



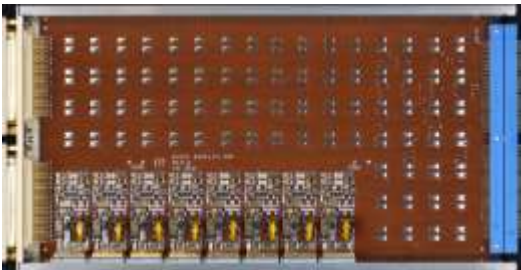
Development of Equipment and Heater Power Distribution

Morten R. Svensson

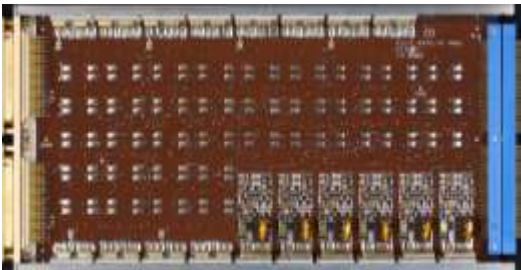
Engineer, Terma Space



Heritage Module Design and Project Goal

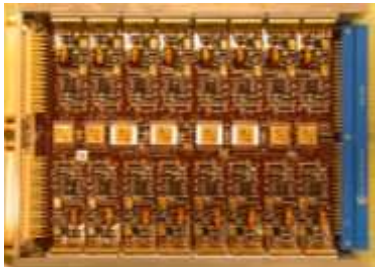


BepiColombo EPD

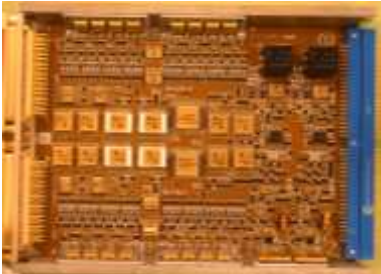


BepiColombo HPD

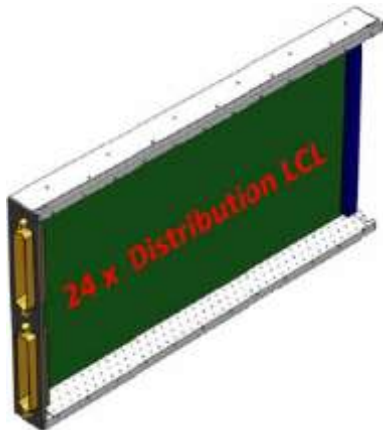
Mission	Module	Dimensions	Features
XMM/INTEGRAL	EPD	240 x 190 x 24 [mm]	28V, 6 LCL's
XMM/INTEGRAL	HPD	240 x 190 x 24 [mm]	28V, 6 LCL's and 12 Switches
Galileo	EPD	193 x 150 x 24 [mm]	50V, 16 LCL's
Galileo	HPD	193 x 150 x 24 [mm]	50V, 2 LCL's and 16 Switches
BepiColombo	EPD	282 x 150 x 24 [mm]	100V, 8 LCL's
BepiColombo	HPD	282 x 150 x 24 [mm]	100V, 6 LCL's and 24 Switches
New GSTP	EPD	282 x 150 x 24 [mm]	28V-100V, 24 LCL's
New GSTP	HPD	282 x 150 x 24 [mm]	28V-100V, 12 LCL's and 48 Switches



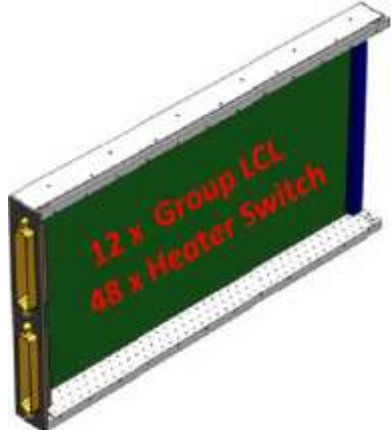
Galileo EPD



Galileo HPD



GSTP Module EPD



GSTP Module HPD

EPD Key Requirements



- **High configurability**
 - **Bus voltage 16V to 100V**
 - **LCL Class current 0.5A to 5A**
 - **LCL Trip-off time 0.35ms to 12.5ms**
 - **Paralleling of up to 12 LCL's (LCL Class up to 60A)**
 - **4 LCL's per module can be commanded by HPC**
 - **2 LCL's per module can be used for R-LCL**
- **LCL output designed to withstand an instantaneous short circuit at module connector level**
- **Low on consumption (3mA per LCL)**
- **Very low off consumption (<0.3mA per LCL)**
- **Regulation stability compatible with a wide range of load impedances**
- **SEU/SET immune**

HPD Key Requirements



- **High configurability**
 - Bus voltage 16V to 100V
 - LCL Class current 0.5A to 5A
 - LCL Trip-off time 0.35ms to 12.5ms
 - Paralleling of up to 2 LCL's (LCL Class up to 10A)
 - Paralleling of up to 4 Heater Switches for high power outputs
 - 4 LCL's per module can be commanded by HPC
 - 2 LCL's per module can be used for R-LCL
 - Heater Group size of 4 or 8 heater switches
- **Heater output designed to withstand an instantaneous short circuit at module connector level**
- **Low on consumption**
 - 3.6mA per Heater Group LCL
 - 0.45mA per Heater Switch
- **Very low off consumption**
 - < 0.3mA per Heater Group
 - < 10 μ A per Heater Switch
- **Output switch on/off dV/dt control**
- **MOSFET Linear mode failure protection**
- **Regulation stability compatible with a wide range of load impedances**
- **SEU/SET immune**



Major Design Challenges

- Paralleling of LCL outputs to obtain high current LCL's
- Heater switch linear mode failure detection

Other Design Challenges

- Reducing component count
- Using MOSFET gate voltage to detect when LCL is in current limitation

Paralleling of LCL Outputs



Limitation Avalanche Effect:

