The overall objective of this document is to be a framework document gathering guidelines for Power Drive Electronics [PDE] design. Those guidelines refer to a set of standard module requirements listed to cover the aircraft application range addressed in “ACTUATION2015” European project. This document is the deliverable D16.19 from SP1 / WP16 and it is merged with deliverable D24.1.
# Table of Contents

1. **GLOSSARY** ......................................................................................................................... 6
2. **EXECUTIVE SUMMARY** ..................................................................................................... 8
3. **INTRODUCTION** ................................................................................................................ 9
   3.1. Terms, References and abbreviations ............................................................................ 9
   3.2. Referenced and Applicable Documents ........................................................................ 9
   3.3. PDE module manufacturer responsibility .................................................................... 10
4. **PRODUCTS REQUIREMENTS** ......................................................................................... 12
   4.1. Product characteristics ................................................................................................. 12
      4.1.1. PDE overview ....................................................................................................... 12
      4.1.2. General description .............................................................................................. 12
         4.1.2.1. Operational Functions .................................................................................... 13
         4.1.2.2. Power Core Module functions (PCM) ............................................................ 13
         4.1.2.3. Control & monitoring Module functions (CMM) ........................................... 14
         4.1.2.4. FILTERING MODULE .................................................................................. 16
         4.1.2.5. PDE ................................................................................................................ 16
   4.1.3. PDE Location ............................................................................................................. 17
   4.2. Performance Characteristics .......................................................................................... 18
      4.2.1. Power range ......................................................................................................... 18
         4.2.1.1. Electrical Motor control .................................................................................. 18
         4.2.1.2. Solenoid control ............................................................................................. 18
      4.2.2. Electric Servo-loop Performances ......................................................................... 18
      4.2.3. Run up time .......................................................................................................... 19
      4.2.4. Thermal and cycle ................................................................................................. 19
      4.2.5. Protection and Monitoring Functions ..................................................................... 19
         4.2.5.1. General ......................................................................................................... 19
         4.2.5.2. Fault Management ......................................................................................... 20
         4.2.5.3. Health Monitoring ......................................................................................... 20
      4.2.6. Actuator Non-Volatile Memory Management ....................................................... 20
      4.2.7. Inter-Unit Bus ........................................................................................................ 21
   4.3. Interface Characteristics ................................................................................................. 22
      4.3.1. Mechanical Interfaces ........................................................................................... 22
      4.3.2. Electrical interface ............................................................................................... 22
         4.3.2.1. PDE Electric Power Supply and Wiring ........................................................... 22
            4.3.2.1.1. HVDC power supply ............................................................................... 22
            4.3.2.1.2. 28 VDC Supply ......................................................................................... 24
            4.3.2.1.3. Wiring ....................................................................................................... 25
            4.3.2.1.4. Internal Segregation Rules ........................................................................ 26
            4.3.2.1.5. Power Consumption ................................................................................ 26
            4.3.2.1.6. Low Signal Power Supplies .................................................................... 26
            4.3.2.1.7. Circuit Breaker Characteristics ................................................................ 27
            4.3.2.1.8. Input / Output Protections ...................................................................... 27
         4.3.2.2. Analogical inputs .............................................................................................. 27
            4.3.2.2.1. Sensor acquisitions characteristics ............................................................ 27
            4.3.2.2.2. Temperature information ......................................................................... 29
            4.3.2.2.3. Hall Effect Proximity Switch (HEP) information ...................................... 30
            4.3.2.2.4. DSI ............................................................................................................ 30
   4.4. PDE Electric Power Supply and Wiring ........................................................................... 24
      4.4.1. HVDC power supply .............................................................................................. 24
      4.4.2. Low Signal Power Supplies .................................................................................. 26
      4.4.3. Circuit Breaker Characteristics .............................................................................. 27
      4.4.4. Input / Output Protections .................................................................................... 27
      4.4.5. Analogical inputs ................................................................................................. 27
      4.4.6. Sensor acquisitions characteristics ........................................................................ 27
      4.4.7. Temperature information ...................................................................................... 29
      4.4.8. Hall Effect Proximity Switch (HEP) information ................................................. 30
4.3.3. Physical Requirements

4.3.3.1. PDE Finish and Colour

4.3.3.2. Mechanical Connections

4.3.3.3. Electrical Connections

4.3.3.4. Mass and Centre of Gravity

4.3.3.5. Locking of Parts

4.3.3.6. Lightning and EMC Protection Devices

4.3.3.7. Electrical Installations

4.3.4. Ergonomic and human factors

4.3.5. Materials

4.3.5.1. Material Characteristics

4.3.5.2. Materials Technologies and Production Processes

4.3.5.3. Fluids and Products used on Aircraft

4.3.5.4. Fire Propagation, Flammability, Smoke and Toxic Emissions

4.3.6. Interchangeability, Mixed configuration operation

4.3.7. Miscellaneous design requirements

4.3.8. Identification and Labelling

4.3.8.1. Electrostatic Discharge Warning Labels

4.3.8.2. RFID

4.3.9. Electrostatic Protection

4.4. Environmental Requirements

4.4.1. General

4.4.1.1. Acceptance criteria

4.4.1.2. Equipment standard

4.4.1.3. PDE fixture

4.4.1.4. Qualification Tests Monitoring

4.4.1.4.1. PDE parameters

4.4.1.5. Environmental conditions and Test requirements associated to Qualification

4.4.1.6. Temperature

4.4.1.6.1. Operational Conditions (Ground/Flight/High/ Low)

4.4.1.6.2. Short-Time Operating Low/High Temperature

4.4.1.6.3. Ground Survival Temperature

4.4.1.6.4. PDE Thermal Integration

4.4.1.7. Atmospheric Pressure/Altitude Requirements

4.4.1.7.1. Steady State – Altitude

4.4.1.8. Temperature Variation

4.4.1.9. Humidity

4.4.1.10. Shocks and Crash Safety

4.4.1.10.1. Operational Shock and Crash Safety

4.4.1.10.2. Shock due to Fan Blade Out

4.4.1.10.3. Bench Handling Shocks

4.4.1.10.4. Shipping Container Shock

4.4.1.11. Vibration

4.4.1.11.1. Operational Vibrations

4.4.1.11.2. Vibrations due to failure conditions

4.4.1.12. Explosion
4.4.1.13. Waterproofness ................................................................. 46
4.4.1.14. Fluid Susceptibility ........................................................ 46
4.4.1.15. Sand and Dust ............................................................... 47
4.4.1.16. Fungus Resistance .......................................................... 47
4.4.1.17. Salt Spray ................................................................. 47
4.4.1.18. Magnetic effect .............................................................. 47
4.4.1.19. Icing ................................................................. 47
4.4.1.20. Hermeticity ................................................................. 48
4.4.1.21. Constant Acceleration .................................................. 48
4.4.1.22. Aircraft Attitude ........................................................... 48
4.4.1.23. Electrical ................................................................. 48
4.4.1.23.1. Power consumption ................................................... 48
4.4.1.23.2. PDE – Supply Related Requirements ............................ 49
4.4.1.23.3. Dielectric and Insulation Resistance Testing .................... 49
4.4.1.23.4. Electrical bonding and power supply returns requirement ................................................... 49
4.4.1.24. Electromagnetic Environmental Test Requirements .......... 49
4.4.1.24.1. General ................................................................. 49
4.4.1.24.2. Lightning .............................................................. 50
4.4.1.25. Electrostatic discharge .................................................... 61
4.4.1.26. Single Event Upset (SEU)/Multiple Bit Upset (MBU) .......... 61
4.4.1.27. Intrinsic safety ............................................................... 62

4.5. Hardware Design Requirements .............................................. 63
4.5.1. Electronic Hardware Development Specific Features .............. 63
4.5.1.1. Electronic Hardware Design Assurance Level Definition ........ 63
4.5.1.2. Dissimilarity .............................................................. 63
4.5.1.3. Electronic Hardware Development Specific Features ............ 63
4.5.1.3.1. Development Methodologies ........................................ 63
4.5.1.3.2. Particular requirements regarding Electronic Hardware Design ................................................... 63
4.5.1.3.3. HDL Language and Synthesizer Considerations ................ 64
4.5.1.3.4. Tool Specification .................................................... 64

4.6. PDE Specific Software Requirements ........................................ 66

4.7. Safety and Reliability ............................................................... 67
4.7.1. Quantitative Safety/Reliability Requirements ......................... 67
4.7.1.1. Quantitative Safety Requirements ....................................... 67
4.7.1.2. Design/Reliability Objectives ........................................... 67
4.7.1.3. MTBF ................................................................. 68

4.8. Maintainability ................................................................. 69
4.8.1. General ................................................................. 69
4.8.2. Maintainability and Maintenance Evaluation ......................... 69
4.8.3. Latched Failures .............................................................. 69
4.8.4. Maintenance Concept ........................................................ 69
4.8.5. MTBUR Objectives .......................................................... 70
4.8.5.1. MTBUR ................................................................. 70
4.8.5.2. MTBUR/MTBF Ratio ................................................... 70
4.8.5.3. Guaranteed MTBUR ................................................... 70
4.8.6. Direct Maintenance Cost.......................................................................................................................... 70
4.8.7. Installation .................................................................................................................................................. 70
4.8.8. Inspection/Test ........................................................................................................................................... 71
4.8.9. Fault Diagnosis ......................................................................................................................................... 72
4.8.10. Servicing/Handling ................................................................. ................................................................. 72
4.8.11. Avoidance of Maintenance Errors ........................................................................................................... 72
4.9. Packaging, Storage and handling ..................................................................................................................... 74
4.9.1. Packaging Storage and Handling Requirements .......................................................................................... 74
5. DESIGN PROCESS REQUIREMENTS ................................................................................................................. 75
5.1. Qualification .................................................................................................................................................... 75
5.1.1. PDE Classification ..................................................................................................................................... 75
5.1.2. Qualification Documentation ....................................................................................................................... 75
5.1.3. Achievements of Qualification .................................................................................................................... 77
5.1.4. Witnessing of Tests ..................................................................................................................................... 77
6. CONCLUSION .................................................................................................................................................... 78
7. APPENDIX 1: POWER DRIVE ELECTRONICS (PDE) DESCRIPTION ................................................................. 79
8. APPENDIX 2: PDE MECHANICAL INTERFACES & SPACE ENVELOP .................................................................. 80
9. APPENDIX 3: ELECTRICAL CONNECTORS ..................................................................................................... 82
10. APPENDIX 4: SINUSOIDAL VIBRATION TEST DUE TO ENGINE FAN BLADE LOSS ........................................... 85
11. APPENDIX A .................................................................................................................................................... 87
12. APPENDIX B .................................................................................................................................................... 88
13. APPENDIX C .................................................................................................................................................... 89
14. APPENDIX D .................................................................................................................................................... 90
15. APPENDIX E .................................................................................................................................................... 91
16. LIST OF THE REQUIREMENTS ........................................................................................................................... 92
## 1. Glossary

<table>
<thead>
<tr>
<th>Abbreviation / acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/C</td>
<td>Aircraft</td>
</tr>
<tr>
<td>A2015</td>
<td>ACTUATION2015</td>
</tr>
<tr>
<td>A664</td>
<td>ARINC specification 664 Avionics Full-Duplex Switched Ethernet (AFDX)</td>
</tr>
<tr>
<td>A664PX</td>
<td>ARINC specification 664 part X</td>
</tr>
<tr>
<td>AC</td>
<td>Alternative Current</td>
</tr>
<tr>
<td>ATP</td>
<td>Acceptance Test Procedure</td>
</tr>
<tr>
<td>BITE</td>
<td>Built In Test Equipment</td>
</tr>
<tr>
<td>CMM</td>
<td>Control &amp; Monitoring Module</td>
</tr>
<tr>
<td>COM</td>
<td>COMmand</td>
</tr>
<tr>
<td>DAL</td>
<td>Design Assurance Level</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>DDR</td>
<td>Detailed Design Review</td>
</tr>
<tr>
<td>DSI</td>
<td>Digital Signal Input</td>
</tr>
<tr>
<td>DSO</td>
<td>Digital Signal Output</td>
</tr>
<tr>
<td>EMA</td>
<td>Electro Mechanical Actuator</td>
</tr>
<tr>
<td>EMI</td>
<td>ElectroMagnetic Interference</td>
</tr>
<tr>
<td>ESD</td>
<td>ElectroStatic Discharge</td>
</tr>
<tr>
<td>FC</td>
<td>Flight Cycles</td>
</tr>
<tr>
<td>FCC</td>
<td>Flight Control Computer</td>
</tr>
<tr>
<td>FCS</td>
<td>Flight Control System</td>
</tr>
<tr>
<td>FH</td>
<td>Flight Hours</td>
</tr>
<tr>
<td>FMECA</td>
<td>Failure Mode, Effects and Criticality Analysis</td>
</tr>
<tr>
<td>HASS</td>
<td>Highly Accelerated. Stress Screening</td>
</tr>
<tr>
<td>HEP</td>
<td>Hall-Effect Proximity sensor</td>
</tr>
<tr>
<td>HES</td>
<td>Hall Effect Sensor</td>
</tr>
<tr>
<td>HIRF</td>
<td>High Intensity Radiated Field</td>
</tr>
<tr>
<td>HLS</td>
<td>High Lift System</td>
</tr>
<tr>
<td>HVDC</td>
<td>High Voltage Direct Current</td>
</tr>
<tr>
<td>ISSI</td>
<td>Internal Standardised Supply Interface</td>
</tr>
<tr>
<td>LRI</td>
<td>In Line Replaceable Item</td>
</tr>
<tr>
<td>LRU</td>
<td>In Line Replaceable Unit</td>
</tr>
<tr>
<td>LVDS</td>
<td>Low Voltage Differential Signalling</td>
</tr>
<tr>
<td>MBU</td>
<td>Multiple Burst Upset</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
</tr>
<tr>
<td>MLG</td>
<td>Main Landing Gear</td>
</tr>
<tr>
<td>MON</td>
<td>MONitoring</td>
</tr>
<tr>
<td>MTBF</td>
<td>Mean Time Between Failure</td>
</tr>
<tr>
<td>MTBUR</td>
<td>Mean Time Between Unscheduled Removals</td>
</tr>
<tr>
<td>NSEU</td>
<td>Neutron Single Event Upset</td>
</tr>
<tr>
<td>NWS</td>
<td>Nose Wheel Steering</td>
</tr>
<tr>
<td>P/N</td>
<td>Part Number</td>
</tr>
<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
</tr>
<tr>
<td>PCM</td>
<td>Power Core Module</td>
</tr>
<tr>
<td>PDE</td>
<td>Power Drive Electronic</td>
</tr>
<tr>
<td>PFCS</td>
<td>Primary Flight Control System</td>
</tr>
<tr>
<td>PICOL</td>
<td>Power Inverter Control Over LVDS</td>
</tr>
<tr>
<td>PR</td>
<td>Plan Review</td>
</tr>
<tr>
<td>PWM</td>
<td>Pulse Width Modulation</td>
</tr>
<tr>
<td>REACH</td>
<td>Registration, Evaluation, Authorisation and Restriction of Chemicals</td>
</tr>
<tr>
<td>RFID</td>
<td>Radio Frequency IDentification</td>
</tr>
<tr>
<td>RMS</td>
<td>Root Mean Square</td>
</tr>
<tr>
<td>RTD</td>
<td>Resistive Temperature Device</td>
</tr>
<tr>
<td>SBI</td>
<td>Single Bus Interface</td>
</tr>
<tr>
<td>S/R</td>
<td>Safety / Reliability</td>
</tr>
<tr>
<td>S/W</td>
<td>Software</td>
</tr>
<tr>
<td>SCADE</td>
<td>Safety Critical Application Development Environment</td>
</tr>
<tr>
<td>SSPC</td>
<td>Solid State Power Controller</td>
</tr>
<tr>
<td>TBA</td>
<td>To Be Answered (by the Airframer or Supplier)</td>
</tr>
<tr>
<td>TBC</td>
<td>To Be Confirmed</td>
</tr>
<tr>
<td>TBD</td>
<td>To Be Defined</td>
</tr>
<tr>
<td>THDi</td>
<td>Total Harmonic Distortion</td>
</tr>
<tr>
<td>THS</td>
<td>Trimmable Horizontal Stabilizer</td>
</tr>
<tr>
<td>VDC</td>
<td>Volt Direct Current</td>
</tr>
</tbody>
</table>
2. Executive summary

This document is the deliverable D16.19 from SP1 / WP16 of ACTUATION 2015 project. The objective of this document is to provide guidelines for the design of the Power Drive Electronics [PDE]. Those guidelines refer to a set of standard module requirements listed to cover the aircraft application range addressed in “ACTUATION2015” European project:

- Power core module (PCM)
- Control and Monitoring Module (CMM)
- Internal Standardised Supply Interface (ISSI)
- Power Inverter Control Over LVDS (PICOL)
- Operative Software (OS)

The main result of this document is a complete technical specification encapsulating all the modules proposed in “ACTUATION2015”, permitting to develop and qualify an electronic module able to control and electric actuator in the range addressed in “ACTUATION2015”. This document will be used to develop and for the test phase of the PDE Module.

