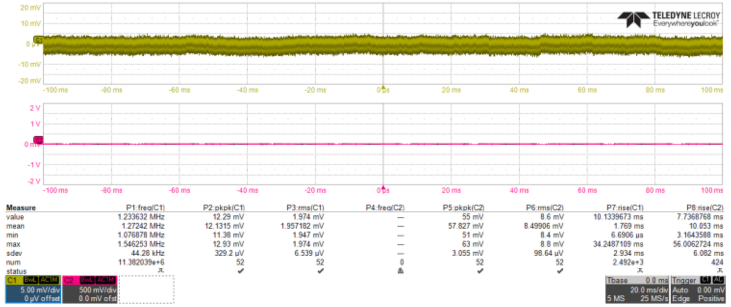


Ripple suppression test (p3, Vout =2.5V, input ripple 50HZ)

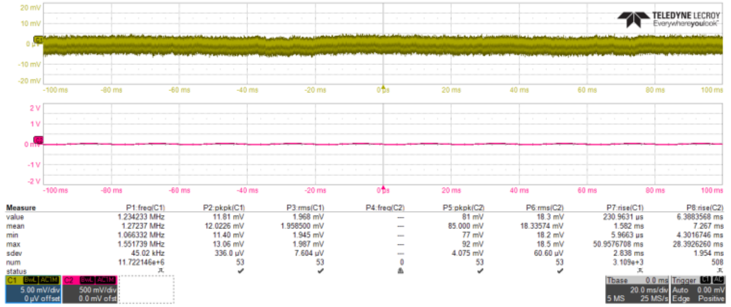
0mV



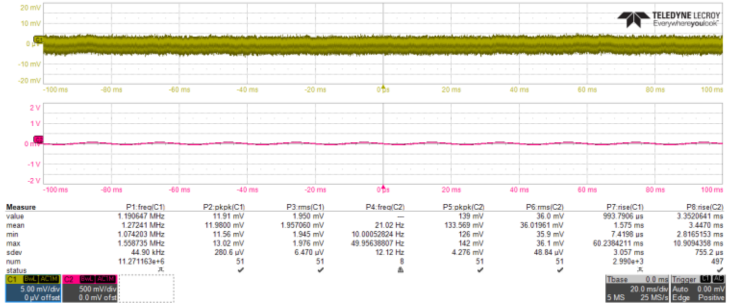
20mV



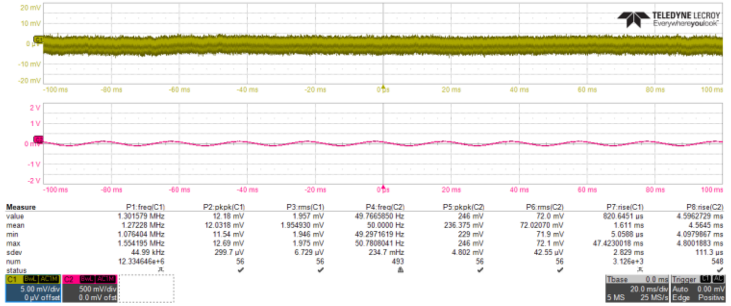
50mV



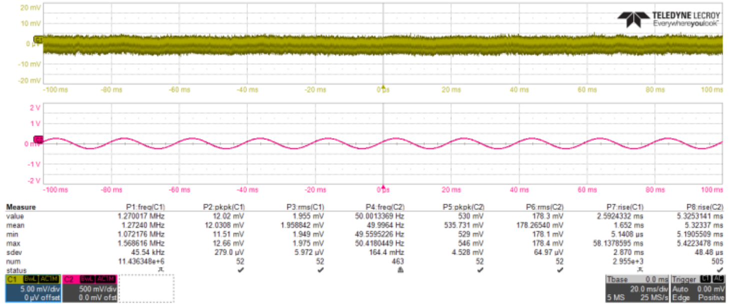
100mV



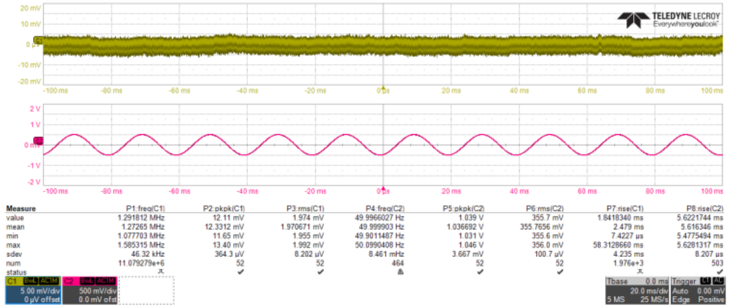
200mV



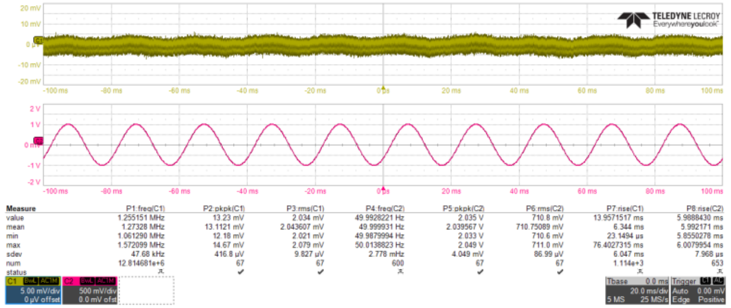
500mV



1000mV



2000mV

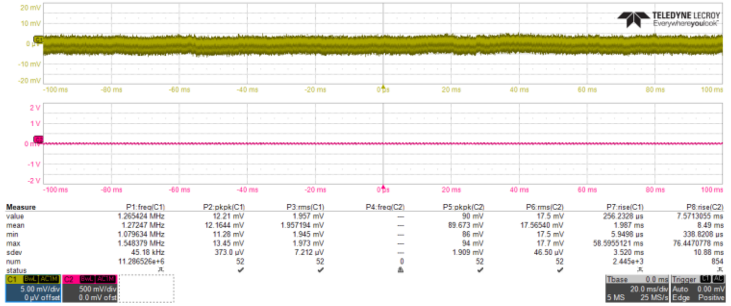


Ripple suppression test (p3 , Vout =2.5V, input ripple 1000HZ)