Cause

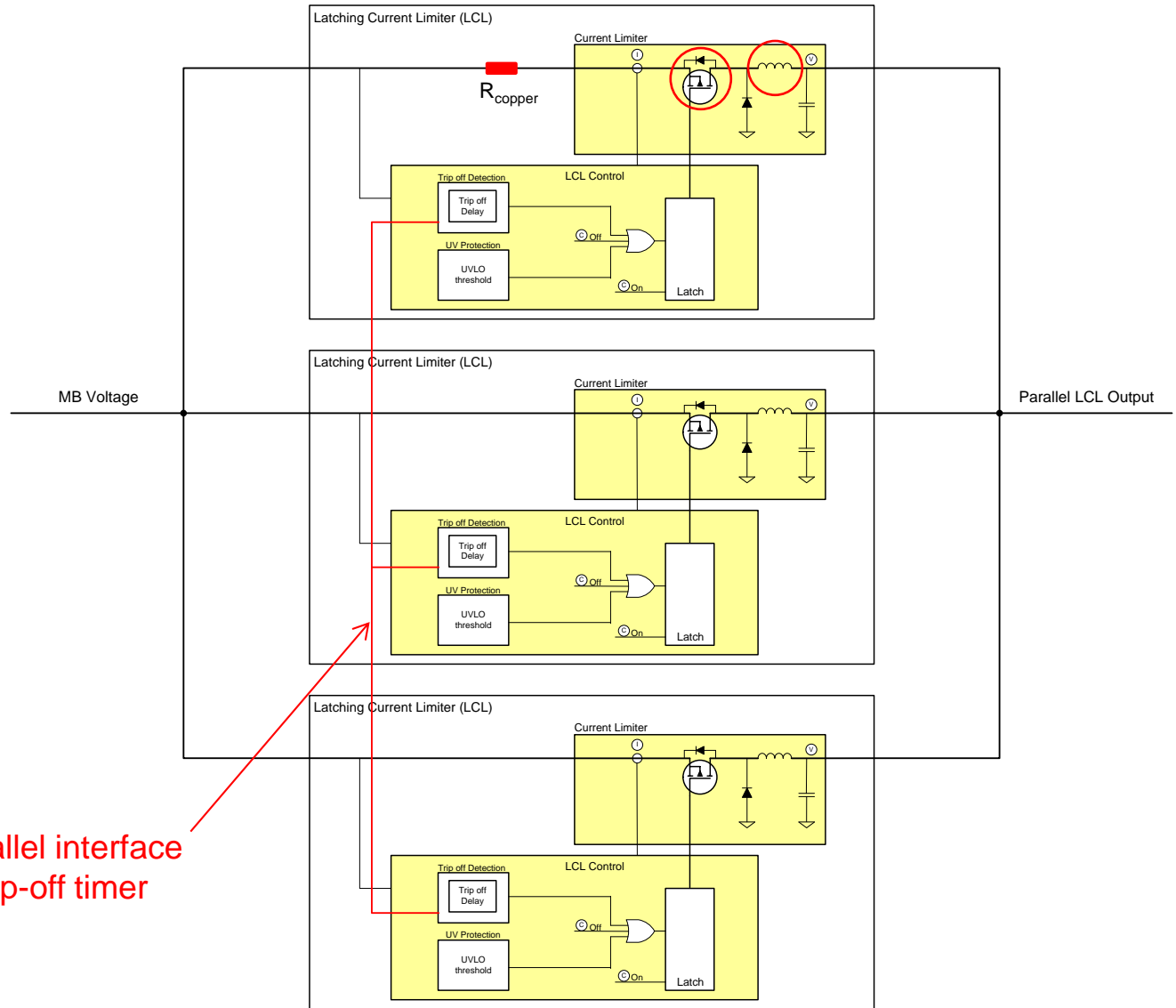
Due to slightly different LCL on resistance.

Effect

One of the parallel LCL's is entering limitation condition before the total limitation current is obtained.

Solution

Prevent Trip off timer activation before all parallel LCL's is in active current limitation.