This document has been merged with deliverable D24.1 – Complementary electronic module specification – as a single document. PDE module specifications have been written in close collaboration between the partners of WP16 (Airbus-F) and WP24 (GAS-F, GAS-UK, MDSC, MBD, SAGEM). As a result the partners of the two work packages considered preferable to produce a unique document covering the two deliverables D16.19 and D24.1. Therefore the content of the D24.1 is exactly the same as the current one, i.e. the D16.19. Those two documents are released but with the same content.
3. Introduction

3.1. Terms, References and abbreviations

The use of "shall", "should", "must", "will" and "may" within this document shall observe the following rules:

- The word SHALL in the text denote a mandatory requirement of this document. Departure from such a requirement is not permissible without formal agreement.
- The word SHOULD in the text denote a recommendation or advice on implementing such a requirement of the document. Such recommendations or advice is expected to be followed unless good reasons are stated for not doing so.
- The word MUST in the text is used for legislative or regulatory requirements (e.g. Health and Safety) and shall be complied with. It is not used to express a requirement of this document. The word WILL in the text denotes a provision or service or an intention in connection with a requirement of this document.
- The word MAY in the text denotes a permissible practice or action. It does not express a requirement of this document.

3.2. Referenced and Applicable Documents

The PDE module shall comply with the applicable documents listed in the following subsection tables and any applicable documents referenced in them.

The PDE Supplier shall request from the Airframer any required document that is not already provided (e.g. ABD).

Standard Motor specification A2015 D16.18-D23.1
Standard Power Core Module specification [PCM] Confidential (See Appendix A)
Standard Control and Monitoring Module (CMM) Confidential (See Appendix B)
Standard Internal Standardised Supply Interface (ISSI) Confidential (See Appendix C)
Standard Power Inverter Control Over LVDS (PICOL) Confidential (See Appendix D)
Standard Operative Software (OS) Confidential (See Appendix E)

It should be noted that any referenced documents are for information only. If a document is identified as applicable then the Supplier shall comply with it.

Quality Documents

<table>
<thead>
<tr>
<th>DOCUMENT REFERENCE</th>
<th>ISS</th>
<th>TITLE/CONTENT</th>
<th>APPLICABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>IQDA-09.26</td>
<td>B</td>
<td>Duplicate inspection procedure</td>
<td>Yes</td>
</tr>
</tbody>
</table>

EUROCAE and RTCA Documents

<table>
<thead>
<tr>
<th>DOCUMENT REFERENCE</th>
<th>ISS</th>
<th>TITLE/CONTENT</th>
<th>APPLICABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUROCAE ED14/ R.T.C.A D0160</td>
<td>G</td>
<td>Environmental Conditions and Test Procedures for Airborne Equipment</td>
<td>Yes</td>
</tr>
<tr>
<td>EUROCAE ED12/ R.T.C.A D0178</td>
<td>B</td>
<td>Software Considerations in Airborne Systems and Equipment Certification</td>
<td>Yes</td>
</tr>
<tr>
<td>EUROCAE ED80/ R.T.C.A D0254</td>
<td>-</td>
<td>Design Assurance guidance for Airborne electronic hardware</td>
<td>Yes</td>
</tr>
</tbody>
</table>
This specification defines the technical requirements that the PDE module shall fulfil.

3.3. PDE module manufacturer responsibility

- The PDE module manufacturer shall be contractually responsible for the design, development, qualification and supply of the PDE that fully meets the standard requirements of this specification.

- The aircraft manufacturer's approval of drawings or documents in no way relieves the equipment manufacturer of this responsibility,

- Considering that the equipment manufacturer is a professional of electronic and electrical actuator technology, it shall ask the aircraft manufacturer for any additional information required for making the PDE complying with this specification if it is not provided in this specification, and, if necessary, shall advise the aircraft manufacturer,

- If requested by the aircraft manufacturer, the equipment manufacturer shall participate to the rig test during the PDE development,

- If requested by the aircraft manufacturer, the PDE manufacturer shall collaborate with the aircraft manufacturer and other equipment manufacturers in order to ensure the correct operation of the aircraft system. This collaboration may involve performing
design work and/or tests concerning the coupling of the PDE or one of its sub-
assemblies with associated computers, aircraft systems or aircraft components,

- If requested by the aircraft manufacturer, the PDE manufacturer shall provide the
  aircraft manufacturer with the elements of the manufacturing drawings (including
  blanks) production processes, component or material specifications required for
  solving any technical problem that might occur.
4. Products requirements

4.1. Product characteristics

The requirements defined in this chapter shall be met at any time of the flight and ground stages, during the whole specified service life and under the operating conditions specified in paragraph “Environmental Requirements”. The extreme operating conditions, supply transients etc....shall not result in any deviation to the specified requirements.

The performances defined in this chapter have to be fulfilled under the normal operating conditions specified in paragraph “Environmental Requirements”. Unless otherwise specified. Possible downgrading that may result from extreme environmental conditions or severe use shall be identified and submitted to Airframer agreement.

4.1.1. PDE overview

The PDE shall include:
- A housing connected to the actuator or to the structure by four fixation points,
- An input stage including EMI/Lightning protections and associated devices in order to comply with standard aircraft requirements,
- A power inverter stage and the associated electronic control in order to control both the electrical motor and a solenoid (Power Core Module),
- Two segregated electronic modules for communication with aircraft by external digital bus and for actuator local control and monitoring (Control & Monitoring Modules),
- An Internal power supply converter (ISSI), galvanically isolated,
- Six electrical connectors (3 for aircraft, 3 for actuator).

4.1.2. General description

The terminology used in the supplier documentation shall be based on this description.

The following main functions shall be performed by the PDE:
- motor control (electrical actuator),
- solenoid control (Anti-extension, brake ...),
- Management of electrical actuator information (position, load, temperature, voltage, current),
- A bus communication device to aircraft computer,
- An input/output filtering and the environmental PDE protection.

Function location
The PDE functional layout is presented in appendix 1.
4.1.2.1. Operational Functions

4.1.2.1.1. Power Core Module functions (PCM)

Motor drive controller device
The PCM shall be able to control three-phase motor in the four quadrants in accordance with CMM-COM order.

Current measurement device
The PCM shall be able to provide the current measure in each motor phase.
The PCM shall be able to provide current measurement for the solenoid device.

Temperature measurement device
A temperature measurement device shall be able to provide two isolated temperature measure of electronic power on the hot point of PCM, and transmitted hard-wired to CMM-COM and/or CMM-MON.

Voltage measurement device
The PCM shall be able to provide measurement voltage on HVDC bus.

Solenoid control device
The PCM shall be able to control a solenoid activation device.

Galvanic Isolation
The PCM high voltage power stage (switches, drivers, current measurement…) shall be galvanically isolated from the PCM low level voltage control stage (communication Bus, discrete signals, rotor position…).

Position motor acquisition
The PCM shall be able to supply and acquire the position motor sensor (HES type sensor).

Analogical to Digital conversion device
The PCM shall be able to convert the sensors information and controls signals into digital information.

High-speed communication interface device
The PCM shall be able to provide high-speed communication bus between PCM and CMM according PICOL specification.

Internal DC power supplies device
The PCM shall be able to generate low level voltage when supplied with +15VDC.
Filter stage device (TBC)
The supplier shall analyse the need to incorporate a minimum filter stage on the PCM.

Program Pin
The CMM-COM shall be configurable by pin programming.

4.1.2.1.2. **Control & monitoring Module functions (CMM)**

4.1.2.1.2.1. **CONTROL CHANNEL (CMM-COM):**

Control functions
The CMM-COM shall be able to perform actuator servo loop according to information exchanged with the sensors and order information coming from FCC.

Signal acquisitions
The CMM-COM shall be able to perform acquisition from the sensors coming from PCM via High-Speed communication bus (HVDC bus voltage, motor phase currents, solenoid current and motor position (HES signals))

Update software functions
The CMM shall be able to perform data loading operations on request.

Aircraft communication bus
The CMM-COM shall be able to send and receive information from/to FCC.

High-speed communication interface device
The CMM-COM shall be able to provide high-speed communication bus between CMM and PCM.

COM-MON Communication
The CMM-COM shall be equipped with a standard bidirectional bus interface between COM and MON boards.

Internal DC power supplies device
The CMM-COM shall be able to generate low level voltage when supplied with +15VDC.

xVDT sensors acquisition device
The CMM-COM shall be able to excite and acquire two (2) sensors type xVDT.

Pressure or Load sensors acquisition device
The CMM-COM shall be able to excite and acquire two (2) load/pressure sensors.
Proximity HEP Acquisition
The CMM-COM shall be able to excite and acquire one proximity HEP sensor, three wires will be used (Signal, Supply and Ref.)

Temperature sensors acquisition device
The CMM-COM shall be able to supply and acquire three (3) temperature sensors.

Segregation
COM and MON lanes shall be mechanically segregated inside the PDE.

Program Pin
The CMM-COM shall be able to be configured by pin programming.

4.1.2.1.2.2. MONITORING CHANNEL (CMM-MON):

Signal acquisitions
The CMM-MON shall be able to perform sensor acquisition and data concentration.

Health monitoring functions
The CMM-MON shall be able to perform Health Monitoring functions.

Update software functions
The CMM-MON shall be able to perform data loading operations on request.

Aircraft communication bus
The CMM-MON shall be able to send and receive information from/to FCC.

High-speed communication interface device
The CMM-MON shall be able to provide high-speed communication bus capabilities.

COM-MON Communication
The CMM-MON shall be equipped with a standard bidirectional bus interface between COM and MON boards.

Internal DC power supplies device
The CMM-MON shall be able to generate low level voltage when is supplied with +15VDC.

xVDT sensor acquisition device
The CMM-MON shall be able to excite and acquire one (1) sensor type xVDT.
The CMM-MON shall be able to acquire one (1) sensor type xVDT without exciting the sensor.

Pressure or Load sensor acquisition device
The CMM-MON shall be able to excite and acquire three (3) load/pressure sensors.

Proximity HEP Acquisition
The CMM-MON shall be able to excite and acquire one proximity HEP sensor, three wires will be used (Signal, Supply and Ref.).

Temperature sensor acquisition device
The CMM-MON shall be able to excite and acquire three (3) temperature sensors.

Non-Volatile Memory (NVM)
The CMM-MON shall be able to provide an external link to communicate and transfer data to an actuator Non-Volatile Memory (NVM) in order to perform electronic rigging and Health Monitoring functions.

Segregation
MON and COM lanes shall be mechanically segregated inside the PDE.

Program Pin
The CMM-MON shall be able to be configured by pin programming.

4.1.2.1.3. FILTERING MODULE
The Filtering Module (FM) shall ensure the compliance with the HVDC network requirements.
If necessary, a filter between the PDE and Actuator should be proposed by the supplier.

4.1.2.1.4. PDE
The PDE shall be designed as a sealed LRI.
The PDE shall be self-contained fire in normal and in failure conditions.
The PDE shall be able to provide lightning protection to the different inputs and outputs.
The PDE shall be equipped with a RFID device.
The High power elements in the PDE shall be compliant to Corona effects.
4.1.3. PDE Location

The PDE module is installed either on the actuator or on central avionics (between 0 and 25m) in a non-pressurised area.

The environmental characteristics of these defined locations, within which the PDE system must be verified to operate, are identified in sub-chapter "Environmental requirements" of this document.
4.2. Performance Characteristics

4.2.1. Power range

4.2.1.1. Electrical Motor control

The PDE shall operate normally for any voltage applied higher than 400 VDC (540VDC electric supply) or 200 VDC (270VDC electric supply).

Three PDE “power sizes” cover the largest possible range of applications. The PDE Operating nominal DC power (540VDC) for motor control shall be below:
- size I: TBA kW (Objective 5 kW max),
- size II: TBA kW (Objective 20 kW max),
- size III: TBA kW (Objective 40 kW max).

Only the standard modules in the PDE are listed in section 3.2. Other parts such as casing, filters, motherboard(s), etc. may be specific to the application.

The electrical motor is a brushless three-phase synchronous motor. The main characteristics of the motor are (at 25°C):

<table>
<thead>
<tr>
<th>Size</th>
<th>Stator Resistance</th>
<th>Stator Inductance (at 1 kHz)</th>
<th>Ke</th>
<th>Pairs of poles</th>
<th>Point at max torque and speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>TBA to TBA</td>
<td>TBA to TBA</td>
<td>TBA</td>
<td>TBA</td>
<td>TBA N.m @ TBA rad/s</td>
</tr>
<tr>
<td>II</td>
<td>TBA to TBA</td>
<td>TBA to TBA</td>
<td>TBA</td>
<td>TBA</td>
<td>TBA N.m @ TBA rad/s</td>
</tr>
<tr>
<td>III</td>
<td>TBA to TBA</td>
<td>TBA to TBA</td>
<td>TBA</td>
<td>TBA</td>
<td>TBA N.m @ TBA rad/s</td>
</tr>
</tbody>
</table>

4.2.1.2. Solenoid control

The PDE maximum consumption Operating nominal DC power (540VDC) for Solenoid control shall be below:
- size I: TBA W (Objective 500 W maximum),
- size II: TBA W (Objective 500 W maximum),
- size III: TBA W (Objective 500 W maximum),

The PDE maximum consumption Operating nominal DC power (270VDC) for Solenoid control shall be below:
- size I: TBA W (Objective 250 W maximum),
- size II: TBA W (Objective 250 W maximum),
- size III: TBA W (Objective 250 W maximum),

4.2.2. Electric Servo-loop Performances

The PDE shall comply with the performance requirements of the application.
Electric servo-loop requirements flow-down shall be done after analysis of motor and/or electrical actuator characteristics.

### 4.2.3. Run up time

The time interval between energizing of the PDE (HVDC) and the beginning of the electrical output to the motor, with the maximum command signal, shall be lower than TBA ms (objective < 50ms) with a nominal power voltage and whatever the external load.

### 4.2.4. Thermal and cycle

The heat-sink of the PDE shall be sized according to specific application dissipation requirements.

The worst case is defined hereafter:

- Static load: TBA daN without time limitation under TBA°C around the PDE
- Dynamic load: Sinusoidal movement +/- TBA mm (or °) at TBA Hz with TBA stall load without limitation of time (skin PDE temperature stabilization under 100°C) Ambient air temperature around the PDE below TBA°C, no air flow.

### 4.2.5. Protection and Monitoring Functions

#### 4.2.5.1. General

The Supplier shall provide the Airframer with the justification elements against the system safety requirements (sensor, performance, algorithms...).

The unit internal monitoring (e.g. implemented in the operating S/W) which have an action on the rest of the system operation must be minimized (objective: none) and limited to system safety aspects. The introduction of internal monitoring shall be submitted to the airframer for approval, please refer to CMM software specification.