0mV

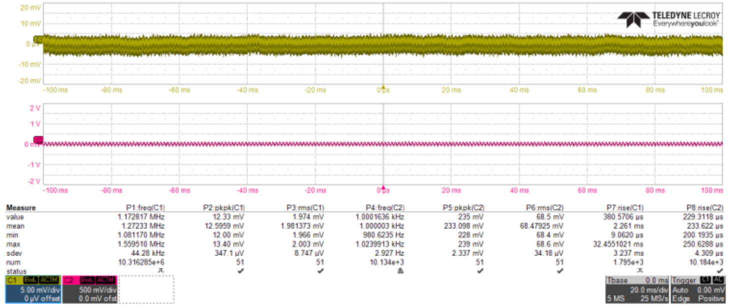
20mV

50mV



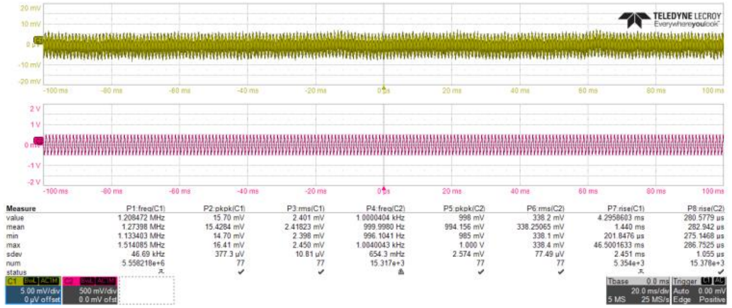
100mV

200mV

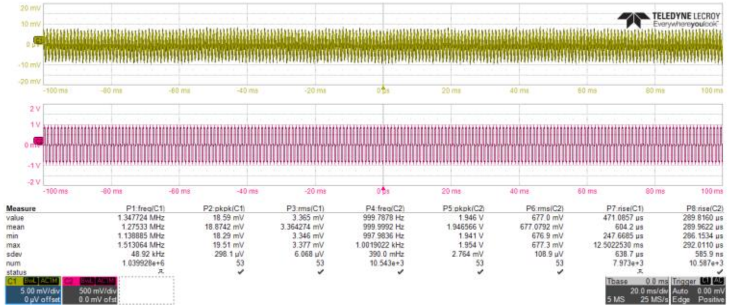


500mV

1000mV

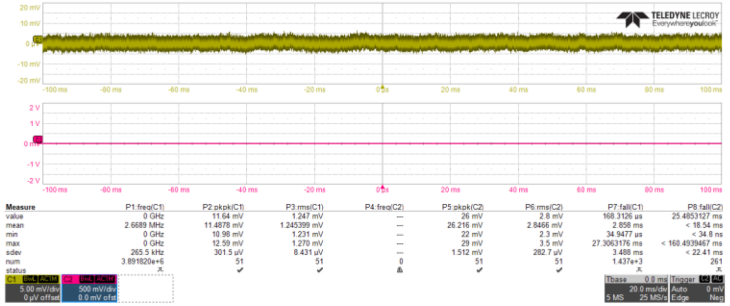


2000mV



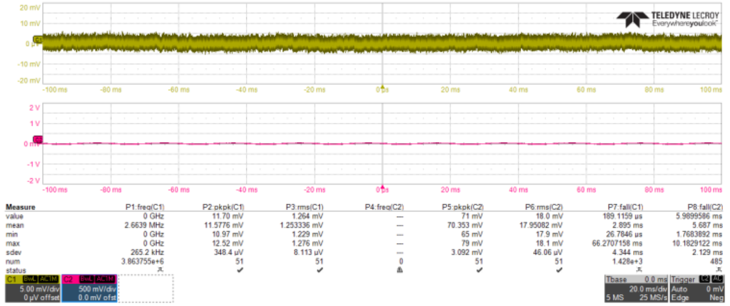
Ripple suppression test (p4 , Vout =2.5V, input ripple 50HZ)