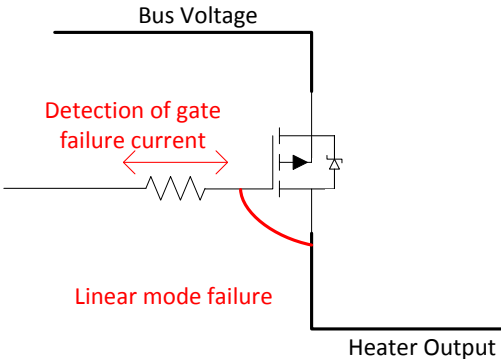
Parallel interface of trip-off timer

Heater Switch Linear Mode Failure Detection

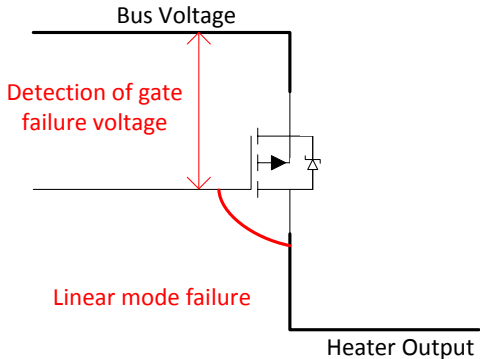


Detection methods analyzed

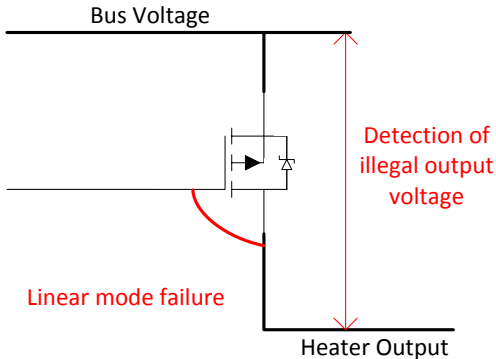
Detection of MOSFET gate fault current



Detection of MOSFET gate fault voltage



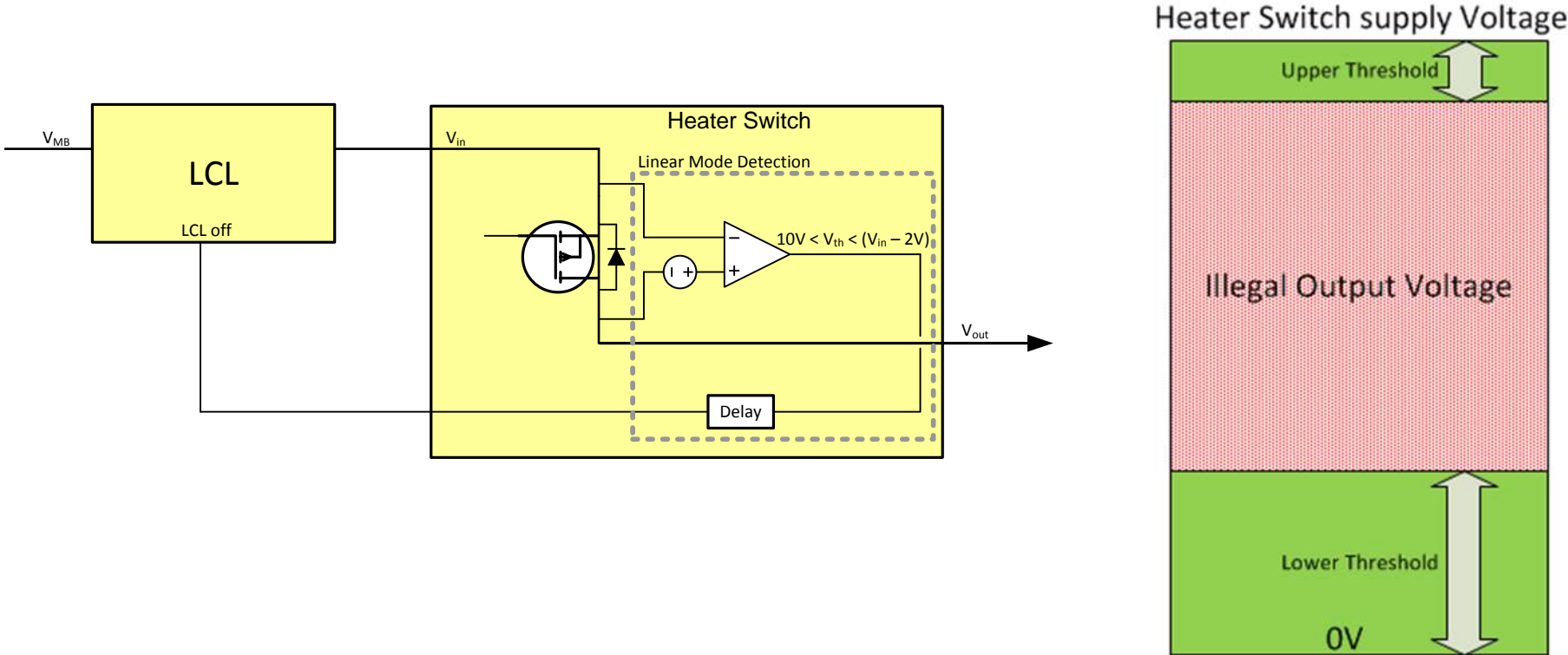
Detection of illegal output voltage



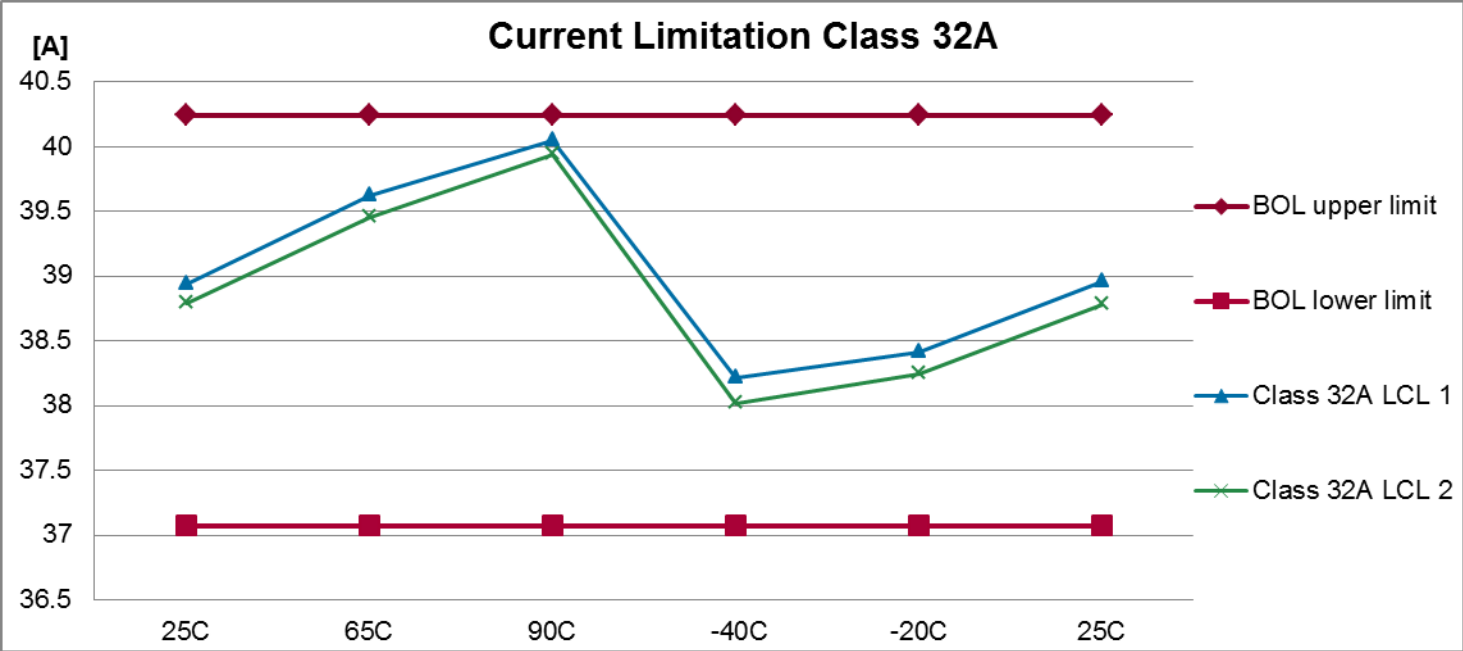
Heater Switch Linear Mode Failure Detection