Unit behaviour following power interrupt shall be deterministic.

Destructive test shall be performed so as to give confidence in compliance with the major safety requirements (mechanical propagation, fire, housing temperature...).

The supplier shall propose a strategy for failure and bad operation detection and management. The trade-off between cautiousness (failures effects are kept under control) and reliability (failure management circuitry will not impair the reliability of the unit) shall be presented. This strategy shall be agreed by the airframer.

Appropriate test procedures shall be proposed by the supplier and submitted to the airframer's acceptance.
4.2.5.2. Fault Management

The supplier shall define the PDE fault tolerance level and show compliance with the requirements for safety.

The actuators internal monitoring (implemented in the operating S/W) which have an action on the actuator operation must be minimized (objective: none) and limited to system safety aspects (e.g. processor integrity...). The use of internal monitoring shall be submitted to the Airframer for approval.

In case of failure, if processor integrity is not guaranteed, and if needed for safety reasons, a variable (TBD) shall be set to TRUE to report the failure, otherwise it shall be set to FALSE.

4.2.5.3. Health Monitoring

The PDE shall provide the electronic hardware and software to implement the Health Monitoring functions.

The hereafter description explains the domain to be covered by Health Monitoring and to be used for the sizing of the PDE.

Each actuator shall contain a so-called Health Monitoring (HM) feature based on internal sensors measurements and internal algorithms.

The objective of the health monitoring is to predict and prevent any abnormal behaviour of the equipment (anticipation of jamming, backlash evolution, degraded performances, etc...).

The supplier shall propose Health monitoring solutions for system actuation that can fulfil the following expectations and functions:

- To anticipate jamming,
- To identify and locate failures,
- To identify and anticipate predictive maintenance tasks,
- To estimate the remaining life time of the PDE and the actuator (based on life cycles, ...),
- To store maintenance operations historical
- To store a working historical (Flight Hour, Flight Cycle, ON/OFF cycles, ...),
- To store the configuration and the location of the equipment (equipment type, P/N, S/N, ...)

The computation and control of these functions will be integrated into the PDE (CMM-MON board).

4.2.6. Actuator Non-Volatile Memory Management

The non-volatile Memory fitted on actuator shall be of read/write type and managed by the PDE.
Health Monitoring data shall be stored in the actuator non-volatile memory.

The non-volatile Memory required within the actuator shall be able to store EMA key parameters, Health Monitoring and electrical rigging data during the whole actuator life.

4.2.7. Inter-Unit Bus

The PDE shall provide a CMM-COM to CMM-MON bus in order to exchange data.

Inter unit bus shall be implemented inside the PDE.

The bus type shall be chosen by the Supplier and agreed by the Airframer.

Inter Unit Bus messages integrity shall be protected at least by a parity bit for each message.

Inter unit bus integrity shall be indicated to Application Software (input) using a failure Boolean variable. The failure Boolean variable shall be set to false if the inter bus integrity is OK, else it shall be set to TRUE.

Maximum lag induced by this communication means in any direction shall be lower than 0.5ms.
4.3. Interface Characteristics

4.3.1. Mechanical Interfaces

The PDE mechanical interfaces and space envelope shall comply with application specific requirements (see Appendix 2 for a specific example).

4.3.2. Electrical interface

4.3.2.1. PDE Electric Power Supply and Wiring

4.3.2.1.1. HVDC power supply

The PDE shall be compatible for operation with two power supply levels: 540VDC and 270VDC.

The PDE shall operate for a maximum range of power supply variation between 250 and 650 VDC without any modification neither additional indication.

4.3.2.1.1. 540 VDC power supply characteristics (HVDC)

In case of PDE supplied with 540VDC, in particular:
Steady rate: The steady state power supply voltage range is 500 VDC to 650 VDC at the PDE level for full performances (see figure hereafter).
Normal voltage transients: The transient power supply voltage according to the HVDC requirements (400 VDC to 750 VDC) shall not affect the good operation of the PDE).
### 4.3.2.1.1.2. 270 VDC power supply characteristics

In case of PDE supplied with 270VDC, in particular:

**Normal operation:**
Normal operation characteristics shall be in accordance with figures and table hereafter.

<table>
<thead>
<tr>
<th>Steady state characteristics</th>
<th>Limits - 270 Volt DC system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steady state voltage</td>
<td>250.0 to 280.0 Volts</td>
</tr>
<tr>
<td>Distortion factor</td>
<td>0.015 maximum</td>
</tr>
<tr>
<td>Distortion spectrum</td>
<td>Figure 18</td>
</tr>
<tr>
<td>Ripple amplitude</td>
<td>6.0 Volts maximum</td>
</tr>
<tr>
<td>Transient characteristics</td>
<td>270 Volts DC system</td>
</tr>
</tbody>
</table>
4.3.2.1.2. **28 VDC Supply**

Damage due to inadvertent application of 28VDC, or ground on one or more pins of a connector shall be limited to inputs/outputs involved.

The PDE will be permanently supplied with one dedicated 28VDC power supply.

<table>
<thead>
<tr>
<th>Steady State Characteristics</th>
<th>Normal</th>
<th>Abnormal</th>
<th>Emergency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage (VDC)</td>
<td>27-30.3</td>
<td>24-32.5</td>
<td>21-32.5</td>
</tr>
</tbody>
</table>
4.3.2.1.3. **Wiring**

**From A/C**

**HVDC:**

Power line impedance will be TBD µH (50 µH max) with a resistance of 1 Ohm (max) for size I, TBD Ohms for size II and TBD Ohms for size III. Power cable length is maximum 40m.

The capacitance between two twisted wires is 0.05 nF/m.

The capacitance between two wires of two separate twisted pairs is 0.005 nF/m.

**28VDC:**

FCC/PDE wiring will be equivalent to an impedance of 1 to 2 Ohm and 80 to 130 µH

The maximum cable length will be of 40 m.

The capacitance between two twisted wires is 0.05 nF/m.

The capacitance between two wires of two separate twisted pairs is 0.005 nF/m.

**A664p7 data BUS:**

Cable reference is TBD according TBD.

**Other Wiring**

The electrical components shall be connected to the computers via twisted gauge 24 wires that may be shielded.

The wires shall be twisted in pairs and, as far as the position transducers are concerned, pairs twisted together.

4.3.2.1.3.1. **Equipment Behaviour following Power Interrupt**

During transients (<3.5ms) on 28VDC, the behaviour of the PDE shall remain in normal operation.

Maximum time between 28VDC power loss and all outputs in inactive state shall not exceed TBA ms (Objective 10ms).

Maximum time between 28VDC power recovery and disposition of stabilised inputs/outputs (A664P7 communication) shall not exceed TBD ms (Objective 250ms).
In case of power interrupt duration between min and max hold up time, PDE behaviour shall be deterministic.

After a power interruption higher than 3.5 ms, discrete mode signal acquired by application software and associated variable shall change from TRUE to FALSE.

### 4.3.2.1.4. Internal Segregation Rules

COM and MON lane shall be mechanically segregated.

The flight control computer interface signals shall be galvanically isolated from the HVDC power supply.

### 4.3.2.1.5. Power Consumption

The electrical consumption shall be minimized.

Maximum power consumption in normal or abnormal electrical system operation shall be less than $TBA$ kW at PDE input terminals whatever power supply conditions (voltage).

When application software variable indicates “power limitation” to TRUE in COM lane, power limitation shall switch from nominal value to emergency value.

Each COM and MON lane shall report the actuator power limitation status by setting the Boolean variable (COM and MON lanes) to TRUE if the power limitation is engaged on the actuator. Else, it shall set it to FALSE.

Actuator power limitation status shall be provided on A664P7 COM data bus.

Actuator power limitation status shall be provided on A664P7 MON data bus.

Maximum lag between engagement of emergency power limitation mode (sent on A664p7 bus) and power limitation status associated software variable (sent on A664P7 buses and used for computation) shall be less than $7,5$ ms.

The maximum current demanded (inrush included) by the PDE should not exceed $TBD$ A peak.

### 4.3.2.1.6. Low Signal Power Supplies

COM lane internal power supplies shall be galvanically isolated from the 28 VDC.
MON lane internal power supplies shall be galvanically isolated from the 28 VDC.

4.3.2.1.7. Circuit Breaker Characteristics

The overall PDE operation, and particularly the inrush current for 540, 270 or 28 VDC supply, shall be compatible with an aircraft circuit breaker.

Note: The purpose of the circuit breaker is not to protect the PDE but the associated power supply wiring.

4.3.2.1.8. Input / Output Protections

The PDE Inputs/Outputs shall be protected from any load short-circuits.

The PDE shall be protected against inadvertent application of 115 VAC, 230VAC, 270 VDC and 540 VDC or ground on one or more pins of the connectors.

The PDE shall be protected against internal power supply failure.

4.3.2.2. Analogical inputs

4.3.2.2.1. Sensor acquisitions characteristics

4.3.2.2.1.1. Motor position information

PDE shall acquire two (2) different HES (TBC) motor position sensor devices (3 and 2 probes each).

Motor position information on PCM

PCM shall provide motor position sensor information using dedicated motor sensor.

The Angular position transducer interface shall be able to receive a HES type sensor.

Info: The HES is composed of three analogue Hall-effect probes.

The three Hall-effect probe signals are transmitted to the PCM on three 4-20mA current loops. The HES is supplied by the +15V DC provided by the motherboard (common power supply with NVM).

Motor speed information shall be provided on A664P7 data bus.
Motor position information accuracy, resolution, coding noise and bandwidth (including lag between physical position and associated software variable sent on A664P7 or used for application software) shall meet the performances requirements defined in at actuator level.

(Accuracy objective for PDE <0,25°)

A monitoring shall be defined by the supplier in order to be able to detect cut wire or supply problem (like oscillatory failure). Motor position sensor wire cut and oscillatory monitoring will be implemented within FCC, shall not impact actuator operation and shall be agreed by the Airframer.

Motor position information on CMM-MON (TBC)

CMM-MON shall provide motor position sensor information using dedicated motor sensor.

Motor speed information shall be provided on A664P7 data bus.

The Angular position transducer interface shall be able to receive a HES type sensor.

The HES sensor interface shall be -TBC wires (three 4-20mA loop interfaces).

Motor position information accuracy, resolution, coding noise and bandwidth (including lag between physical position and associated software variable sent on A664P7 or used for application software) shall meet the performances requirements defined in at actuator level.

(Accuracy objective for PDE <0,5°)

A monitoring shall be defined by the supplier in order to be able to detect cut wire or supply problem (like oscillatory failure). Motor position sensor wire cut and oscillatory monitoring will be implemented within FCC, shall not impact actuator operation and shall be agreed by the Airframer.

4.3.2.2.1.2. RVDT / LVDT position information

CMM-COM unit shall acquire two (2) xVDT positions.

CMM-MON unit shall acquire two (2) xVDT positions.

CMM-COM xVDT sensor shall be power supplied by COM unit (shared ACS).

Two (2) MON xVDT sensors shall be one (1) xVDT power supplied by CMM-COM and the other one (1) power supplied by MON unit (single ACS).
A monitoring shall be defined by the supplier in order to be able to detect cut wire or supply problem (like oscillatory failure). xVDT position sensor wire cut and oscillatory monitoring will be implemented within FCC, shall not impact EMA operation and shall be agreed by the Airframer.

### 4.3.2.2.1.3. Pressure or Load information

CMM-COM unit shall acquire two (2) pressure or load sensors.

CMM-MON unit shall acquire three (3) pressure or load sensors.

<table>
<thead>
<tr>
<th></th>
<th>CMM-COM</th>
<th>CMM-MON</th>
</tr>
</thead>
<tbody>
<tr>
<td>pressure or load sensors acquisition</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>pressure or load sensors supply</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Pressure or load information shall be provided on A664P7 data bus.

A monitoring shall be defined by the supplier in order to be able to detect cut wire or supply problem (like oscillatory failure). Pressure transducers/load sensor wire cut and oscillatory monitoring will be implemented within FCC, shall not impact EMA operation and shall be agreed by the Airframer.

The Pressure transducer / load sensor interface shall be composed of two wires with power supply allowing current measurement for sensors consuming less than 4mA.

Pressure transducer / load sensor input shall be provided through a 4-20mA / 15V analogue interface.

Pressure transducer / load sensor 15V power supply shall stay between 12V at 20mA and 18V at 4mA output current.

The voltage supply shall be 15VDC

### 4.3.2.2.2. Temperature information

Each CMM unit shall be able to acquire three (3) temperature sensors.

As far as possible, this sensor shall be placed near the hottest point (Power switches on the PCM for example).
Range of temperature sensor acquisition shall be comprised in the interval [-60°, +255°] (MR = 315°).

Temperature sensors characteristics shall be PT100 (100 Ohm at 0°C).

Temperature information shall be provided on A664P7 data bus.

Temperature information shall be available for application software on dedicated lane or in the other lane.

### 4.3.2.2.3. Hall Effect Proximity Switch (HEP) information

The PDE shall be able to acquire two (2) HEP proximity information sensors, one per CMM lane,

The HEP sensor interface shall be 3 wires (1: reference, 1: supply, and 1: analog sensor signal output).

The voltage supply shall be 0-5VDC

HEP input current consumption in absolute value shall be < 1mA.

### 4.3.2.2.4. DSI

DSI shall be used for pin programming.

Each CMM unit shall acquire 8 discrete input named DSIx with x=[1-8].

5 pins for position identification + 1 pin for CMM identification within the PDE (2 CMM) + 1 parity pin + 1 DSI for UVD signal from ISSI.

DSI shall be DSI Ground / Open type.
Ground/Open discrete inputs shall use a 15V DC polarisation voltage internal to the equipment.

Ground/Open discrete inputs hysteresis shall be greater than 3V.

### 4.3.2.3. Analogical Outputs

#### 4.3.2.3.1. DSO

Each CMM unit shall provide one GND / Open low power (4 mA) discrete output. 4 mA allows driving 4 DSI.

Output equivalent impedance shall be higher than 1 MΩ when output is open or when the equipment is not powered.

Low power discrete output, Ground/Open circuit type shall be:
- Ground state = voltage < 0.5 V at 4 mA,
- Open state = equivalent impedance > 1 MΩ.
(Over the whole temperature range specified for this equipment)

### 4.3.2.4. Bus interface

As reference, the communication bus type specified in this document is following ARINC 664 Part 7 (A664p7) standard.

For more details see A664p7 specification.

### 4.3.2.5. Actuator NVM interface

The CMM-MON shall be capable to obtain/provide data on the actuator NVM.

MON unit shall provide a one (1)a TBD NVM bus interface in order to read and write data in the actuator memory.

The SPI NVM bus interface shall use a RS-485 half-duplex physical layer.A2015_D16_19_PDE_0601

### 4.3.2.6. The alimentation between the actuator NVM and the PDE shall be 15V coming from ISSI module with appropriated output protection.Pin Programming

The supplier shall propose a robust PDE H/W pin programming strategy in order to comply with safety objectives.
The PDE address shall be programmable using dedicated pin program on the A/C plugs.

Each pin program shall be achieved by a strap between 2 points on the A/C plug.

The two points strapped shall be considered as an active Pin Program (Value = TRUE (1)).

The two points not strapped shall be considered as an inactive Pin Program (Value = FALSE (0)).

Pin PROGRAM value shall be obtained by the application software using BPPx (x=0 to 6) variable on each CMM.

Seven pins program (PP0 to PP6 and PP7 to PP13) shall define the PDE position in the A/C. PDE position shall be used for E/S configuration during PDE initialization and may be used by application software. Detail A664P7 bus configuration will be provided by an ICD for each position.

The seventh pin program shall be used as parity (odd parity) for each CMM.

COM lane shall acquire seven (7) pin program (PP0 to PP6)

MON lane shall acquire seven (7) pin program (PP7 to PP13)

In case of bad pin programing parity, the respective CMM shall start with E/S disabled. Inter unit bus shall remain available.