0mV



20mV

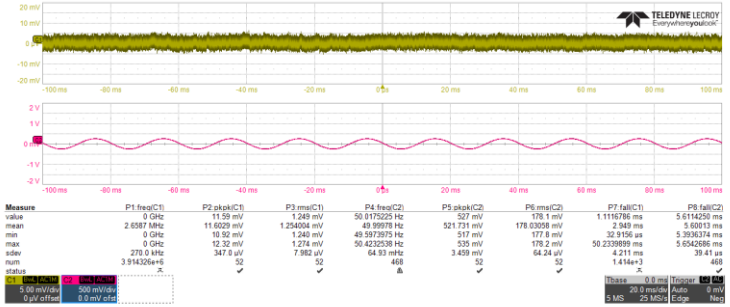
50mV



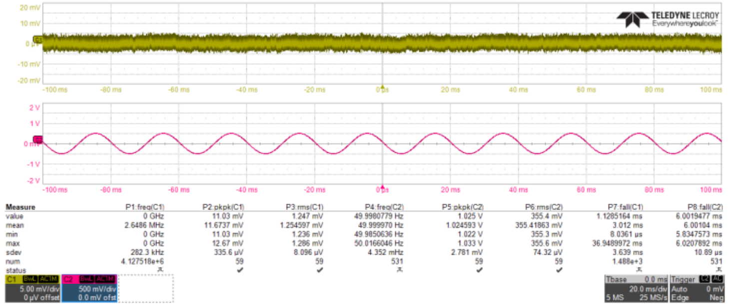
100mV

200mV

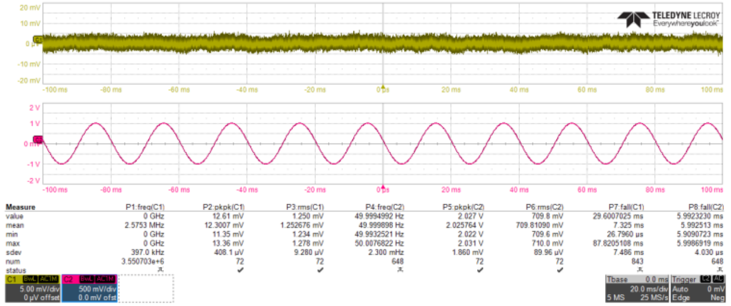
500mV



1000mV

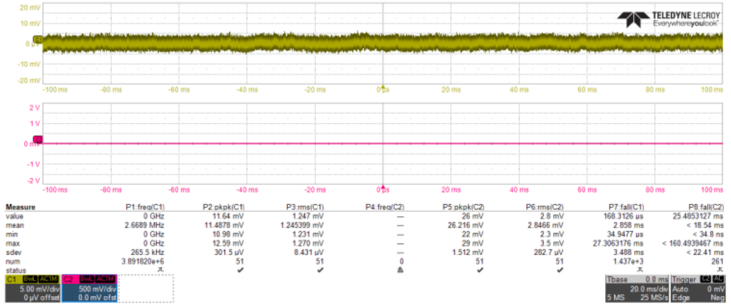


2000mV



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

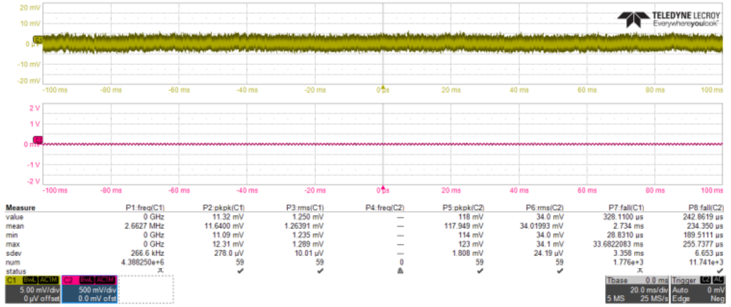
0mV



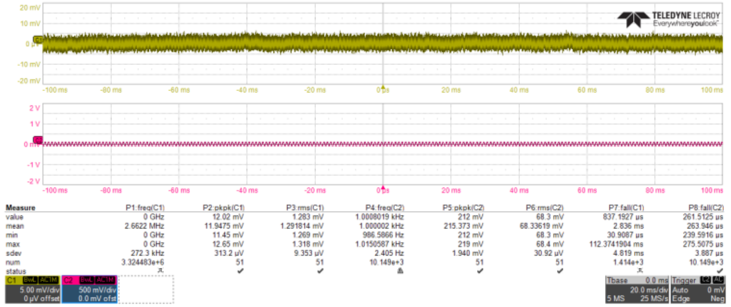
20mV

50mV

100mV

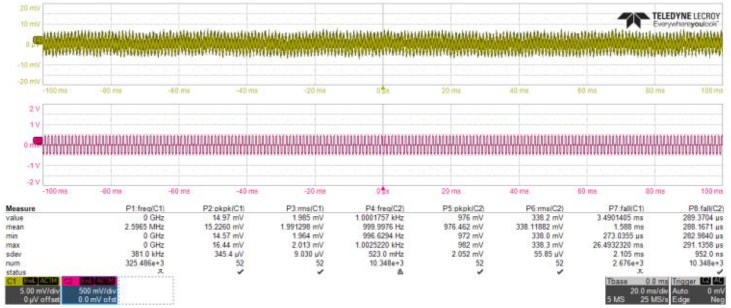


200mV

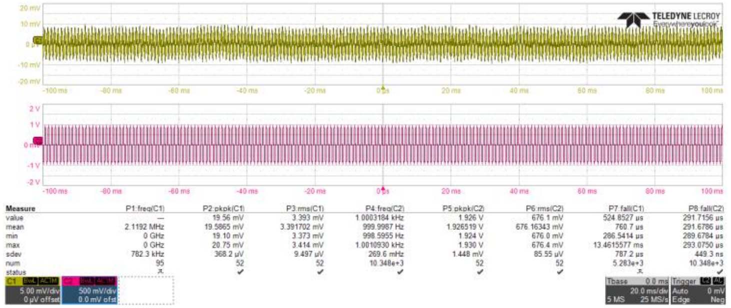


500mV

1000mV

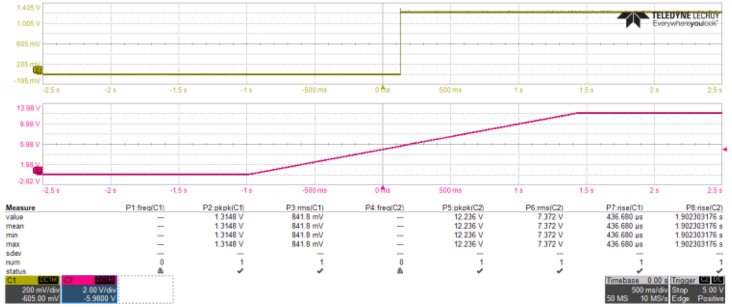


2000mV

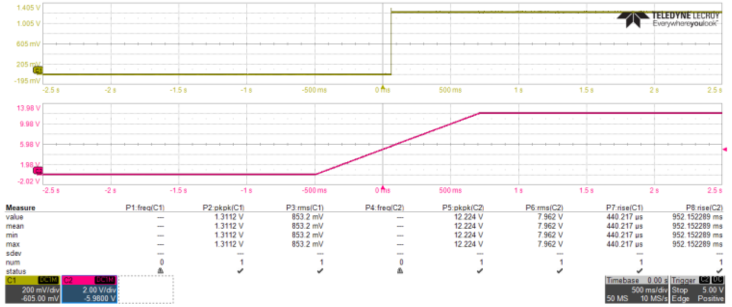


Output Rising time (p3, Vout = 1.2V)