Detection of illegal output voltage

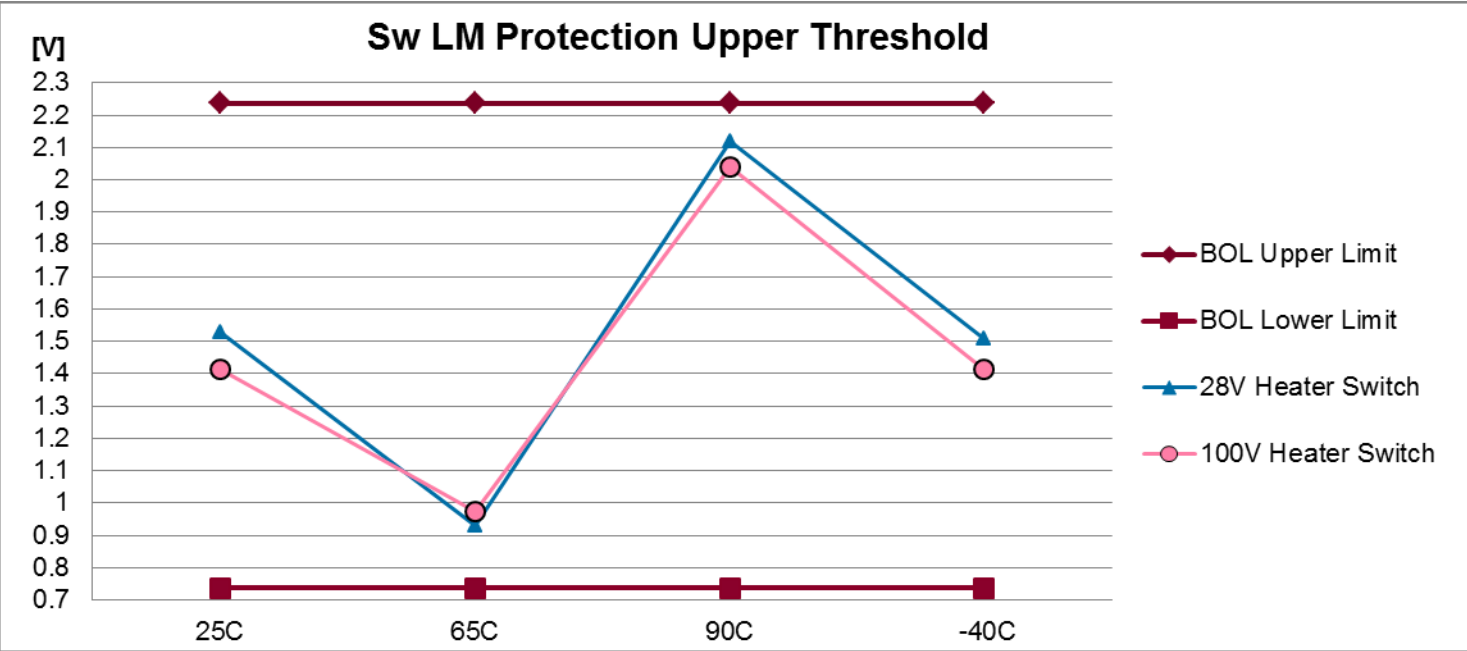


LCL Current Limitation Test Results

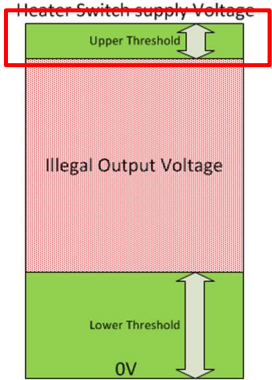


Class 32 A LCL current limitation:
EOL minimum (110%) = 35.2A
EOL maximum (130%) = 41.6A