### 4.3.2.7. Grounding and Bonding

The PDE shall comply with the bonding and grounding requirements defined in standard requirement.

The power supply interface shall have a galvanic insulation from the mechanical housing.

HVDC power shall have a galvanic insulation from 28 VDC power and from secondary circuits.

Electronic circuits shall be insulated from the mechanical housing (0V reference not connected to PDE casing).

No protection device such as diodes, tranzorbs shall be connected between an insulated circuit or line and the mechanical housing. Only lightning protection connected between two lines is allowed.
For insulated circuits, the impedance between the circuit and the mechanical housing shall be superior to 100 Ohms over the frequency range [DC- 10 kHz]. As a consequence the total capacitance between the circuit and the mechanical housing shall be less than 150 nF.

The PDE shall be capable of discharging the electrostatic loads and electric loads due to possible short circuits.

The fixed body of the PDE shall be connected to the aircraft structure by a bonding wire through the connector.

All PDE subparts shall be together grounded.

The resistance between any part of the actuator and the bonding wire pin or jumper attachment shall not exceed 20 mOhms.

Connectors shall be of conductive shell type.

4.3.3. Physical Requirements

No special tool shall be required to install the PDE or to remove it from the aircraft.

4.3.3.1. PDE Finish and Colour

If painted, the PDE colour shall be agreed with the Airframer.

4.3.3.2. Mechanical Connections

The PDE Supplier shall identify ground support PDE connections where applicable.

The space envelope and mechanical interface shall comply with the referenced space envelope drawing in Appendix 2.

The final objective is to reduce this space envelope.

4.3.3.3. Electrical Connections

The PDE shall have 6 connectors as baseline.

The electrical wiring diagram is shown in appendix 8.

The connectors’ standard shall be, see Appendix 9.
Wires leading to different connectors shall be segregated as far as possible.

Suitable protection shall be provided to electrical connectors against fluids and products.

Connectors with fool-proofing means, such as connector polarization and Index Pin Coding shall be used in order to prevent erroneous installation on the aircraft.

Connectors shall be fitted with all its pins.

The PDE shall support to be unplugged at any time, even if it is powered, except for power supply connector and for electric motor connector.

### 4.3.3.4. Mass and Centre of Gravity

The guaranteed maximum weight of the PDE shall be:
- Size I: TBA Kg (objective lower than 1.5 Kg with reference architecture)
- Size II: TBA Kg (objective lower than 3 Kg with reference architecture)
- Size III: TBA Kg (objective lower than 4 Kg with reference architecture)

The Supplier shall state the precise centre of gravity location on the PDE.

### 4.3.3.5. Locking of Parts

The locking of mechanical parts shall not be achieved by gluing process.

Positive locking devices shall be used.

The choice of the locking devices shall be submitted to the Airframer for agreement.

### 4.3.3.6. Lightning and EMC Protection Devices

The PDE shall not be damaged, and its operation shall not be disturbed when subjected to the specified level of induced voltage and current resulting from lightning strikes and external radiations.

Refer to chapter §4.4.1.24.2.2 for common mode protection.

### 4.3.3.7. Electrical Installations

The PDE has to comply with the standard requirement.
4.3.4. **Ergonomic and human factors**

Refer to paragraph Maintainability.

4.3.5. **Materials**

All materials used for manufacturing the PDE and the production processes shall be in accordance with the material requirements of standard requirements.

For any deviation to the above mentioned requirements the Supplier shall submit them to the Airframer for acceptance.

4.3.5.1. **Material Characteristics**

Bolts and nuts shall be made from stainless steel.

Threaded caps that must be unscrewed during maintenance operations must not be made from aluminium alloy.

Magnesium alloys shall not be used.

The use of electrical wires insulation with PVC (polyvinyl-chloride) or polyamide materials or polyimide alone (Kapton) shall not be used.

Aluminium alloy for structural parts may be proposed as an alternative solution. This proposition shall be associated with a risk mitigation plan (based on in-service experience, analysis, tests...).

4.3.5.2. **Materials Technologies and Production Processes**

Cadmium and chromates shall not be used unless otherwise agreed by the Airframer.

Particular attention shall be paid to minimising the detrimental effects of contamination during PDE design.

The use of conformal coatings, isolation of contamination sensitive elements, etc. shall be considered for the design.

For protection against corrosion, the environmental conditions as described in Environmental Conditions and Test Requirements Associated to Qualification §4.4.1.5 and products defined in §4.3.5.3 Fluids and Products used on Aircraft shall be considered.
Corrosion protection

The PDE shall be protected from corrosion throughout the service life of the aircraft. For this purpose material shall be either corrosion resistant or suitably protected.

The supplier shall undertake to define any modification that might prove necessary in the event of appearance of corrosion in service.

The Supplier shall provide the list of materials, treatments and protections against galvanic corrosion.
4.3.5.3. Fluids and Products used on Aircraft

Suitable protection to the fluids identified in the table below shall be provided for the PDE.

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Code</th>
<th>Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>FU01</td>
<td></td>
</tr>
<tr>
<td>Hydraulic fluid</td>
<td>HY02</td>
<td></td>
</tr>
<tr>
<td>Lubricating oil</td>
<td>LO01</td>
<td></td>
</tr>
<tr>
<td>Common grease</td>
<td>CG01</td>
<td></td>
</tr>
<tr>
<td>Common grease</td>
<td>CG02</td>
<td></td>
</tr>
<tr>
<td>Anti-icing and De-icing materials</td>
<td>AD01</td>
<td></td>
</tr>
<tr>
<td>Cleaning agent</td>
<td>CA01</td>
<td></td>
</tr>
<tr>
<td>Cleaning agent</td>
<td>CA02</td>
<td></td>
</tr>
<tr>
<td>Cleaning agent</td>
<td>CA04</td>
<td></td>
</tr>
<tr>
<td>Disinfectants</td>
<td>DE01</td>
<td></td>
</tr>
<tr>
<td>Extinguishing agents</td>
<td>EA01</td>
<td></td>
</tr>
<tr>
<td>Extinguishing agents</td>
<td>EA02</td>
<td></td>
</tr>
<tr>
<td>Extinguishing agents</td>
<td>EA03</td>
<td></td>
</tr>
<tr>
<td>Extinguishing agents</td>
<td>EA04</td>
<td></td>
</tr>
<tr>
<td>Insecticides</td>
<td>IN01</td>
<td></td>
</tr>
<tr>
<td>Drinks</td>
<td>DR01</td>
<td></td>
</tr>
<tr>
<td>Heat Transfer fluid</td>
<td>HT01</td>
<td></td>
</tr>
</tbody>
</table>

The Supplier shall provide a material technical data sheet.

4.3.5.4. Fire Propagation, Flammability, Smoke and Toxic Emissions

PDE shall be self-contained fire.

4.3.6. Interchangeability, Mixed configuration operation

Mixed Operation (also referred to as Interchangeability) shall comply with standard requirements.

4.3.7. Miscellaneous design requirements

The list of mated parts is:

**TBA** (objective: none)

Screws with diameter smaller than 6.35 mm shall not be used where failure of a screw could lead to malfunctioning.
The PDE fixing bolts/screws shall be unloosening bolts/screws.

The wire ways shall be either fully potted or sealed.

Relays and power switches shall be equipped with diodes for protection against overvoltage.

Minimum wall thickness at min tolerance shall be higher than 2.5 mm for all the pressurized parts of the unit, including LRI’s.

Cable assemblies shall be designed for minimum conductor lengths.

Cables shall be secured at appropriate intervals to prevent chafing or other damage

All wires and bundles shall be supported sufficiently so that strain or load at the terminal(s) cannot cause joint failures.

Cable bundles shall not be tied to adjacent electrical components or sub-assemblies.

Wire size shall be chosen to be compatible with current carrying and voltage drop.

All cable backshell shall be oriented downward.

Any cable shall end with a drip loop before entering electrical panels, boxes, and equipment and connector plates.

Electronic component attachment holes on cards shall be bonded.

Electronic components life duration shall not be guaranteed by a minimum power on frequency, included in storage conditions.

Aluminium capacitors with non-solid electrolyte and tantalum capacitors shall be avoided whenever possible.

Optocouplers shall be avoided whenever possible.

The power electronic components shall be chosen with minimum 1200 V withstanding voltage class whenever possible.

Self-extinguishing materials (cables) shall be used.

Micro-switches shall not be used.
4.3.8. Identification and Labelling

The PDE shall be fitted with an identification plate and marking complying with standard requirements, completed with the mention of the CMS number for the equipment and bar code.

The bar code fields shall be verified before delivering to the Airframer.

The inscriptions shall be photo engraved or made by electroetching and only English shall be used.

The inscriptions shall be permanent and legible.

The connectors shall be identified by 4 mm high engraved capital letters A, B, P…

Markings as nameplates, PNRs shall remain legible during A/C life and shall be arranged so that they are clearly readable by the human eye and also machine readable by data scanning PDE when installed in the aircraft.

The identification label (including LRIs) shall be attached by mechanical means plus glue or Laser etching considering the application / environment in which the equipment is used.

The identification plate affixed to the PDE shall always be visible when the equipment is installed on the aircraft (except for Instruments and Indicators).

Placards and markings shall be capable of withstanding exposure to consumable fluids used in the corresponding Aircraft zone.

Detachable sub-units and Modules shall be provided with individual part number and serial number for maintenance and record purposes, especially for those, which require more maintenance actions than the equipment on which they are installed.

Loaded software shall be considered as an LRI and then identified following standard requirement.

4.3.8.1. Electrostatic Discharge Warning Labels

ESD Warning labels shall be in accordance with standard requirement.

4.3.8.2. RFID

Each PDE shall include a RFID tag.

Where feasible, each PDE RFID tag shall be attached close to the PDE nameplate.
The PDE RFID tag shall be qualified following SAE AS5678.

PDE RFID tag with a higher reading distance capability shall be considered as the preferred choice where their larger size is feasible.

The PDE RFID Data content shall be configured according to ATA Spec 2000 Chapter 9.5.

The PDE RFID Data content shall be subjected to Airframer agreement.

The PDE RFID shall be of UHF High memory type with minimum of 12 Kilo Bytes storage capability.

The repair shop performing the PDE RFID tag replacement and programming shall ensure consistency between the PDE nameplate data and the PDE RFID tag data.

The supplier shall define the installation/removal & verification procedures of the PDE RFID tag in the associated CMM.

The loss of one PDE RFID tag shall not lead to the removal of the corresponding PDE.

**4.3.9. Electrostatic Protection**

Electrostatic protection shall be in accordance with standard requirement.
4.4. Environmental Requirements

The location of the PDE is described in "location" chapter.

The PDE shall function normally and without degradation under the environmental conditions experienced by the equipment and aircraft through its service life, in active and applicable passives mode(s), unless otherwise stated in this specification.

The performances and the life of the PDE shall not be impacted by those environmental conditions.

4.4.1. General

4.4.1.1. Acceptance criteria

Pass/Fail criteria: For each subchapter of the Environmental Requirements section, in addition to specific requirements (if any), there shall be no deviation on PDE performances before and after the test whatever the environmental conditions.

The pass/fail criteria shall be defined in the individual qualification test procedures.

4.4.1.2. Equipment standard

Environmental testing used as evidence of compliance with environmental requirements shall only be carried out on production build standard PDE and with EIS standard software if any, unless otherwise agreed with the Airframer.

Any deviation from the requirements of this document shall be agreed by the different partners.

The build standard of the PDE to be tested shall be officially documented and monitored by the suppliers normal quality procedures and be subjected to a quality release note.

4.4.1.3. PDE fixture

Test sets, simulators and PDE fixture designed to represent other elements of the system around the PDEs under test shall be designed in such a way as to ensure that during environmental testing any error or upset that occurs can only be due to the PDEs under test.

Performance characteristics of A/C PDEs under testing in environmental conditions shall be representative of those which may be encountered in airborne operation of the PDEs.
4.4.1.4. Qualification Tests Monitoring

4.4.1.4.1. PDE parameters

The PDE parameters to be monitored during any formal environmental tests shall be described in the QTP.

4.4.1.5. Environmental conditions and Test requirements associated to Qualification

Info

Environmental conditions are typically application specific however, for the sake of standardization, the worst environmental conditions across all the applications are listed below, they shall be withstood by all standard modules.

In the event of any dispute over the test procedures used in order to demonstrate compliance, the identified environmental test document shall be the reference procedure, except when specified differently below.

4.4.1.6. Temperature

The PDE shall meet the requirements of EUROCAE ED14/ RTCA DO160 Section 4, Cat. D2.

4.4.1.6.1. Operational Conditions (Ground/Flight/High/ Low)

In accordance with RTCA/DO-160, Category D2, the following operating temperatures shall be considered:

- Normal operating temperature (ambient air) : - 40°C to + 70°C
- Extreme operating temperature (ambient air) : - 55°C to + 70°C
- Extreme temperature with actuator not operating (ambient air): - 60°C to + 85°C

Start-up and active mode selection shall be possible for an air temperature of -55°C.
4.4.1.6.2. **Short-Time Operating Low/High Temperature**

The PDE shall comply with its applicable performance standards during and after testing to the conditions defined in EUROCAE ED14/ RTCA DO160 Section 4, Cat. D2.

- -55°C to + 70°C

4.4.1.6.3. **Ground Survival Temperature**

The PDE shall comply with its applicable performance standards after testing to the conditions defined in EUROCAE ED14/ RTCA DO160 Section 4, Cat. D2.

- -55°C to + 85°C

4.4.1.6.4. **PDE Thermal Integration**

This PDE shall be designed so that the internal heat power is dissipated only by natural heat convection and radiation to the ambiances.

Preliminary Aircraft conditions for thermal sizing shall be considered as follows:

- The maximum ambient air temperature around the PDE at the electrical power ON : +70°C;
- The offset between air temperature around the PDE and external air temperature: +20°C;
- No heat conduction of the PDE with the A/C structure shall be considered;
- For hot day condition, the external air temperature shall follow the ISA+35°C profile.

Laboratory conditions shall be considered as follows:

- Ambient air temperature: +20°C;
- No heat conduction of the PDE with the structure shall be considered;
- No forced convection is considered.

4.4.1.7. **Atmospheric Pressure/Altitude Requirements**

4.4.1.7.1. **Steady State – Altitude**

The PDE shall meet the requirements of EUROCAE ED14/ RTCA DO160 Section 4, Cat. D2 (Unpressurized area) (between -2 000ft to 50 000ft).

4.4.1.8. **Temperature Variation**

The PDEs shall meet the requirements of EUROCAE ED14/ RTCA DO160 Section 5, Cat. A.
4.4.1.9. Humidity

The PDEs shall meet the requirements of EUROCAE ED14 / RTCA DO160 Section 6, Cat. C.

4.4.1.10. Shocks and Crash Safety

4.4.1.10.1. Operational Shock and Crash Safety

The PDEs shall meet the requirements of EUROCAE ED14 / RTCA DO160 Section 7, Cat. D.

Only "operational shocks" and 20G crash safety shocks during 11ms (saw-tooth) shall be considered, the PDE shall operate during the test.

4.4.1.10.2. Shock due to Fan Blade Out

TBD

4.4.1.10.3. Bench Handling Shocks

The PDE shall comply with the requirements of MIL STD 810F Method 516.5 Procedure VI.

4.4.1.10.4. Shipping Container Shock

The PDEs shall meet the requirements of MIL STD 810F Method 516.5 Procedure II.

4.4.1.11. Vibrations

4.4.1.11.1. Operational Vibrations

The PDE shall meet the requirements of EUROCAE ED14 / RTCA DO160 Section 8, Cat R, Curve E & E1 (3 hrs Endurance level (repeat in all 3 axes)); TBC depending on attachment configuration.


4.4.1.11.2. Vibrations due to failure conditions

The PDE shall meet the requirements of EUROCAE ED14 / RTCA DO160 Section 8, Cat. H

Vibrations due to Engine Fan Blade Loss

High Power Condition

The PDE shall operate and meet its functional requirements during and after the High-Level Short-Duration vibration test, defined in EUROCAE ED14 / RTCA DO160, section 8, Cat H, Curve P; TBC depending on attachment configuration.