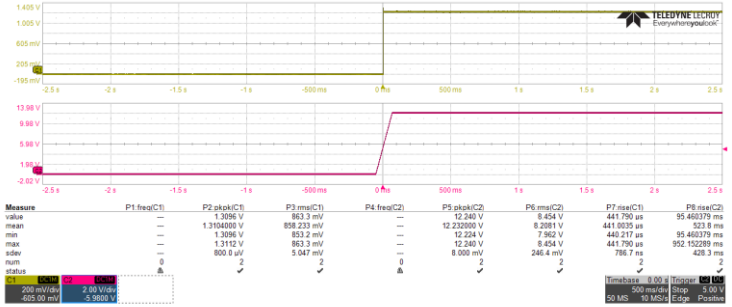
5V/s



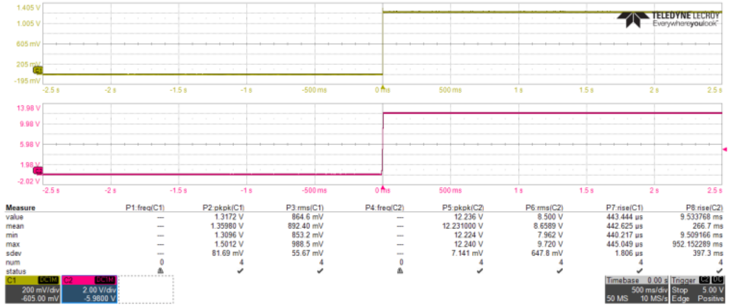
10V/s



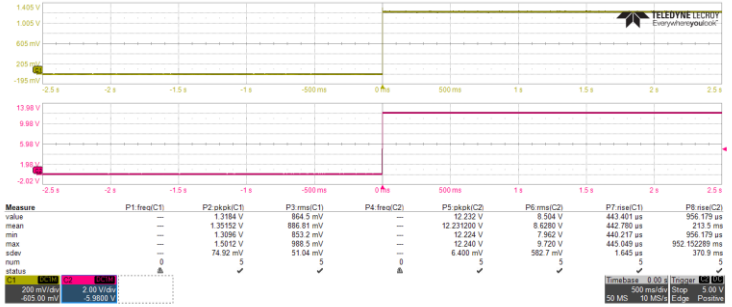
100V/s



1000V/s

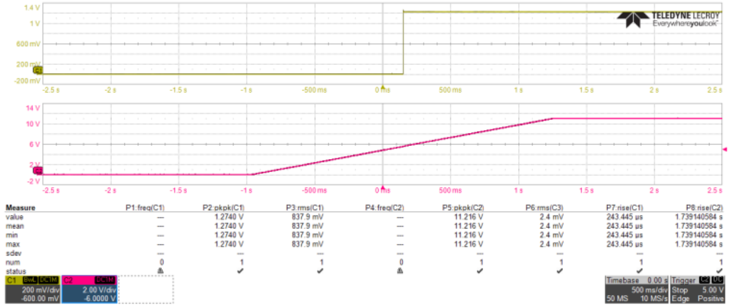


10000V/s

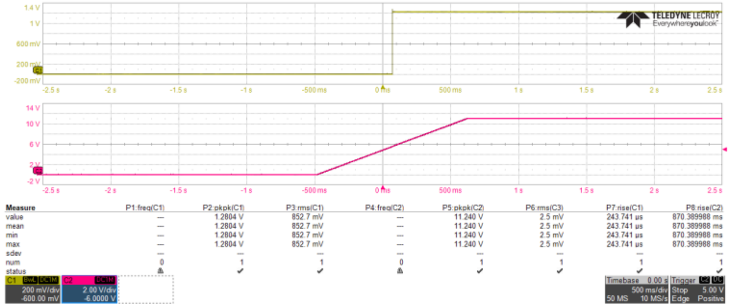


Output Rising time (p4, Vout = 1.2V)