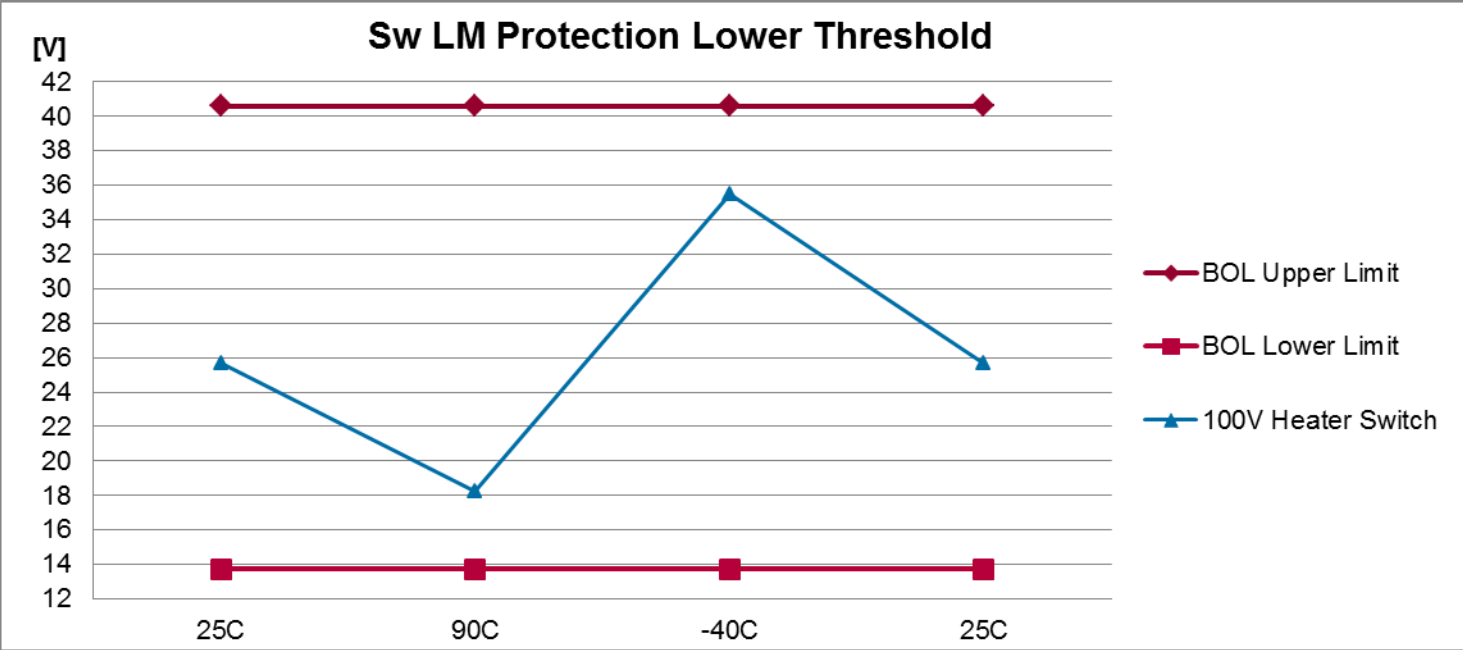
Linear Mode Protection Test Results



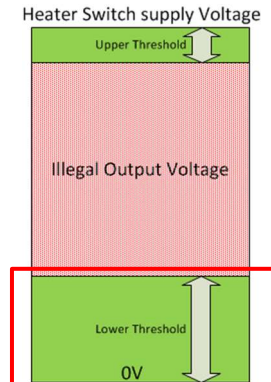
WC Heater Switch LM Upper Threshold:
 EOL minimum = 0.614V
 EOL maximum = 2.349V



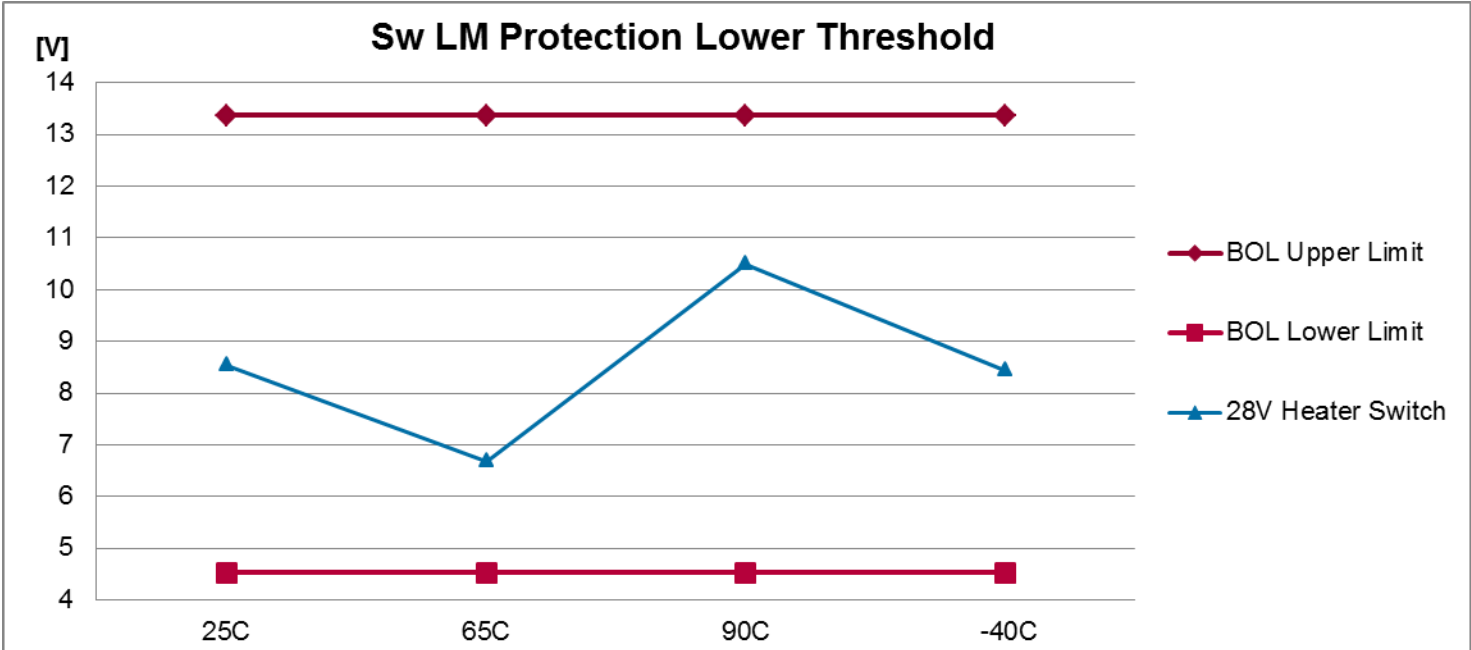
Linear Mode Protection Test Results



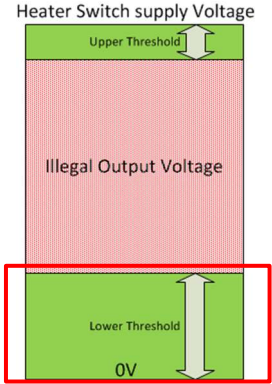
WC Heater Switch LM Lower Threshold @100V:
 EOL minimum = 12.43V
 EOL maximum = 42.10V



Linear Mode Protection Test Results



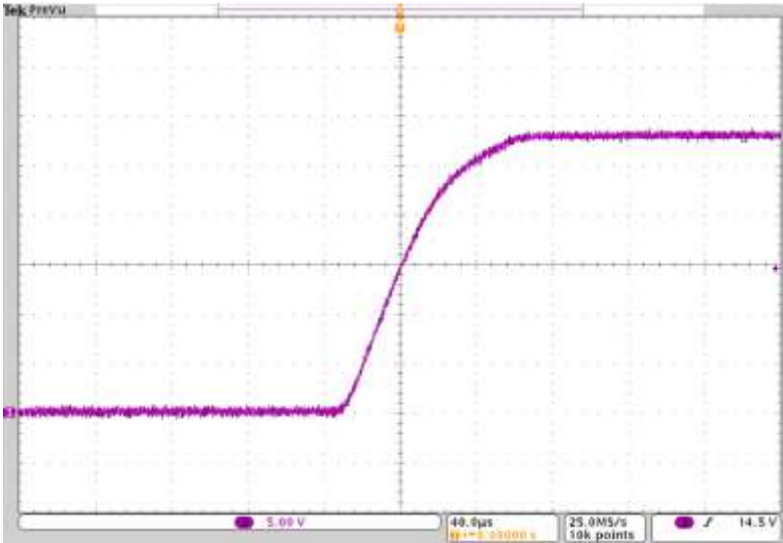
WC Heater Switch LM Lower Threshold @28V:
 EOL minimum = 4.10V
 EOL maximum = 13.86V