Windmilling Condition

The PDE shall be compliant with the requirements defined by the curve and procedure specified in appendix 10; TBC depending on attachment configuration.

The first resonant frequency of the PDE should be higher than 20Hz in order to minimize the risk with regard to windmilling condition.

Vibrations due to Nose Wheel Imbalance

The PDE shall operate and meet its functional requirements during and after the Nose Wheel Imbalance vibration test.

In each of the PDE’s three orthogonal axes, perform the sine frequency vibration spectrum defined below, by varying the vibration frequency at a constant sweep rate; TBC depending on attachment configuration.

Any change in the critical frequencies that occur during the test shall be described and communicated to the Airframer. If no change occurs, a statement to that effect shall be included in the declaration.

Figure 2: Spectrum vibrations
4.4.1.12. Explosion

The PDE shall meet the requirements of EUROCAE ED14/ RTCA DO160 Section 9, Cat. H, environment type II in normal operation and in failure mode.

Any failure with a failure rate >1E-09/FH shall neither lead to a skin temperature over 200°C nor enable external spark.

The PDE shall be self-contained fire.

4.4.1.13. Waterproofness

The PDE shall meet the requirements of EUROCAE ED14/ RTCA DO160 Section 10, Cat. S.

The Waterproofness Pass/Fail criteria shall be: TBD.

4.4.1.14. Fluid Susceptibility

The PDE shall comply with its applicable performance standards after testing to the conditions defined. - "Fluid Susceptibility" with Fluids identified in the "Fluids and Products used on Aircraft" chapter of this document.

The PDE shall also meet the requirements of EUROCAE ED14/ RTCA DO160 Section 11, Cat. F.

Fluid susceptibility Pass/Fail criteria shall be: TBD
4.4.1.15. Sand and Dust

The PDE shall meet the requirements of EUROCAE ED14/ RTCA DO160 Section 12, Cat. S. 6 directions to be considered.

The Sand and Dust Pass/Fail criteria shall be: TBD

The PDE shall comply with its applicable performance standards after testing to the conditions under carbon dust environment (conditions TBD before end of 2007).

4.4.1.16. Fungus Resistance

The PDE shall comply with its applicable performance standards after testing to the conditions defined in EUROCAE ED14/ RTCA DO160 Section 13, Cat. F.

The Fungus Resistance Pass/Fail criteria shall be: TBD

4.4.1.17. Salt Spray

The PDE shall meet the requirements of EUROCAE ED14/ RTCA DO160 Section 14, Cat. T. The minimum duration of exposure to salt spray shall be 120 hours.

Pass/Fail criteria: In addition to EUROCAE ED14/ RTCA DO160 Section 14 success criteria, the PDE shall not show any sign of corrosion after the test. Otherwise, the supplier shall redesign the affected zone (material, protection or else) and the salt spray test shall be performed again.

4.4.1.18. Magnetic effect

The PDE shall comply with its applicable performance standards after testing to the conditions defined in EUROCAE ED14/ RTCA DO160 Section 15, Cat. A.

4.4.1.19. Icing

The PDE shall meet the requirements and EUROCAE ED14/ RTCA DO160 Section 24, Cat. B.

200 temperature cycles shall be applied.

The insulation resistance between each pin and casing shall be monitored, at least each 25 cycles.
The insulation resistance shall not vary during the test. Any variation shall be considered stabilized at least 50 cycles before the end of the 200 cycles and shall be analysed by Supplier and submitted to Airframer for approval.

In addition, the insulation resistance measured during the test shall also be done at ambient temperature (+20°C).

### 4.4.1.20. Hermeticity

The PDE shall be hermetic to a ΔP of 1 bar. According to the standard requirements.

### 4.4.1.21. Constant Acceleration

The PDE shall meet the requirements of ISO 2669 Cat. B functional test only with the levels defined in the following table:

<table>
<thead>
<tr>
<th>Functional Test Category B</th>
<th>Acceleration for arbitrarily mounted PDE (*)</th>
<th>Acceleration for non-arbitrarily mounted PDE(**)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FWD</td>
<td>AFT</td>
</tr>
<tr>
<td>16g</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(*) Note: If the mounting position is unknown or if the PDE is mounted in different positions, use the acceleration for arbitrarily mounted PDE.

(**) Note: The directions defined in the tables correspond to the aircraft directions. The PDE directions can be different, so the PDE position in the aircraft should be taken into account.

### 4.4.1.22. Aircraft Attitude

The PDE shall operate whatever the aircraft attitude.

### 4.4.1.23. Electrical

The PDE shall be compliant with HVDC and 28VDC supply requirements.

#### 4.4.1.23.1. Power consumption

The Supplier shall include a measurement of the power consumption (expressed in W) for each voltage line connected to the PDE for each of its standby and operating modes.

If the consumption varies with time or duty cycle then additional measurements shall be made to fully characterise these variations (acceleration phase, stall, and speed at load).
Power line switch-on surges shall be characterized (current and voltage waveform).

**4.4.1.23.2. PDE – Supply Related Requirements**

For the electrical PDE, the requirements identified in HVDC specification shall be met.

**4.4.1.23.3. Dielectric and Insulation Resistance Testing**

The Supplier shall demonstrate compliance with standard requirement

**4.4.1.23.4. Electrical bonding and power supply returns requirement**

These requirements apply to all PDE with electrical components or wiring. The Supplier shall demonstrate compliance with HVDC requirement and standard requirement.

**4.4.1.24. Electromagnetic Environmental Test Requirements**

**4.4.1.24.1. General**

This sub-chapter deal with the tests specification related to the electrical/electronic PDE in electromagnetic environment:

- Lightning direct and indirect effects,
- HIRF (High Intensity Radiated Field),
- On board PDE electromagnetic environment including intentional radio transmission inside aircraft,

**4.4.1.24.1.1. Tests**

The justification that the PDE meets the requirements shall be done by test.

Indeed, the straightforward demonstration that the PDE complies with the protection requirements is to test the PDE with the specified test method and levels and to prove that in such conditions, the specified functional acceptance criteria are verified.

The calibration dates, PNR and SNR of the used test PDE shall be provided in the Qualification Test Report (QTR).

**4.4.1.24.1.2. PDE Categories for Lightning and HIRF**

The PDE category for Lightning direct and indirect effects and HIRF is category A.
4.4.1.24.1.3. Location of PDE and PDE wiring

The PDE and its wiring are located in exposed area

4.4.1.24.2. Lightning

4.4.1.24.2.1. Lightning Direct Effects

Test to be carried out on PDE consists in a voltage breakdown test and a high current transfer test.

The intention of the voltage breakdown test is to determine whether the actuator internal insulating interfaces are able to withstand the predicted induced voltage that shall be developed at these interfaces during a lightning strike.

If this test fails a high current transfer test shall be carried out to assess whether the actuator is able to withstand the passage of lightning current without suffering unacceptable damage.

4.4.1.24.2.1.1. High voltage breakdown test

The test shall be performed to check the intrinsic electrical insulation of the PDE between the casing and the attachment to the actuator (bonding braid between the PDE casing and the actuator).

The test shall be carried out under dry conditions. If no breakdown occurs test shall be repeated in wet conditions.

The test shall be repeated five times with both polarities.

The voltage breakdown test shall consist in:

- A short wave form (waveform 2 according DO-160/ED-14 Section 22 WF2) at a level of 9kV,
- A long waveform (waveform 4 according DO-160/ED-14 Section 22 WF4) at a level of 400V.

The output current shall be at least 1 A peak, but the action integral \( I^2 dt \) shall not exceed 1000 A²s.

Pass / fail criteria:

- The PDE has passed the test if high voltage breakdown did not occur (no visual evidence during test and no trace found after strip examination),
- As soon as one breakdown occurs, the test is considered as failed. In such a case, high voltage breakdown test can be stopped and high current transfer test shall be done.
4.4.1.24.2.1.2. High current transfer test

This test shall be performed only if the actuator has failed the high voltage breakdown test.

The test shall consist in applying:
- A high current pulse with a peak of 20 kA and following the Waveform 1 per DO-160/ED-14 Section 22,
- A continuous current of 35A with a transfer charge of 9C and with the component C as per EUROCAE ED-84.

Remark: the current amplitude and duration could be changed as far as the transfer charge criterion is met.

Pass / fail criteria:
- Test is passed if no actuator damage occurred (after detailed investigation),
- Test is failed if at least one damage is reducing fatigue life potential,
- Test is failed if one damage is reducing endurance life potential and is not detectable during visual inspection of the actuator in situ,
- Test is failed if one damage is reducing endurance life potential so that it is less than TBA FH (target > 25000 FH), whatever is the already consumed endurance potential of the actuator.

4.4.1.24.2.2. Lightning Indirect Effects

PDE located in exposed area and in composite structure shall have a common mode isolation of loads:
- No use of common mode clamping devices between each input/output (power and signals) and chassis;
- Capacitance between the power supply or signal I/O and the piece of PDE casing lower than 150 nF.

4.4.1.24.2.2.1. Lightning Indirect Effects - Damage testing

The Supplier shall demonstrate compliance with standard requirement.

The Supplier shall use the Pin injection test method.

Power shall be applied on PDE under testing.

Refer to RTCA DO160E /EUROCAE ED14E Section 22 for waveforms definition.
<table>
<thead>
<tr>
<th>Category</th>
<th>Power Supply: 540 VDC</th>
<th>1600V / 107A</th>
<th>1500V / 60A</th>
<th>N/A</th>
<th>1500V / 1500A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal: 28VDC (exposed area differential signal– electronic bay to wing)</td>
<td>1600V / 107A</td>
<td>1500V / 60A</td>
<td>500 V / 500 A</td>
<td>1500V / 1500A</td>
<td></td>
</tr>
<tr>
<td>Signal: Insulated shielded bus (i.e.: µAFDX)</td>
<td>750V / 50A</td>
<td>600V / 24A</td>
<td>N/A</td>
<td>500V / 500A</td>
<td></td>
</tr>
<tr>
<td>Signal: Casing referenced signals (i.e.: Surface RVDT, EMA sensors interfaces)</td>
<td>1600V / 107A</td>
<td>1500V / 60A</td>
<td>N/A</td>
<td>1500V / 15A</td>
<td></td>
</tr>
</tbody>
</table>

For the PDE 270 VDC power input: Damage test (pin to case): the way of injection for WF5A is « all pin together versus casing ».

For the ±270 VDC PDE output (three phase motor and coil): Damage test: applicable but with the PDE not supplied by the HVDC power source.

For EMA sensors: Damage test (pin to case): the way of injection for WF5A is « all pin together versus casing ».

The test level shall be applied between each pin and the ground.

For PDE installed in composite zone, the qualification test procedure shall follow the requirements below:

Depending on PDE grounding design and waveform, a common mode and/or a differential mode procedure as described below shall be used during the test.
For WF2, WF3, and WF5A first lightning level, when performing pin injection on:

- Any power pin, the corresponding power return pin shall be electrically bonded to the PDE housing, or to the case ground pin (Differential injection).
- Common mode signal pins (like discrete for instance), the signal return pin must be bonded to the PDE housing, or the case ground pin (Common Mode injection).

For WF5A second lightning level:

- Any power pin and its associated power return pin must be tested simultaneously, i.e. injections on both the power “direct” and return pins (Common Mode injection).
- Any signal (like discrete for instance) and return pins must be tested simultaneously (Differential injection).

The Pass/Fail criteria shall be the following: when the PDE is submitted to the above-defined environment, no permanent failure shall occur i.e. any permanent modification of the electrical and dielectric characteristic of any component of the PDE during and after the test.
4.4.1.24.2.2.2. Functional Upset Testing (Multiple Stroke/Burst)

The PDE shall pass the tests defined in RTCA DO160E / EUROCAE ED14E “Functional upset testing (Multiple stroke/burst)“.

The PDE shall be operational during the test.

The following table gives the test level of the transient to be applied on each group of wires and on the power supply for PDE of categories A, B and C that cannot be reset from the cockpit or cannot be automatically reset.

This test shall use the cable bundle injection technique.

Multiple stroke definition: Two levels are defined: one for the first stroke and a lower one (divided by 2 for WF3 and divided by 4 for WF5.A) for the 13 subsequent stroke. Compliance can be demonstrated by injecting during two separate tests, a first test using a pulse at the higher level, and a second test using 13 pulses at the lower levels.

Note 1: Refer to RTCA DO160E / EUROCAE ED14E Section 22 for waveforms definition.
Note 2: An analysis shall be carried out to determine if a specific frequency between 1 MHz and 30 MHz could disturb the specified PDE. If specific frequencies are identified, these frequencies (at least two different ones) shall be considered for the tests with the oscillatory waveform. If there are no specific frequency two frequencies 1 MHz and 10 MHz will be applicable for the oscillatory waveform.

Depending on PDE grounding design (use of optional wire) and waveform, a common mode or a differential mode procedure as described below shall be used during the test.
The test shall be run individually on each bundle.

For each of these bundles, group of wires shall be tested separately in accordance to the wire categories defined in the specification.

For PDE installed in composite zone, the qualification test procedure shall follow the requirements below:

For WF2, WF3

- The power “direct” leads (i.e. without the return wires) shall be tested independently from any other cabling. If the PDE has several power supplies (28 VDC and HVDC), all the “direct” leads might be tested together, i.e. grouped under the injection probe, provided all other wires are not under the injection probe.
- The common mode signals shall be tested independently from the signal return wire(s). The common mode signals can be tested along with the differential mode signals.
- The signal return wire shall be tested grouped with the power supply return wires.
- The entire bundle assembly, i.e. all but the case ground, shall be grouped under the injection probes and test performed at the highest applicable level.

For WF5

- The power supply direct and return leads shall be tested together, grouped under the injection probe. HVDC and LVDC power supplies can be tested together.
- The common mode signals wires and the signal return wires shall be tested together, grouped under the injection probe. The common mode signals and signal return wires can be tested along with the differential mode signals.

The entire bundle assembly, i.e. all but the case ground, shall be grouped under the injection probes and test performed at the highest applicable level.
For Multiple Strokes and Multiple Burst bundle injection, the shield of any shielded cable of the bundle shall be disconnected from ground and any other point.

Where several cable bundles connect to PDE under test, simultaneous injection on all bundles is the normal practice. If this is not practicable, then, with the agreement of the Airframer (shall be defined in the Control Plan), successive injection on each bundle in turn will be accepted with the provision that an additional injection test on the entire interconnection bundling is carried out at the highest level required in the specification.

**Pass/Fail criteria:** The required PDE functional behaviour that shall be exhibited by the PDE both during exposure to the environment and after the environmental threat removal, shall be in agreement with the following rules:

- Corresponding function must not be adversely affected during and after the test on the PDE.

For 'Lightning Indirect Effects - Functional upset testing', in the case a functional failure is detected before the maximum test levels are reached and that this failure is considered acceptable (within the requirement pass/fail criteria), the test shall be completed up to the maximum level and the behaviour of the PDE recorded up to this level.

### 4.4.1.24.2.3. Radio Frequency Susceptibility

The test procedure and set-up shall be in accordance with ED-14/D0160, section 20 "radio frequency susceptibility".

The supplier shall determine the necessary time to detect any malfunction or upset of the PDE under test. The dwell time used for the test shall be selected in accordance with this time.

In any case, the test application shall guarantee that

- below 100kHz: a minimum of 10 test frequencies per decade with a minimum dwell time of 2s per test frequency are applied;
- above 100kHz: a minimum of 100 test frequencies per decade with a minimum dwell time of 2s per test frequency are applied;

### 4.4.1.24.2.3.1. Radio Frequency Conducted Susceptibility (10kHz to 400MHz)

The PDE shall pass the tests defined in ABD0100.1.2, chapter 3.3.2. “Radio Frequency Conducted Susceptibility (10 kHz to 400 MHz)".