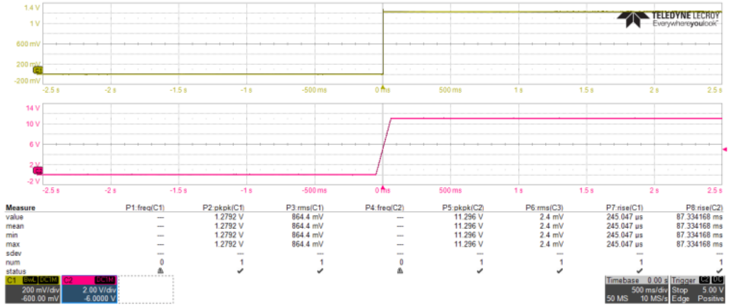
5V/s



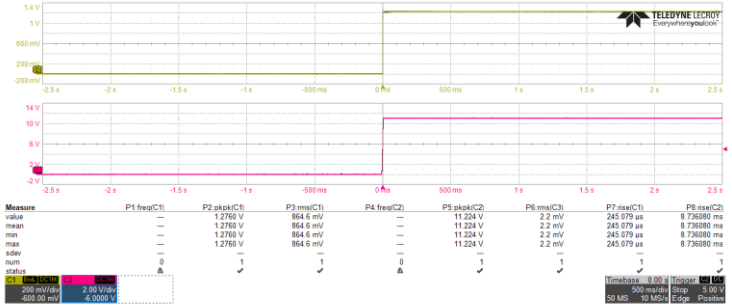
10V/s



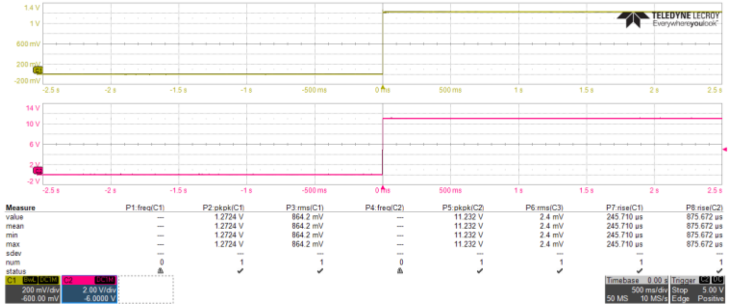
100V/s



1000V/s

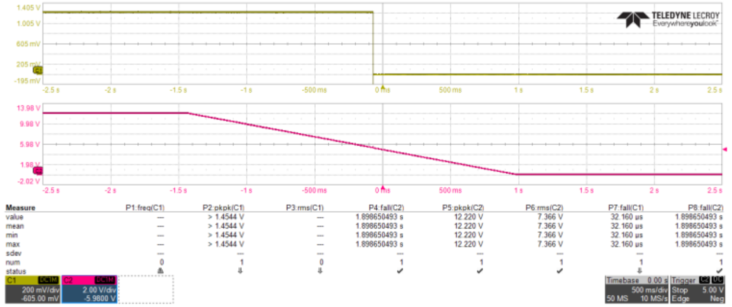


10000V/s

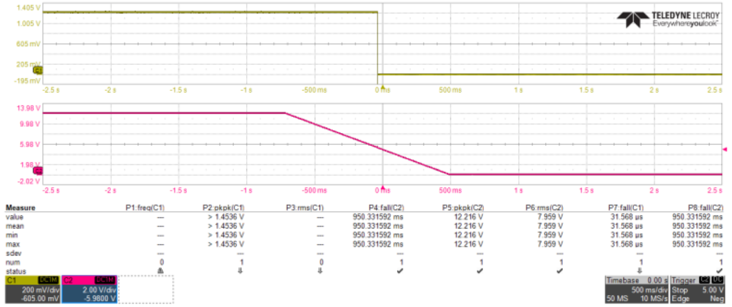


Output falling time (p3, Vout = 1.2V)

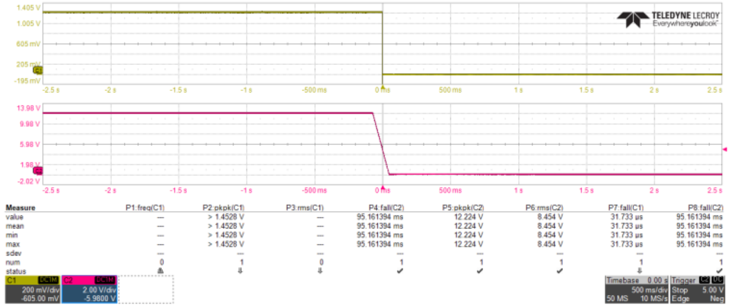
5V/s



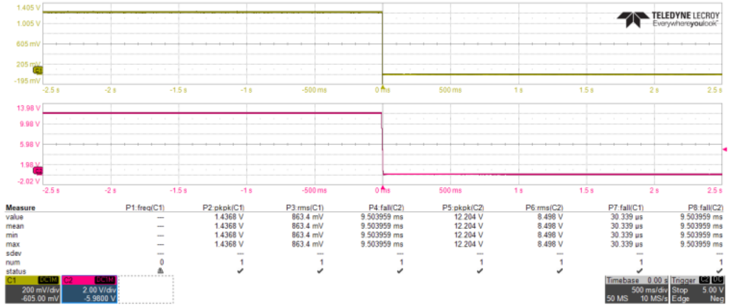
10V/s



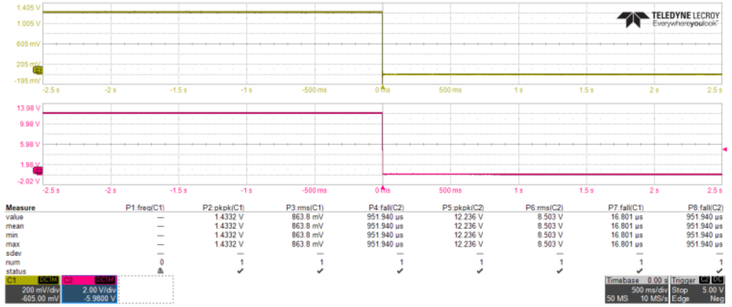
100V/s



1000V/s

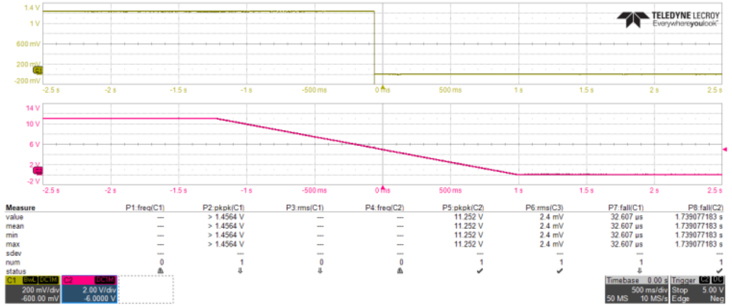


10000V/s

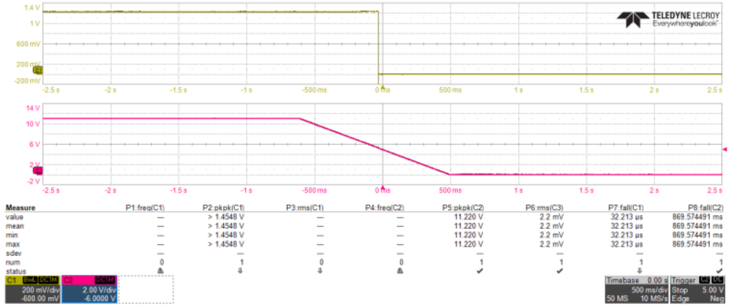


Output falling time (p4, Vout = 1.2V)