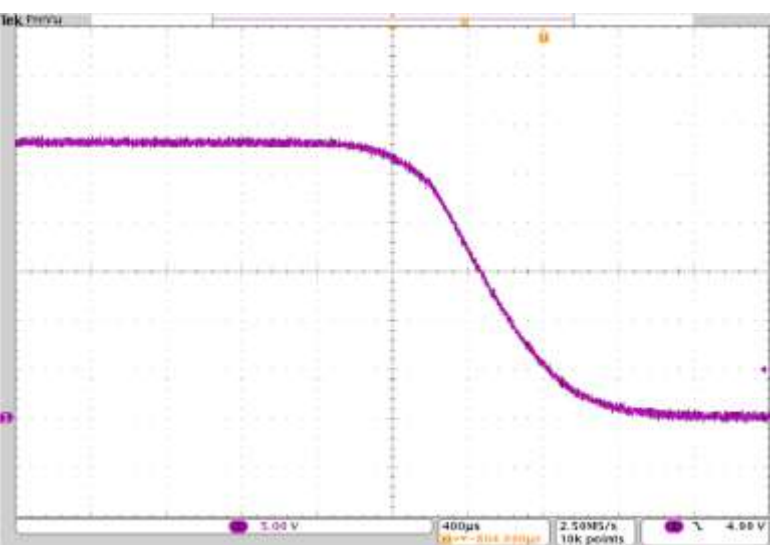
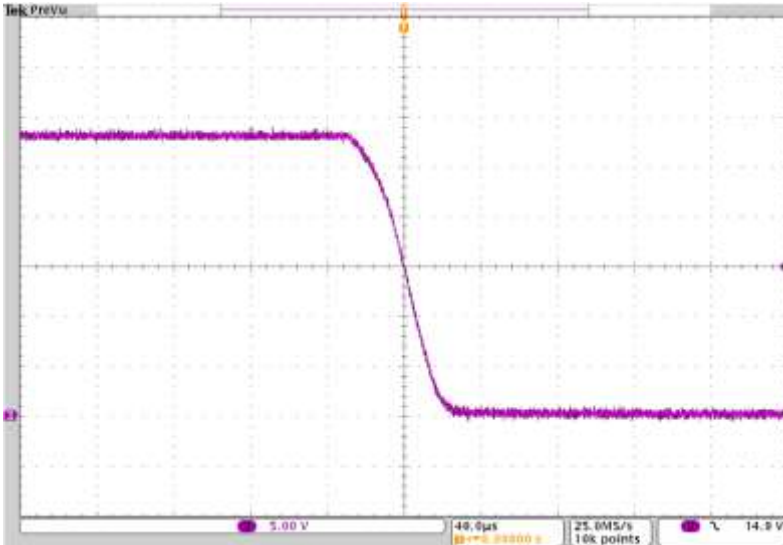
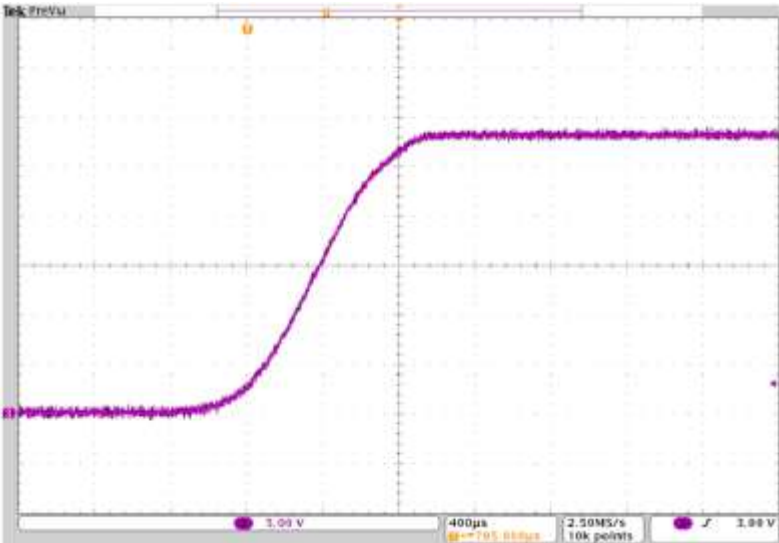
LCL and Switch Turn on/off Test Results