The test procedure and test set-up shall be in accordance with EUROCAE ED14 E/ RTCA DO 160E section 20:

The modulation defined by the EUROCAE ED14 E/ RTCA DO160E section 20 shall be used.
The frequency sweep rate shall be compatible with the time needed to detect any PDE malfunction or upset. The default sweep rate to be used is 3 minutes per decade.

The following table gives the test level of the current to be injected on each group of wires following procedure.

<table>
<thead>
<tr>
<th>EQUIPMENT CATEGORY</th>
<th>GROUP OF WIRE LOCATION</th>
<th>TEST LEVELS (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category A Critical equipment FCS and ECS</td>
<td>Power supply : All Exposed Area : Wing</td>
<td>150 mA</td>
</tr>
</tbody>
</table>

Defined levels are RMS levels of the calibrated current; below 500 kHz, the specified test level must follow a 20 dB/decade decreasing slope.

During the test, when necessary, adjust and control the forward power to limit the induced current on the bundle to no more than 3.3 times the specified level.

For conducted susceptibility testing, the shield of any shielded cable of the bundle shall be disconnected from ground and any other point.

Where several cable bundles connect to PDE under test, simultaneous injection on all bundles is the normal practice. If this is not practicable, then with the agreement of the Airframer (shall be defined in the Control Plan), successive injection on each bundle in turn will be accepted with the provision that an additional injection test on the entire interconnection bundling is carried out at the highest level required in the specification.

**Pass/Fail criteria:** To define this behaviour the rules defined in the following shall be followed around neutral position:

- Category A Critical equipment FCS and ECS

In case of a functional failure is detected before the maximum test levels are reached and that this failure is considered acceptable (within the requirement pass/fail criteria), the test shall be completed up to the maximum level and the behaviour of the PDE recorded up to this level.
4.4.1.24.2.3.2. Radio Frequency Radiated Susceptibility (100MHz to 18GHz)

The PDE shall pass the tests defined in RTCA DO160E /EUROCAE ED14E.

The test procedure and test set-up shall be in accordance with EUROCAE ED14 E/ RTCA DO 160E section 20:

The modulation defined by the EUROCAE ED14 E/ RTCA DO160E section 20 shall be used.

The frequency sweep rate shall be compatible with the time needed to detect any PDE malfunction or upset. The default sweep rate to be used is 3 minutes per decade.

The following tables give respectively the Average test level and the Pulse test level of the electric field to be radiated on the PDE following procedure.

<table>
<thead>
<tr>
<th>EQUIPMENT CATEGORY</th>
<th>EQUIPMENT LOCATION</th>
<th>TEST LEVELS (V/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category A</td>
<td>Exposed Area : Wing</td>
<td>100 MHz - 1GHz: 100</td>
</tr>
<tr>
<td>Critical equipment FCS and ECS</td>
<td>1 GHz - 18 GHz: 300</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EQUIPMENT CATEGORY</th>
<th>EQUIPMENT LOCATION</th>
<th>TEST LEVELS (V/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category A</td>
<td>Exposed Area : Wing</td>
<td>400 MHz - 1GHz: 700</td>
</tr>
<tr>
<td>Critical equipment FCS and ECS</td>
<td>1 GHz - 18 GHz: 3000</td>
<td></td>
</tr>
</tbody>
</table>

Pass/Fail criteria: corresponding function shall not be adversely affected during and after the test and actuator movement shall be less than +/- TBD° around neutral position.

In the case a functional failure is detected before the maximum test levels are reached and that this failure is considered acceptable (within the requirement pass/fail criteria), the test shall be completed up to the maximum level and the behaviour of the PDE recorded up to this level.

4.4.1.24.2.3.3. Radio Frequency Radiated Susceptibility in the 300MHz to 6GHz band (Internal Transmitter Environment)

N/A
4.4.1.24.2.4.  On Board System Electromagnetic Environment

Regarding on board system electromagnetic environment, dedicated 28 VDC power supply shall be considered as a signal line.

4.4.1.24.2.4.1.  Magnetic Effect

The Supplier shall demonstrate compliance with the PDE test specification defined in RTCA DO160E /EUROCAE ED14E "Magnetic effects".

The applicable test category shall be Category A according to D0 160 section 15.

4.4.1.24.2.4.2.  Power Supply Voltage Spike

The Supplier shall demonstrate compliance with the PDE test specification defined in Specific requirement on HVDC network.

4.4.1.24.2.4.3.  Power Supply Audio Frequency Conducted Susceptibility

The Supplier shall demonstrate compliance with the PDE test specification defined in RTCA DO160E /EUROCAE ED14E "Power Supply Audio Frequency Conducted Susceptibility".

The applicable test category is R according to DO160 chapter 18.

4.4.1.24.2.4.4.  Induced Signal Susceptibility

The Supplier shall demonstrate compliance with the PDE test specification defined in RTCA DO160E /EUROCAE ED14E "Induced Signal Susceptibility".

The applicable category shall be Category ZC according to DO160 chapter 19.

4.4.1.24.2.4.5.  Emission of Radio Frequency Energy (150kHz – 6GHz)

The supplier shall demonstrate compliance with the PDE specification defined in RTCA DO160E /EUROCAE ED14E "Emission of Radio Frequency energy".

The applicable test category shall be Category H according to ED14E/DO160E Section 21. This requirement shall be extended up to 200 MHz with the same level than the level defined at 30 MHz.
RF emissions test shall be performed at maximum power consumption of the PDE.

*Radio Frequency Radiated Emission*

The Supplier shall demonstrate compliance with ED14E/DO160E Section 21 Radiated Emissions. The PDE category is Category H.

*Radio Frequency Conducted Emission on power supply*

The Supplier shall demonstrate compliance with ED14E/DO160E Section 21 Conducted Emissions on Power Lines. The PDE category is Category H. This Conducted Emission requirement shall be extended up to 200 MHz with the same level than the level defined at 30 MHz (see next figure).

![Figure 5: Levels of test](chart)

*Radio Frequency Conducted Emission on interconnecting cable*

The Supplier shall demonstrate compliance with ED14E/DO160E Section 21 Conducted Emissions on Interconnecting Cables. The PDE category is Category H. This Conducted Emission requirement shall be extended up to 200 MHz with the same level as at 30 MHz (see next figure).

![Figure 6: Levels of test](chart)

### 4.4.1.24.2.5. Common mode ground reference fluctuation

This test is applicable only if optional grounding wire voltage reference is used.
The test shall be run in accordance with TBD.

4.4.1.25. Electrostatic discharge

The Supplier shall demonstrate compliance with the PDE test specification defined in RTCA DO160E /EUROCAE ED14E “Electrostatic Discharge Susceptibility”.

The test is applicable for all electronic PDE, which are accessible to any person during operation or maintenance of the aircraft.

The applicable test category shall be Category B.

4.4.1.26. Single Event Upset (SEU)/Multiple Bit Upset (MBU)

The standard requirement chapters shall be applicable.

4.4.1.26.1. Protection Objectives

The PDE shall comply with the SEU/MBU requirements of the RTCA DO160E /EUROCAE ED14E.

The impact of SEU/MBU on the occurrence of the Safety / Reliability (S/R) unexpected events given listed in PTS paragraph 3.2.2.25 "S/R unexpected events" as well as the impact of MTBUR shall be assessed taking into account that the aircraft is exposed to an Atmospheric Neutron Flux in the range of 1 Mev to 800 Mev of 8600 n/cm2/h. For that purpose, the component failure conditions that could be triggered by this particle environment shall be identified and their consequences on the PDE behaviour analysed.

If the SEU/MBU rate is too high for demonstrating either safety objectives or reliability objectives without specific design precautions, the Hardware and Software implementation shall be tolerant to SEU/MBU.

For that purpose, refer to the next paragraph that gives some design recommendations.

4.4.1.26.1. Design recommendations

Based on the current technology status, the recommended design points for SEU/MBU rate limitation are:

- Limit the use of RAM,
- Where possible, the use of EPROM is preferred,
- Assess the risk of the use of RAM,
- Assess the risk to the register part of microcircuits (microprocessors, programmable circuits, ...),
- Analyze the technologies of components to determine their SEU/MBU sensitivity,
Avoid unnecessary control,
Ensure that the integrated circuit packaging cannot be a source of high-energy particles when exposed to the neutron flux.

4.4.1.26.1.3. SEU/MBU Risk Analysis

The PDE supplier shall provide a specific document giving the SEU/MBU risk analysis as required in RTCA DO160E /EUROCAE ED14E.

If necessary (defined at the "verification method" of the SEU/MBU document), the PDE supplier shall include into the qualification plan and qualification test reports specific sections dealing with the efficiency and integrity demonstration of the protection mechanisms linked to SEU/MBU protection.

4.4.1.27. Intrinsic safety

Where aircraft electrical PDE operates in a flammable atmosphere or is connected to PDE in a flammable atmosphere then the intrinsic safety requirements of standard requirement shall apply.

The supplier shall provide an intrinsic safety report analysing the system design.
4.5. Hardware Design Requirements

The PDE design assurance shall comply with standard requirements.

The Electronic Hardware Design Assurance Process shall comply with the standard requirements.

The development and management of the hardware of the electronic module shall be in accordance with RTCA/EUROCAE DO-254/ED-80.

4.5.1. Electronic Hardware Development Specific Features

4.5.1.1. Electronic Hardware Design Assurance Level Definition

The electronic hardware design assurance level, as identified by the System Safety Process, is Level A according to the categorisation of failure conditions of EUROCAE ED-80 / RTCA DO-254.

4.5.1.2. Dissimilarity

No dissimilarity hardware shall be developed.

The objectives of RTCA/DO-254 shall be considered.

4.5.1.3. Electronic Hardware Development Specific Features

4.5.1.3.1. Development Methodologies

The development of electronic hardware shall be done according to the mandatory guidelines of EUROCAE ED-80 / RTCA DO-254.

4.5.1.3.2. Particular requirements regarding Electronic Hardware Design

Regarding their documentation all items shall be treated as "complex" until Customer agrees to the evidence that an item can be rated as "simple".

The documentation shall be started immediately in the planning phase with all necessary documents in reference to EUROCAE ED-80 / RTCA DO-254.

In the conceptual design data and in the detailed design data, block diagrams shall be provided and the function and complexity of each block shall be explained.
Traceability in both directions between high level blocks, lower level blocks and to the respective code shall be established.

Single Event Upsets shall be taken into account according to the design assurance level.

At power-up a self-test shall assess and confirm the device’s functionality. After self-test the device shall enter operational mode from a certain initial condition.

4.5.1.3.3. **HDL Language and Synthesizer Considerations**

Programming language:
- A high-level Hardware Description Language like VHDL or Verilog shall be preferred,
- RAM Based FPGA shall be forbidden.

4.5.1.3.4. **Tool Specification**

Assessment and qualification of electronic hardware development tools shall be in accordance with EUROCAE ED-80 / RTCA DO-254 section 11.4.

Tools for supporting verification/validation activities (including timing analysis, behavioural simulation, gate level simulation...) – refer to EUROCAE ED-80 / RTCA DO-254 section 6.

Test tools as listed below shall be mandatory:
- HDL-Code checker,
- Static Timing Analyser,
- Simulator (behavioural),
- Simulator (gate level),
- Simulator (back-annotation).

A configuration management tool (concurrent version system) shall be used to control design artefacts as for example design files and life cycle data documents.

**Electronic Hardware re-use**

The re-use of electronic hardware components shall be in compliance with EUROCAE ED-80 / RTCA DO-254 section 11.1 and applicable CRIs.

**Commercial Off The Shelf (COTS) Components Usage**

Usage of COTS components shall be in accordance with EUROCAE ED-80 / RTCA DO-254 section 11.2 and 11.3.

Usage of complex COTS (including usage of IP-cores) shall be stated in the Plan for Hardware Aspects of Certification and shall satisfy EUROCAE ED-80 / RTCA DO-254 according to the design assurance level.
Dissimilarity of Complex COTS shall be respected between COM and MON computation units.

**Initialisation of FPGAs**

Non-volatile FPGA configuration/programming shall be confirmed by appropriate check-methods.
4.6. PDE Specific Software Requirements

The software product shall comply with standard requirements.

The software level, as identified by the System Safety Process, is level A according to DO178 classification.

The development and management of the software shall be in accordance with RTCA/EUROCAE DO-178/ED-12 Level A.
4.7. Safety and Reliability

The general safety and reliability requirements are contained in:

- The "PDE - Design - General Requirements for Suppliers - Safety and Reliability Requirements" (standard requirements),
- If applicable, in the "Requirements and Guidelines for System Designer - Safety and Reliability Requirements" (standard requirements).

The failure behaviour shall be analysed in respect to the FMEA or Fault tree analysis.

4.7.1. Quantitative Safety/Reliability Requirements

4.7.1.1. Quantitative Safety Requirements

A single failure on input/output of one connector shall be limited to the connector involved (flight control electrical segregation rules).

Safety relevant failures, which are dormant, shall be avoided.

Precautions shall be taken to avoid incorrect assembly and adjustment.

The design must ensure that the equipment cannot operate unless all the hardware safety feature are correctly included.

A hardware Fault Tree Analyses must be done to support the safety justification and the dedicated V&V activities for AC25-981-1C.

In normal and in failure case conditions, the risk of fire due to an internal cause shall be self-contained within the unit (i.e. skin temperature not exceeds 204°C, no external spark).

The unit shall also incorporate temperature sensors information on hot points against the risk of fire. The system computers may use these informations to switch off the electrical power supply.

4.7.1.2. Design/Reliability Objectives

The failure cases of the items of PDEs have been identified as significant for reliability. The requirements have been defined taking into account the eventual customers/airlines specific requirements as well as Airframer specific design requirements.

Additional failure conditions and their associated design/reliability objectives are possible during the development. Also alterations to objectives are possible during the development. The values hereafter shall be considered as maximum values to satisfy the requirements.
4.7.1.3. MTBF

The global PDE MTBF shall be TBA FH. (Objective size 1, 2 and 3: 150 000FH).
4.8. Maintainability

4.8.1. General

PDE designs shall take benefit of lessons learnt from supplier previous programs.

The impact analysis of options on the aircraft supportability performances (operational reliability, maintainability, testability, maintenance program...) shall be provided and approved by the Airframer.

Concepts featuring new technology shall be subjected to rigorous evaluation against reliability, maintainability, reparability and supportability criteria before final concept selection.

4.8.2. Maintainability and Maintenance Evaluation

Supplier shall feed with details the “Maintainability & Maintenance Evaluation” document, ref. X00FM0500302 to be presented as the initial supplier proposal and the final version shall be delivered and validated at the CDR.

4.8.3. Latched Failures

The following failures shall be latched until the end of the flight:

- **TBA** (Objective: none)

4.8.4. Maintenance Concept

To reduce number of Flight Deck Effects and to reduce unscheduled maintenance tasks, it shall be possible to reconfigure LRIs, automatically or manually in flight or on the ground, that are held as cold spares.

A failure, which has no operational consequence for the current and next flight, shall not be visible to the flight crew.

In order to reduce the number of unjustified LRI removals due to design bugs leading to software failures, the supplier shall issue specific procedures enabling the operator to maintain the LRM/LRI on-board the aircraft, any safety impact being addressed. A customer/supplier/manufacturer specific procedure shall be issued to track and to fix software faults.

Hard Time limited components in PDE design shall be avoided. If their use cannot be avoided, a justification shall be provided to the Airframer for agreement.
As a requirement, no Preventative Maintenance shall be required between Flights on the same day.

4.8.5. **MTBUR Objectives**

4.8.5.1. **MTBUR**

The MTBUR (Mean Time Between Unscheduled Removal) is obtained by dividing the total number of flight hours logged by a population of an item of PDE over a certain period of time by the total number of unscheduled removals during that same period.

4.8.5.2. **MTBUR/MTBF Ratio**

The MTBUR/MTBF shall be at least equal to $\frac{TBA\ FH}{TBA\ FH}$.