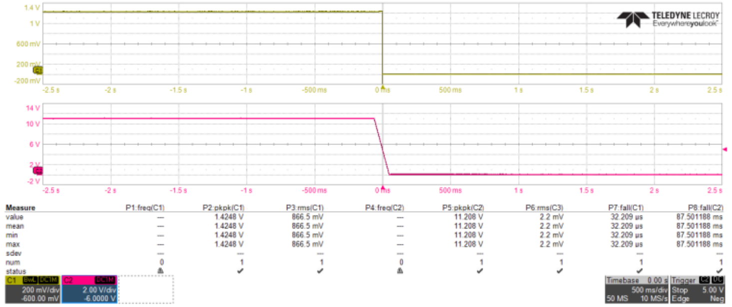
5V/s



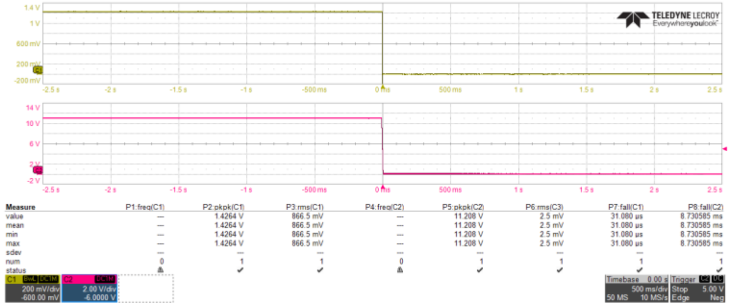
10V/s



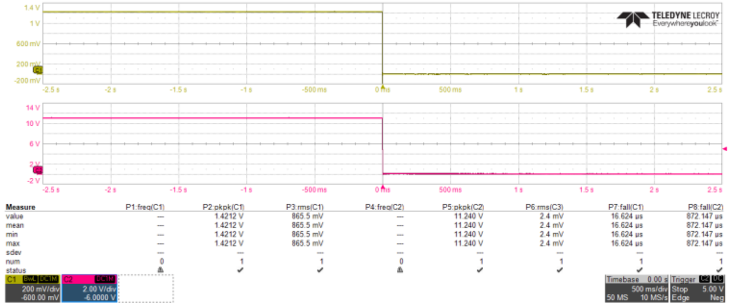
100V/s



1000V/s

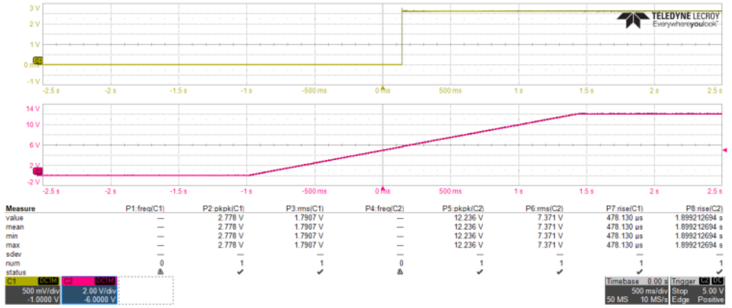


10000V/s

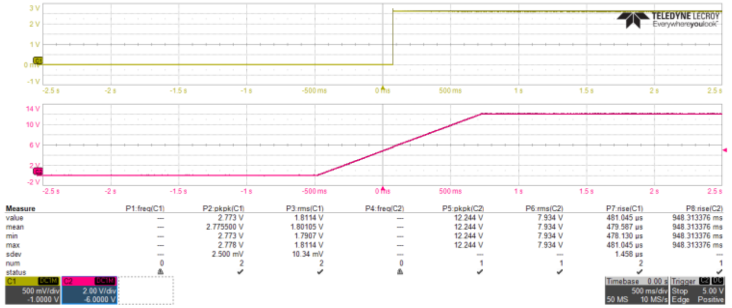


Output Rising time (p3, Vout = 2.5V)