28V Class 5A LCL Rise and Fall Time



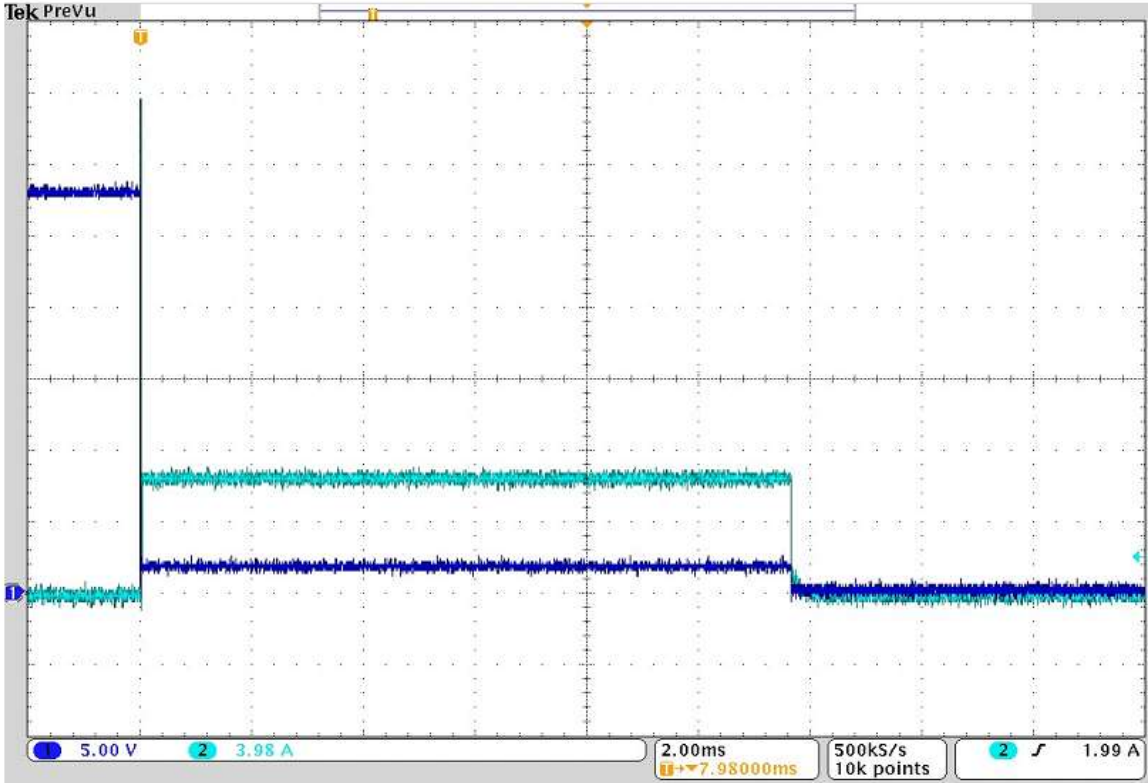
28V Heater Switch Rise and Fall Time



LCL Limitation Test Results



28V Class 5A LCL Trip off into short circuit

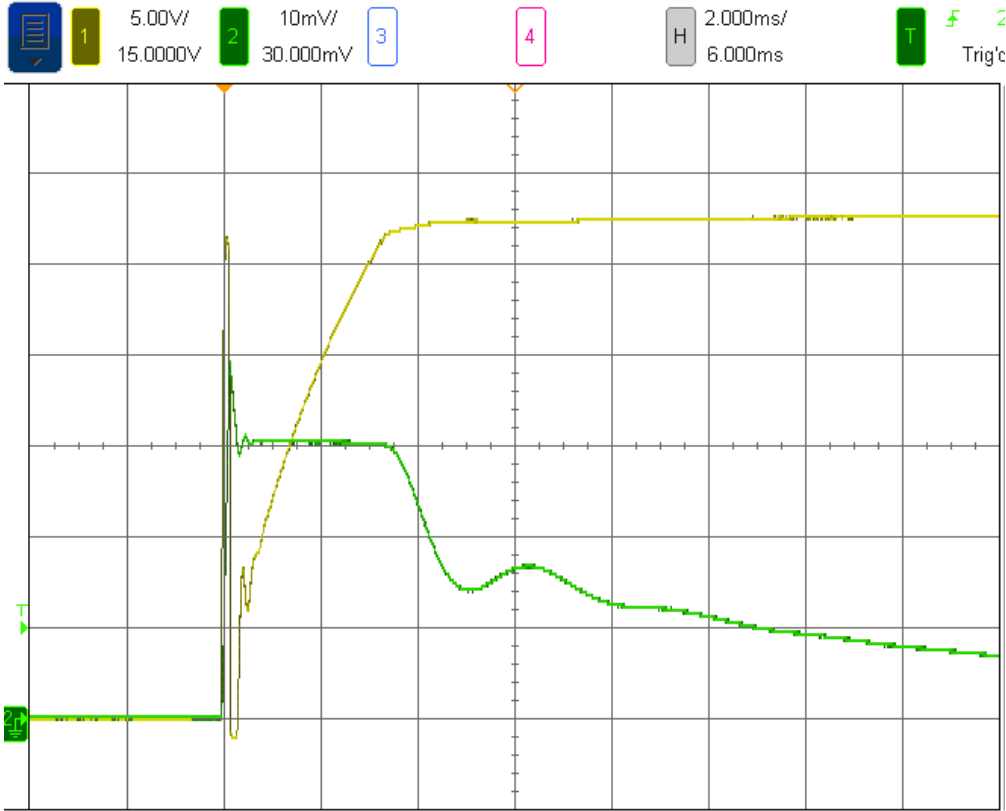


CH 1: Vout
CH 2: Iout

LCL Regulation Stability Test Results



28V Class 5A LCL Turn on into input filter with 500uH

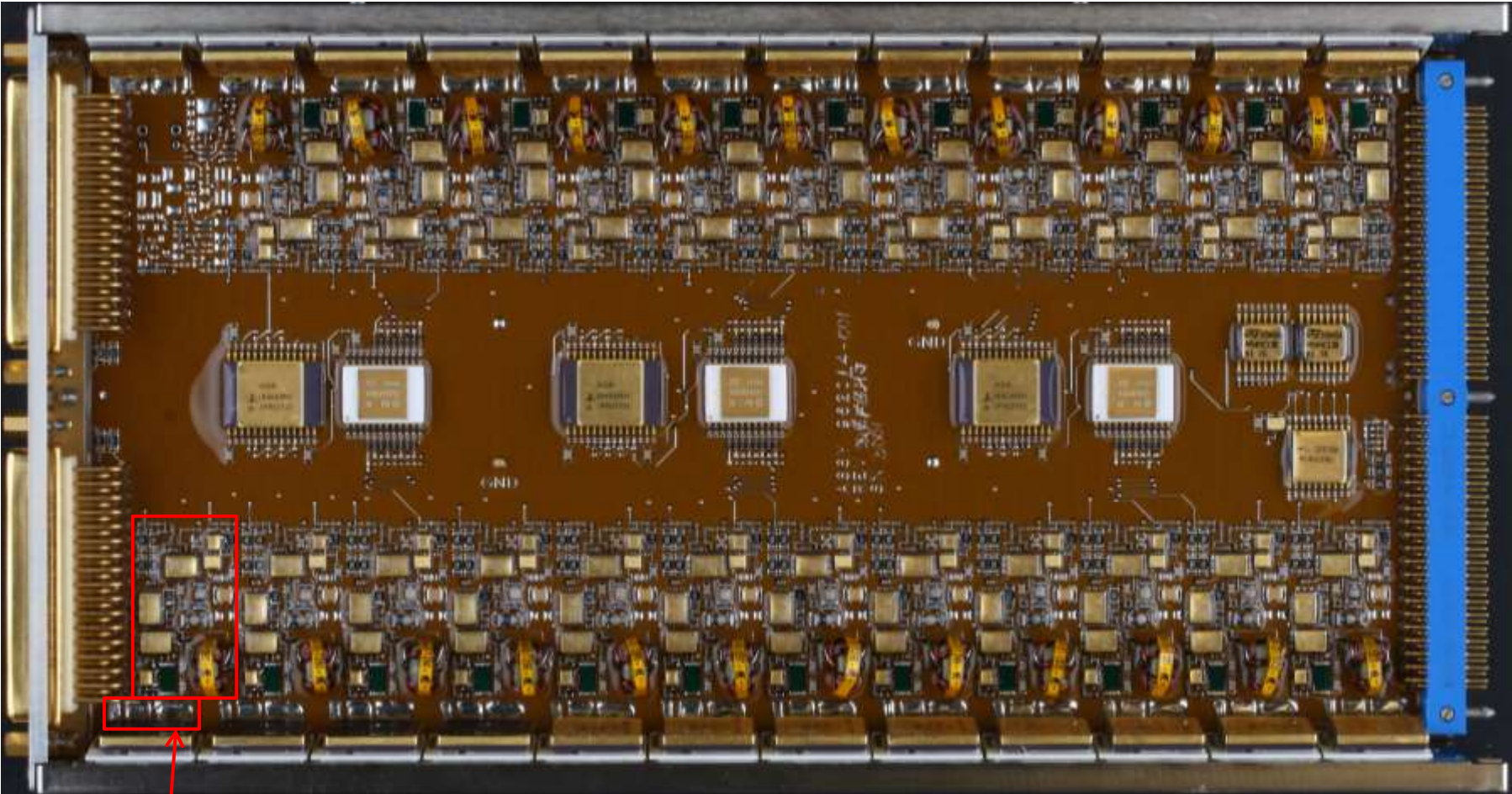


Final Module Layout EPD



← 282mm →

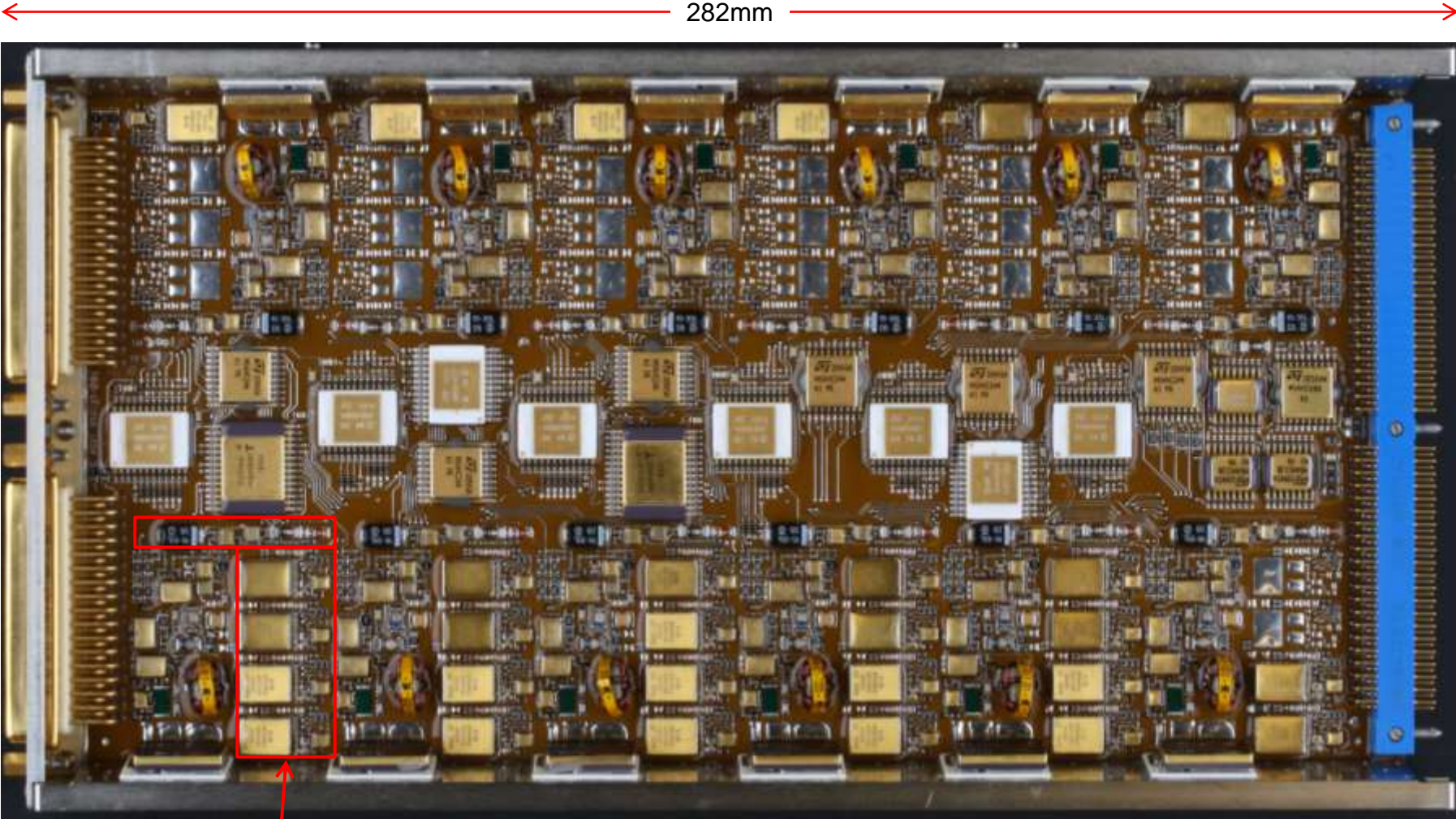
150mm



LCL PCB area: 840 mm²

37 gram per LCL

Final Module Layout HPD



Heater Group of 4 switches PCB area: 1010 mm²

17 gram per HS

End of Presentation



Questions or more information, please contact:

Morten R. Svensson

Phone: +45 40823400

E-mail: mrsv@terma.com

Web: www.terma.com

At present EPD and HPD modules are used in:

Euclid PCDU

- 8 EQM modules (28V regulated bus)
- 8 FM modules (28V regulated bus)

SARah PCDU

- 3 EM Modules (100V unregulated bus)
- 6 FM Modules (100V unregulated bus)