To achieve the Operational Reliability and DMC targets, the NFF rate shall be lower than 15% for PDE.

4.8.5.3. **Guaranteed MTBUR**

The supplier shall provide the Airframer with a guaranteed MTBUR value.

4.8.6. **Direct Maintenance Cost**

The supplier shall provide the Airframer guaranteed direct maintenance cost values on component level and shipset level.

4.8.7. **Installation**

Shop and On-aircraft maintenance activities shall be performed using standard tools list ref TBD.

Maintenance and test device operating force shall not be higher than 15daN.

Tightening torque required for the installation or adjustment of the complete PDE shall be minimized and submitted to the Airframer approval. The installation of the complete PDE shall not require application of tightening torque higher than 5 mdaN.

All LRIs of the unit must be replaceable without the removal of other equipment.

LRI design shall ensure that units are physically interchangeable only when they are functionally interchangeable. Mechanical keying may be used.
LRIs shall be fixed by non-losable fasteners means.

Hinge pins and attachment bolts shall be locked. The choice of the locking devices shall be submitted to the Airframer for agreement.

Where wire locking of a component or assembly is required, wire lock pigtailed should be protected to avoid injury of pilots or maintenance crew.

Electrical connectors to interface with A/C shall be arranged so that ingress of water into the plug connections be avoided (e.g. drip loops) and installed where they cannot be damaged by the hydraulic fluid.

All adjustment points, rigging marks shall be permanently identifiable and easily accessible:

When vertically installed, bolts should be fitted with their head uppermost and when this is not possible additional locking features shall be considered.

Adjustment devices shall be locked so that the adjustment point cannot unintentionally be altered.

Adjustment devices shall be provided with markings or indicators which show the extent and type of adjustment.

As maintenance procedure recommendations are not always followed, the occurrence of PDE removal with "power on" sometimes happens (considered as Human Factors). As a consequence, the supplier shall take this bad practice into account in the design in order to prevent reliability impact and to protect personal health.

4.8.8. Inspection/Test

The Supplier shall propose to A/C manufacturer suitable inspection and test procedures to permit cost-effective verification of correct installation and functionality of the PDE (through the MME, “Maintainability & Maintenance Evaluation”).

Adjustment or calibration of a component after replacement shall be avoided.

There shall be no flight test requirements for safety reasons, after any components have been changed or reinstalled.

As far as practical, LRI and component functions, including redundancies, shall be testable in situ (on A/C).
The incorrect repositioning of any PDE/parts after maintenance tasks shall be detected before flight.

If not possible, the Supplier shall ensure that:

- the item will automatically recover its normal working functionality after maintenance tasks are performed,
- the criticality of the item will be known by maintenance crew,
- for critical and essential items (in compliance with system Safety/Reliability requirements), a double maintenance inspection task should be foreseen if necessary.

### 4.8.9. Fault Diagnosis

Fault diagnosis of the PDE shall be performed thanks to the Health Monitoring function.

### 4.8.10. Servicing/Handling

All wiring shall be coded, as necessary, for ease of identification during in-service maintenance.

Connectors shall be fitted with all the pins specified in the standard. Pins must be crimped and not soldered, except if necessary and to be submitted to the Airframer.

### 4.8.11. Avoidance of Maintenance Errors

Aircraft design (structure, PDE, systems, component and items) shall eliminate (when possible) or minimize all potential hazards and risks for maintainers.

If it is technically impossible to eliminate Health & Safety risks by design, an appropriate combination of the following requirements shall be provided to minimize the risk to maintainers.

- Means of protection against hazards and risks (collective protections shall be favoured above individual protections);
- Provide sufficient information to identify, avoid or protect against hazards and risks;
- Provide an appropriate training for Health & Safety related procedures;

Note: Placards and markings alone shall not be considered as satisfactory Health & Safety solution.

The design of any PDE, components, and items on the aircraft shall take into account maintenance tasks that will be performed on them and the real conditions under which the tasks are performed: environmental, operational and climatic conditions.
All PDE, components, or items and their orientation, location, routing, and order shall be designed to ensure that all associated maintenance tasks are easy, intuitive, self-evident, and unambiguous to identify and to perform.

Special care shall be taken to protect the PDE against the effects of mishandling, miss-operation or human errors during maintenance operations (through the MME, “Maintainability & Maintenance Evaluation”).

The PDE shall be designed wherever possible such that incorrect assembly, transposed connections and installations are impossible by means such as symmetry of attachments, locating spigots, different end spigots, different end fitting to be utilized.

Connections shall be arranged so that cross connection or wrong connection is impossible (e.g. by segregation or differing cable lengths/sizes). The control of cable length by clipping is not considered to be an adequate safeguard against cross connection.

It shall be impossible to install any PDE, component, or item in the wrong orientation, in the incorrect location, using improper routing, or in the wrong order.

Screws which are not lock wired shall not include a lockwire hole.

All rigging pins/locking devices shall be provided with warning flags that can be seen from the ground when device is installed.

The Supplier shall provide all means and assistance required to the Airframer during development phases, to guarantee that any maintenance tool cannot be kept fitted on the PDE in flight configuration (visual warning means are not considered sufficient).

All components which could be used as a step or handle shall be protected or withstand such inadvertent use of the component.
4.9. Packaging, Storage and handling

4.9.1. Packaging Storage and Handling Requirements

The Supplier shall ensure that when packaging and/or storage devices (e.g. dust covers, protective covers, blanking caps, etc.) are fitted they comply with one or more of the following requirements:

- The PDE/item cannot be installed.
- Those such devices are temporarily fitted with means to ensure that the installer removes them before installation, e.g. a red flag.
- That they are designed so that no damage or malfunction occurs if the PDE is operated.

The supplier shall also ensure that no parts, e.g. seals, can be inadvertently left on the PDE/item when the packing/storage devices are removed.

The Supplier shall minimize the cost of storage and handling.

The electrical connectors shall be equipped with protective caps.

The storage conditions are as follows:

- The PDE shall be capable of being stored up to 5 years in its original packaging without retest prior to use.
5. Design Process Requirements

5.1. Qualification

5.1.1. PDE Classification

The actuators are classified in certification Category Critical (DAL A).

All technical steps of the qualification program shall be discussed and agreed by the Airframer. All justification documents, including test schedules and programs shall be available to the Airframer in advance for review and agreement.

The Airworthiness Authorities may ask to witness any test in the Supplier premises, in particular as part of category 1 qualification follow up. In this case, the Supplier shall authorize Airworthiness Authorities to access its premises during qualification phases.

5.1.2. Qualification Documentation

The qualification documents shall comply with standard requirements Formal qualification and Airframer acceptance process.

The qualification dossier shall include at minimum the following items:

- A development plan identifying the task on the critical path,
- A qualification time schedule covering the production of the documentation below and the detail of the testing activities,
- A requirement verification program which defines the type of compliance demonstration proposed for each specified requirement (e.g. test, analysis, description....),
- A description of the PDE including the schematics required for understanding its operation and the features of the main components,
- A full scale sectional drawing including all the views required for understanding the construction and operation of the PDE,
- A part list giving the materials, treatments and protection against galvanic effect,
- A detailed weight breakdown,
- A performance analysis,
- An assessment of the effect of temperature variation,
- A thermal model (MATLAB format is required) file giving for the characterization of the main components (electronic inverter …) heat transfer functions
- A failure analysis including a failure mode and effect analysis giving the effect and probabilities of all possible single failures and the fault trees of certain failures conditions. Further downgrading of failure probabilities will be submitted to the approval of the Airframer,
  - Inverter,
  - …
The report shall include a list of modifications performed following the Limit or Destructive Test process, and justifications for the omission of modifications to correct certain failure modes:

- A built standard document describing the changes to the PDE definition,
- A qualification test procedure, with associated specification and test coverage and demonstration of the test rig capability, with associated Reproducibility & Repetitivity plan,
- A qualification test report,
- The analyses, that may have been agreed as acceptable qualification means,
- A production acceptance test procedure, with associated specification and test coverage and demonstration of the test rig capability, with associated Reproducibility & Repetitivity plan,
- Lessons learnt document based on the Supplier experience.

They shall be updated to cover any evolution of the unit. Refer to DRL (Appendix 6) for delivery details.
5.1.3. Achievements of Qualification

The qualification of the PDE is under the responsibility of the Supplier but shall be agreed by the Airframer.

Qualification activities to be performed:

- Acceptance test,
- Enhanced Stress screening test for the PDE
- Performance tests,
- Thermal test demonstration
- Limit or Destructive Test / Screening Test.
- Power supply tests including Voltage spikes.
- Shocks
- Constant Acceleration
- Hermeticity test,
- High and low temperature performance tests,
- Mechanical vibrations in all functioning mode.
- Lightning damage testing
- Radio frequency susceptibility (conducted and radiated)
- Emission of Radio Frequency Energy
- Lightning Multiple Pulses/Strokes;

5.1.4. Witnessing of Tests

Airframer may ask to witness any test in the supplier premises.
6. Conclusion

On this document the technical specifications for a PDE are compiled. Also the links to the other standard modules are included.

This specification shall permit to develop, test and qualify a complete PDE permitting to be used in any of the application on “ACTUATION2015”.

This specification will be the input for the SP2, SP5 and SP6.
7. Appendix 1: **Power Drive Electronics (PDE)**

**DESCRIPTION**
8. APPENDIX 2: PDE MECHANICAL INTERFACES & SPACE ENVELOP

The PDE shall comply with the following dimensions (grey: thermal dissipater faces).

<table>
<thead>
<tr>
<th></th>
<th>Size I</th>
<th>Size II</th>
<th>Size III</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>TBA mm</td>
<td>TBA mm</td>
<td>TBA mm</td>
</tr>
<tr>
<td></td>
<td>Obj: 100 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>TBA mm</td>
<td>TBA mm</td>
<td>TBA mm</td>
</tr>
<tr>
<td></td>
<td>Obj: 75 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>TBA mm</td>
<td>TBA mm</td>
<td>TBA mm</td>
</tr>
<tr>
<td></td>
<td>Obj: 150 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>TBA mm</td>
<td>TBA mm</td>
<td>TBA mm</td>
</tr>
<tr>
<td></td>
<td>Obj: 10 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>TBA mm</td>
<td>TBA mm</td>
<td>TBA mm</td>
</tr>
<tr>
<td></td>
<td>Obj: 10 mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Connectors shall be integrated on each PDE side:
3 connectors for aircraft on one side + 3 connectors on the other side
9. APPENDIX 3: ELECTRICAL CONNECTORS

From Aircraft side:

Baseline: Connector P (High Power): four points #16 for the size I, (for the size II and III TBD). From Glenair 805 series, ref. 805-0XX-YYZZ11-4PA.

*For the ACTUATION2015 demonstrator only* the following connector shall be used for the connector P (High Power) four points #16 for the size I, (for the size II and III TBD). From Glenair 801 series, ref. 801-0XX-YYZZ9-4PA.

| 1  | Bonding |
| 2  | +HVDC (+270VDC) |
| 3  | Spare |
| 4  | -HVDC (-270VDC) |

Baseline: Connector A: Connector (polarized Quadrax) with 32 contacts, From Glenair 805 series Ref. 805-0XX-YYZZ18-208PA

*For the ACTUATION2015 demonstrator only* the following connector shall be used for the connector A: Connector (polarized Quadrax) with 32 contacts, From Glenair 801 series Ref. 801-0XX-YYZZ16-208PA

01 – PP1  10 – PP5GND
02 – PP1GND  11 – PP6
03 – PP2  12 – PP6GND
04 – PP2GND  13 – Supplier
05 – PP3  14 – Supplier
06 – PP3GND  15 – Supplier
07 – PP4  16 – Supplier
08 – PP4GND  17 to 32 – Spare
09 – PPS

1. µAFDX A Tx+
2. µAFDX A Rx+
3. µAFDX A Tx-
4. µAFDX A Rx-
5. µAFDX Shielding

Baseline: Connector B: Connector (polarized Quadrax) with 32 contacts, From Glenair 805 series Ref. 805-0XX-YYZZ18-208PB

*For the ACTUATION2015 demonstrator only* the following connector shall be used for the connector B: Connector (polarized Quadrax) with 32 contacts, From Glenair 801 series Ref. 801-0XX-YYZZ16-208PB

01 – PP7  15 – 28VDC high
02 – PP7GND  16 – 28VDC low
03 – PP8  17 – RVDT1 VA high
04 – PP8GND  18 – RVDT1 VA low
05 – PP9  19 – RVDT1 VB high
06 – PP9GND  20 – RVDT1 VB low
07 – PP10  21 – RVDT1 supply high
08 – PP10GND  22 – RVDT1 supply low
09 – PP11  23 – Supplier
10 – PP11GND  24 – Supplier
11 – PP12  25 – Supplier
12 – PP12GND  26 – Supplier
13 – Spare  27 to 32 – Spare
14 – Spare

1. µAFDX B Tx+
2. µAFDX B Rx+
3. µAFDX B Tx-
4. µAFDX B Rx-
5. µAFDX Shielding

Note:
XX ➔ Plug Style
YY ➔ Shell Style
ZZ ➔ Shell Material and Finish (Recommendation to use Z1 material)
The Pin assignment for ACTUATION2015 Demonstrator shall be on A/C side the following:

<table>
<thead>
<tr>
<th>Pin Number</th>
<th>Connector P (A/C)</th>
<th>Connector A (A/C COM)</th>
<th>Connector B (A/C MON)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PP1</td>
<td>PP7</td>
<td>PP7</td>
</tr>
<tr>
<td>2</td>
<td>PP10GND</td>
<td>PP10GND</td>
<td>PP10GND</td>
</tr>
<tr>
<td>3</td>
<td>PP2</td>
<td>PP8</td>
<td>PP8</td>
</tr>
<tr>
<td>4</td>
<td>PP20GND</td>
<td>PP20GND</td>
<td>PP20GND</td>
</tr>
<tr>
<td>5</td>
<td>PP3</td>
<td>PP9</td>
<td>PP9</td>
</tr>
<tr>
<td>6</td>
<td>PP30GND</td>
<td>PP30GND</td>
<td>PP30GND</td>
</tr>
<tr>
<td>7</td>
<td>PP4</td>
<td>PP10</td>
<td>PP10</td>
</tr>
<tr>
<td>8</td>
<td>PP40GND</td>
<td>PP40GND</td>
<td>PP40GND</td>
</tr>
<tr>
<td>9</td>
<td>PP5</td>
<td>PP11</td>
<td>PP11</td>
</tr>
<tr>
<td>10</td>
<td>PP50GND</td>
<td>PP50GND</td>
<td>PP50GND</td>
</tr>
<tr>
<td>11</td>
<td>PP6</td>
<td>PP12</td>
<td>PP12</td>
</tr>
<tr>
<td>12</td>
<td>PP60GND</td>
<td>PP60GND</td>
<td>PP60GND</td>
</tr>
<tr>
<td>13</td>
<td>Supplier1</td>
<td>Spare</td>
<td>Spare</td>
</tr>
<tr>
<td>14</td>
<td>Supplier2</td>
<td>Spare</td>
<td>Spare</td>
</tr>
<tr>
<td>15</td>
<td>Supplier3</td>
<td>Spare</td>
<td>Spare</td>
</tr>
<tr>
<td>16</td>
<td>Supplier4</td>
<td>GND-28VDC</td>
<td>GND-28VDC</td>
</tr>
<tr>
<td>17</td>
<td>Spare</td>
<td>XVDT1 VA high</td>
<td>XVDT1 VA high</td>
</tr>
<tr>
<td>18</td>
<td>Spare</td>
<td>XVDT1 VA low</td>
<td>XVDT1 VA low</td>
</tr>
<tr>
<td>19</td>
<td>Spare</td>
<td>XVDT1 VB high</td>
<td>XVDT1 VB high</td>
</tr>
<tr>
<td>20</td>
<td>Spare</td>
<td>XVDT1 VB low</td>
<td>XVDT1 VB low</td>
</tr>
<tr>
<td>21</td>
<td>Spare</td>
<td>XVDT supply high</td>
<td>XVDT supply high</td>
</tr>
<tr>
<td>22</td>
<td>Spare</td>
<td>XVDT supply low</td>
<td>XVDT supply low</td>
</tr>
<tr>
<td>23</td>
<td>Spare</td>
<td>Supplier1</td>
<td>Spare</td>
</tr>
<tr>
<td>24</td>
<td>Spare</td>
<td>Supplier2</td>
<td>Spare</td>
</tr>
<tr>
<td>25</td>
<td>Spare</td>
<td>Supplier3</td>
<td>Spare</td>
</tr>
<tr>
<td>26</td>
<td>Spare</td>
<td>Supplier4</td>
<td>Spare</td>
</tr>
<tr>
<td>27</td>
<td>Spare</td>
<td>Spare</td>
<td>Spare</td>
</tr>
<tr>
<td>28</td>
<td>Spare</td>
<td>Spare</td>
<td>Spare</td>
</tr>
<tr>
<td>29</td>
<td>Spare</td>
<td>Spare</td>
<td>Spare</td>
</tr>
<tr>
<td>30</td>
<td>Spare</td>
<td>Spare</td>
<td>Spare</td>
</tr>
<tr>
<td>31</td>
<td>Spare</td>
<td>Spare</td>
<td>Spare</td>
</tr>
<tr>
<td>32</td>
<td>Spare</td>
<td>Spare</td>
<td>Spare</td>
</tr>
</tbody>
</table>