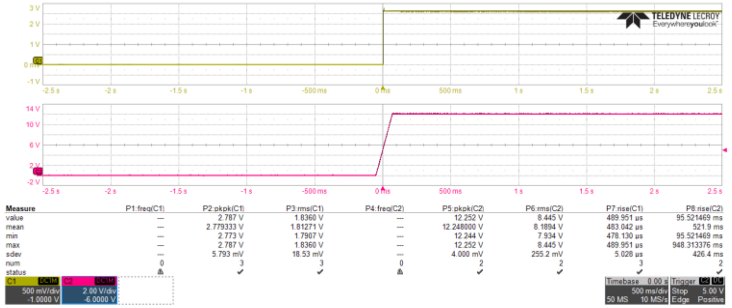
5V/s



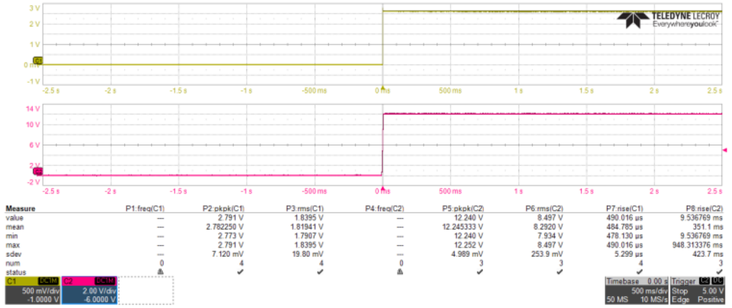
10V/s



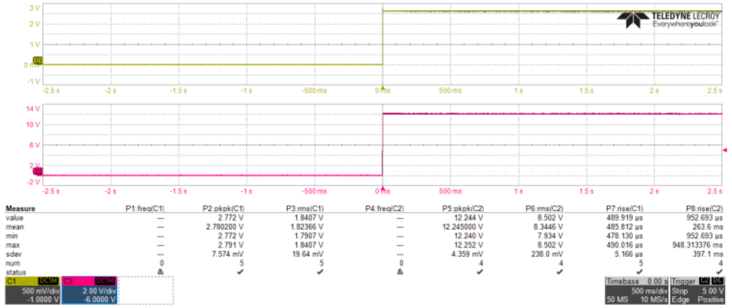
100V/s



1000V/s

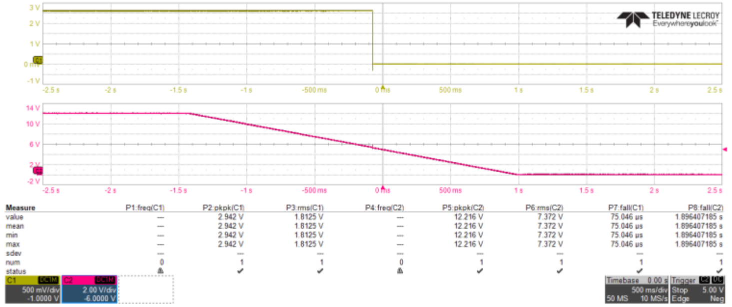


10000V/s

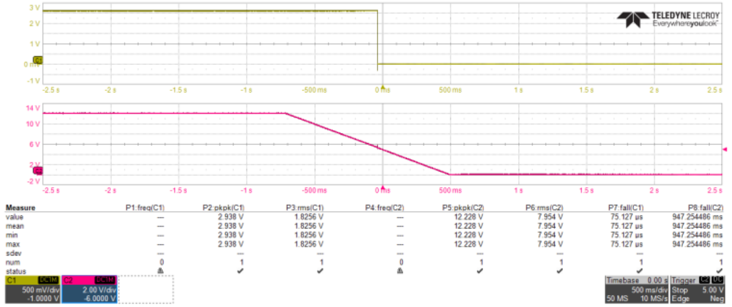


Output Rising time (p4, Vout = 2.5V)

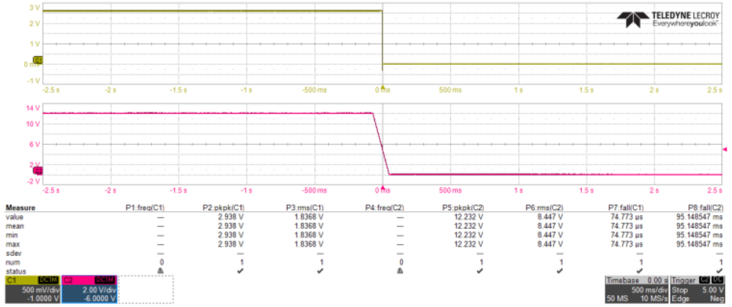
5V/s



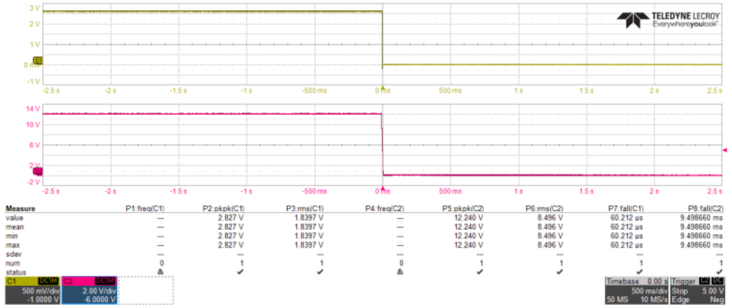
10V/s



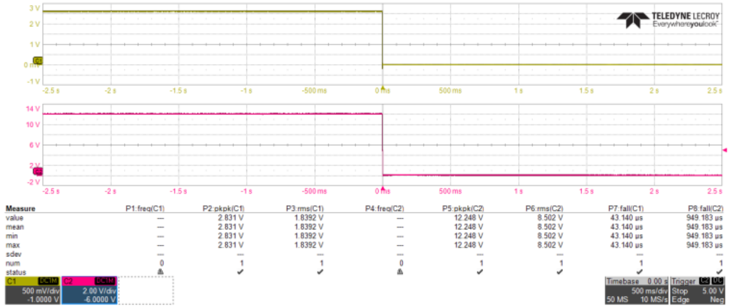
100V/s



1000V/s

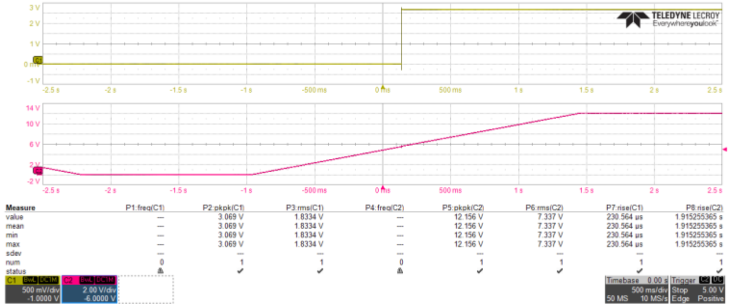


10000V/s

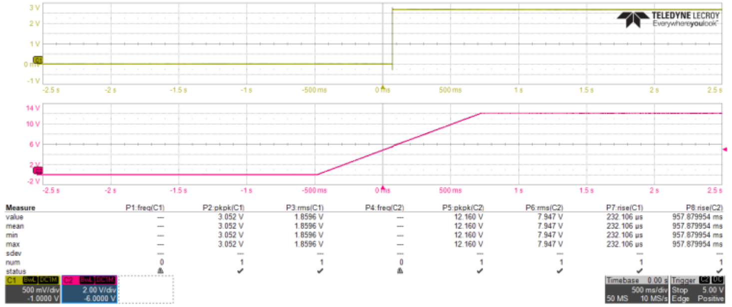


Output falling time (p3, Vout = 2.5V)

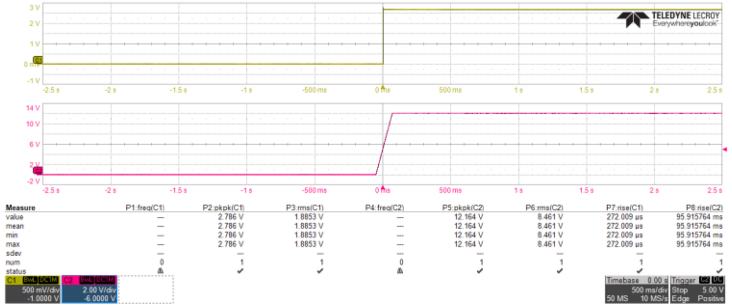
5V/s



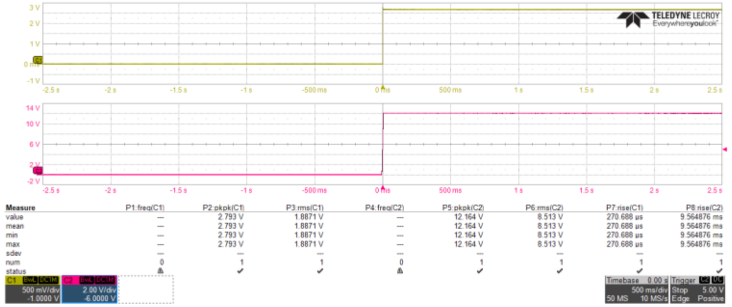
10V/s



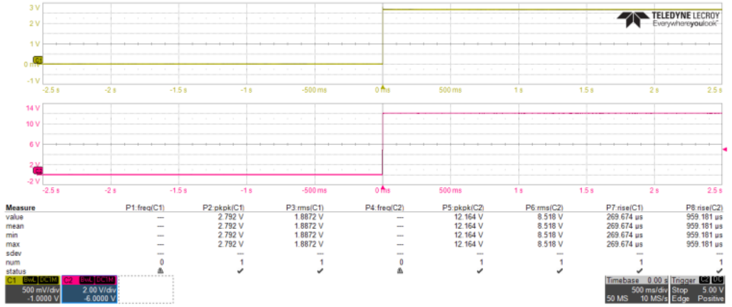
100V/s



1000V/s

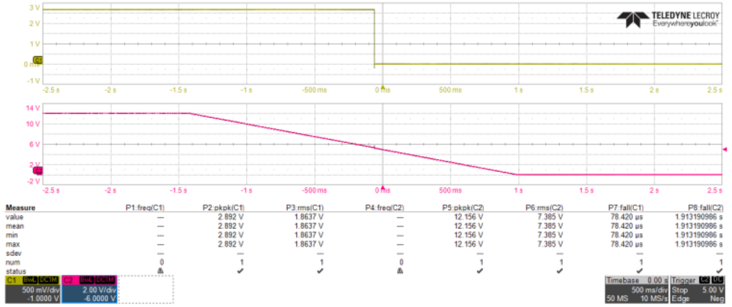


10000V/s

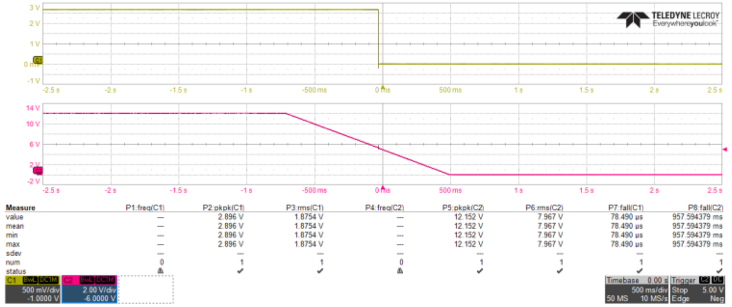


Output falling time (p4, Vout = 2.5V)

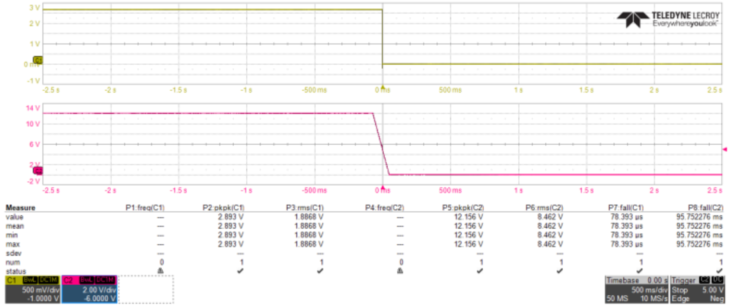
5V/s



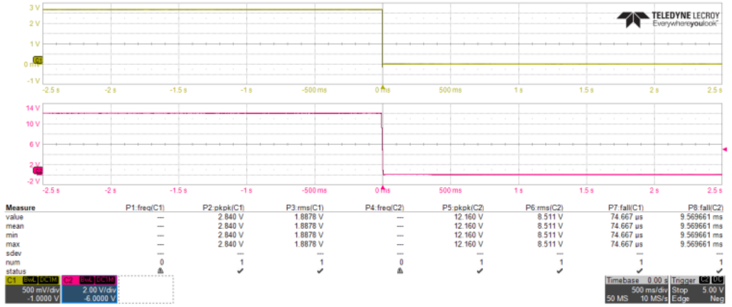
10V/s



100V/s



1000V/s



10000V/s