The Pin assignment for ACTUATION2015 Demonstrator shall be on EMA side the following:

<table>
<thead>
<tr>
<th>Pin Number</th>
<th>Connector F (COM EMA)</th>
<th>Connector H (MON EMA)</th>
<th>Connector G (PCM EMA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>XVDT2 VA high</td>
<td>Load/pressure sensor 1 high</td>
<td>Solenoid interface +</td>
</tr>
<tr>
<td>2</td>
<td>XVDT2 VA low</td>
<td>Load/pressure sensor 1 low</td>
<td>Solenoid interface –</td>
</tr>
<tr>
<td>3</td>
<td>XVDT2 VB high</td>
<td>Temperature sensor 1 high</td>
<td>Ground</td>
</tr>
<tr>
<td>4</td>
<td>XVDT2 VB low</td>
<td>Temperature sensor 1 low</td>
<td>Motor Phase A</td>
</tr>
<tr>
<td>5</td>
<td>XVDT supply high</td>
<td>Temperature sensor 2 high</td>
<td>Motor Phase B</td>
</tr>
<tr>
<td>6</td>
<td>XVDT supply low</td>
<td>Temperature sensor 2 low</td>
<td>Motor Phase C</td>
</tr>
<tr>
<td>7</td>
<td>XVDT VA high</td>
<td>NVM+ RS485 A</td>
<td>Spare</td>
</tr>
<tr>
<td>8</td>
<td>XVDT VA low</td>
<td>NVM: RS485 B</td>
<td>Spare</td>
</tr>
<tr>
<td>9</td>
<td>XVDT VB high</td>
<td>Load/pressure sensor 2 high (Possible Spare)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>XVDT VB low</td>
<td>Load/pressure sensor 2 low (Possible Spare)</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>XVDT supply high</td>
<td>Load/pressure sensor 3 high (Possible Spare)</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>XVDT supply low</td>
<td>Load/pressure sensor 3 low (Possible Spare)</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Temperature sensor 3 high</td>
<td>Provision HEP</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Temperature sensor 3 low</td>
<td>Provision 5VDC-HEP</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Load/pressure sensor 4 high</td>
<td>Provision GND-5VDC-HEP</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Load/pressure sensor 4 low</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Load/pressure sensor 5 high (Possible Spare)</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Load/pressure sensor 5 low (Possible Spare)</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>15VDC high</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>15VDC low</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>HES 1: 4-20mA</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>HES 1: return</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>HES 2: 4-20mA</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>HES 2: return</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>HES 3: 4-20mA</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>HES 3: return</td>
<td>Spare</td>
<td></td>
</tr>
</tbody>
</table>

Note: For the demonstrator the pin assignment could be discussed and modified if the airframer and all the suppliers are agree.
From EMA side:

**Connector F (EMA sensors) (Ref. 801-0XX-YYZZ10-26SA)** 26 contacts, Size 23 (COM):

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>XVDT2 VA high</td>
</tr>
<tr>
<td>02</td>
<td>XVDT2 VA low</td>
</tr>
<tr>
<td>03</td>
<td>XVDT2 VB high</td>
</tr>
<tr>
<td>04</td>
<td>XVDT2 VB low</td>
</tr>
<tr>
<td>05</td>
<td>XVDT2 supply high</td>
</tr>
<tr>
<td>06</td>
<td>XVDT2 supply low</td>
</tr>
<tr>
<td>07</td>
<td>XVDT1 VA high</td>
</tr>
<tr>
<td>08</td>
<td>XVDT1 VA low</td>
</tr>
<tr>
<td>09</td>
<td>XVDT1 VB high</td>
</tr>
<tr>
<td>10</td>
<td>XVDT1 VB low</td>
</tr>
<tr>
<td>11</td>
<td>XVDT1 supply high</td>
</tr>
<tr>
<td>12</td>
<td>XVDT1 supply low</td>
</tr>
<tr>
<td>13</td>
<td>Temperature sensor 3 high</td>
</tr>
</tbody>
</table>

---

**Connector H (EMA sensors) (Ref. 801-0XX-YYZZ9-19SB)** 19 contacts, Size 23 (MON):

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Load/pressure sensor 1 high</td>
</tr>
<tr>
<td>02</td>
<td>Load/pressure sensor 1 low</td>
</tr>
<tr>
<td>03</td>
<td>Temperature sensor 1 high</td>
</tr>
<tr>
<td>04</td>
<td>Temperature sensor 1 low</td>
</tr>
<tr>
<td>05</td>
<td>Temperature sensor 2 high</td>
</tr>
<tr>
<td>06</td>
<td>Temperature sensor 2 low</td>
</tr>
<tr>
<td>07</td>
<td>NVM+ RS485_A</td>
</tr>
<tr>
<td>08</td>
<td>NVM- RS485_B</td>
</tr>
<tr>
<td>09</td>
<td>Load/pressure sensor 2 high (provision)</td>
</tr>
<tr>
<td>10</td>
<td>Load/pressure sensor 2 low (provision)</td>
</tr>
</tbody>
</table>

---

**Connector G (Motor, solenoid) (Ref. 801-0XX-YYZZ13-7SA):** 7 power wires size 16.

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Solenoid Interface +</td>
</tr>
<tr>
<td>02</td>
<td>Solenoid Interface -</td>
</tr>
<tr>
<td>03</td>
<td>Motor Phase A</td>
</tr>
<tr>
<td>04</td>
<td>Motor Phase B</td>
</tr>
<tr>
<td>05</td>
<td>Motor Phase C</td>
</tr>
<tr>
<td>06</td>
<td>Ground</td>
</tr>
<tr>
<td>07</td>
<td>Spare</td>
</tr>
</tbody>
</table>

Note:

XX → Plug Style  
YY → Shell Style  
ZZ → Shell Material and Finish
10. APPENDIX 4: SINUSOIDAL VIBRATION TEST DUE TO ENGINE FAN BLADE LOSS

In each of the PDE’s three orthogonal axes, perform the following sinusoidal test procedure:

In this procedure replace 30,0 Hz by 12,5 Hz and 28,5 Hz by 11,0 Hz.

The PDE shall be attached to the fixture or vibration table by means representative of its installation on the A/C. If possible, the test should be performed with the PDE support to be used on A/C.

For the curve referenced “xx – x – D”, levels to be applied (given in A/C axis) shall be applied on the good PDE axis, depending on its orientation in A/C ➔ TO BE CLARIFIED WITH SYSTEM DESIGNER (except when xx – x – D = xx – x – E).

In each of the three orthogonal axes, the following sinusoidal test procedure with the levels given in the selected curve shall be performed.

**Step 1/ Initial resonance frequencies search**

With the PDE operating, perform a 0.5 g-PK sinusoidal scan from 2,0 Hz (or a lower frequency able to be reach by the test bench than 2,0 Hz) to 30,0 Hz at a sweep rate not exceeding 0,5 octave/minute. Record plots of response accelerometers at selected position on the PDE and identify critical frequencies.

Critical frequencies are defined at those frequencies where:

- mechanical vibration resonances have peak acceleration amplitudes greater than twice the input acceleration amplitude, or
- a change in performance or behaviour is noticeable whether or not performance standards are exceeded.

If any, select the most severe frequency.

**Step 2/ (Initial Descent phase)**

With the PDE operating, perform one sinusoidal linear frequency sweep from the highest (30,0 Hz) to the lowest (28,5 Hz) at a sweep rate not to exceed 0,067 Hz/min (total duration of step 2/ sweep = 30 minutes).

Determine compliance with the applicable PDE performance standards during vibration.

**Step 3/ Between 7,5 Hz and 28,5 Hz (Cruise phase)**

For the critical frequency (if one between 7,5 Hz and 28,5 Hz) identified in step 1/, dwell at this frequency for **133 minutes**. During the resonance dwell, the applied frequency shall be adjusted, if necessary, to maintain the maximum acceleration response at the vibration resonance being dwelled. Any change in the critical frequency that occurs during the test shall be noted.

If no critical frequency is identified between 7,5 Hz and 28,5 Hz, then no dwell need to be performed. Continue sweep cycling the vibration frequency over the appropriate frequency range (bounded by the frequency band [7,5; 28,5] Hz) with a logarithmic sweep rate not to exceed 0,5 octave/minute for **133 minutes** minimum.

Determine compliance with the applicable PDE performance standards during vibration.

**Step 4/ Between 2,0 Hz and 7,5 Hz (Final Descent, Approach and Landing phases)**

With the PDE operating, perform one sinusoidal linear frequency sweep from the highest (7,5 Hz) to the lowest (2,0 Hz) at a sweep rate not to exceed 0.323 Hz/min (total duration of step 4/ sweep = 17 minutes).

Determine compliance with the applicable PDE performance standards during vibration.

**Step 5/ Final resonance frequencies search**
With the PDE operating, perform a 0.5 g-PK sinusoidal scan from 2 Hz (or a lower frequency able to be reach by the test bench than 2 Hz) to 30,0 Hz at a sweep rate not exceeding 0.5 octave/minute. Record plots of response accelerometers at selected position on the PDE, identify critical frequencies and compare them to those recorded in step 1/.

Critical frequencies are defined at those frequencies where:
- mechanical vibration resonances have peak acceleration amplitudes greater than twice the input acceleration amplitude, or
- a change in performance or behaviour is noticeable whether or not performance standards are exceeded.

**Step 6/ Inspection / Verification of compliance**

**Structural compliance:** at the completion of the test, the PDE shall be inspected and shall show no evidence of structural failure of any internal or external component.

If it is a structurally required unit in cabin area, minor damage is allowed, providing demonstration that it stays in place and that passenger safety would not be compromised.

**Functional compliance:** during step 2/, step 3/ and step 4/ of vibration test, PDE shall be compliant with its performance standards.

At the completion of the test, the PDE shall be inspected and shall show no evidence of structural failure of any internal or external component.

---

**SINUSOIDAL VIBRATION TEST CURVE FOR PDE LOCATED IN THE PRESSURIZED ZONE**
11. APPENDIX A

Confidential
12. APPENDIX B

Confidential
13. APPENDIX C

Confidential
14. APPENDIX D

Confidential
15. APPENDIX E

CONFIDENTIAL
16. List of the requirements

A2015_D16_19_PDE_0610.......................................................... 9
A2015_D16_19_PDE_0001.......................................................... 10
A2015_D16_19_PDE_0002.......................................................... 10
A2015_D16_19_PDE_0003.......................................................... 10
A2015_D16_19_PDE_0004.......................................................... 10
A2015_D16_19_PDE_0005.......................................................... 10
A2015_D16_19_PDE_0006.......................................................... 11
A2015_D16_19_PDE_0007.......................................................... 12
A2015_D16_19_PDE_0008.......................................................... 12
A2015_D16_19_PDE_0009.......................................................... 12
A2015_D16_19_PDE_0010.......................................................... 12
A2015_D16_19_PDE_0011.......................................................... 13
A2015_D16_19_PDE_0012.......................................................... 13
A2015_D16_19_PDE_0013.......................................................... 13
A2015_D16_19_PDE_0014.......................................................... 13
A2015_D16_19_PDE_0015.......................................................... 13
A2015_D16_19_PDE_0016.......................................................... 13
A2015_D16_19_PDE_0017.......................................................... 13
A2015_D16_19_PDE_0018.......................................................... 13
A2015_D16_19_PDE_0019.......................................................... 13
A2015_D16_19_PDE_0020.......................................................... 13
A2015_D16_19_PDE_0021.......................................................... 14
A2015_D16_19_PDE_0658.......................................................... 14
A2015_D16_19_PDE_0022.......................................................... 14
A2015_D16_19_PDE_0023.......................................................... 14
A2015_D16_19_PDE_0024.......................................................... 14
A2015_D16_19_PDE_0025.......................................................... 14
A2015_D16_19_PDE_0026.......................................................... 14
A2015_D16_19_PDE_0027.......................................................... 14
A2015_D16_19_PDE_0028.......................................................... 14
A2015_D16_19_PDE_0029.......................................................... 14
A2015_D16_19_PDE_0030.......................................................... 14
A2015_D16_19_PDE_0605.......................................................... 15
A2015_D16_19_PDE_0606.......................................................... 15
A2015_D16_19_PDE_0031.......................................................... 15
A2015_D16_19_PDE_0032.......................................................... 15
A2015_D16_19_PDE_0033.......................................................... 15
A2015_D16_19_PDE_0034.......................................................... 15
A2015_D16_19_PDE_0035.......................................................... 15
A2015_D16_19_PDE_0036.......................................................... 15
A2015_D16_19_PDE_0037.......................................................... 15
<table>
<thead>
<tr>
<th>Document Code</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2015_D16_19_PDE_0136</td>
<td>27</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0137</td>
<td>27</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0664</td>
<td>27</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0138</td>
<td>27</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0139</td>
<td>28</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0140</td>
<td>28</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0646</td>
<td>28</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0647</td>
<td>28</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0648</td>
<td>28</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0649</td>
<td>28</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0650</td>
<td>28</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0651</td>
<td>28</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0141</td>
<td>28</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0630</td>
<td>28</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0142</td>
<td>28</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0631</td>
<td>28</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0144</td>
<td>29</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0145</td>
<td>29</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0146</td>
<td>29</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0148</td>
<td>29</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0149</td>
<td>29</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0601</td>
<td>29</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0632</td>
<td>29</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0633</td>
<td>29</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0602</td>
<td>29</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0150</td>
<td>29</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0151</td>
<td>29</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0152</td>
<td>30</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0634</td>
<td>30</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0154</td>
<td>30</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0155</td>
<td>30</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0607</td>
<td>30</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0608</td>
<td>30</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0609</td>
<td>30</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0635</td>
<td>30</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0636</td>
<td>30</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0637</td>
<td>30</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0638</td>
<td>30</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0639</td>
<td>31</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0640</td>
<td>31</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0641</td>
<td>31</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0642</td>
<td>31</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0643</td>
<td>31</td>
</tr>
<tr>
<td>File Name</td>
<td>Page</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0156</td>
<td>31</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0167</td>
<td>31</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0168</td>
<td>31</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0644</td>
<td>31</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0645</td>
<td>31</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0601</td>
<td>31</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0169</td>
<td>31</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0170</td>
<td>32</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0171</td>
<td>32</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0172</td>
<td>32</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0172</td>
<td>32</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0173</td>
<td>32</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0174</td>
<td>32</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0175</td>
<td>32</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0176</td>
<td>32</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0177</td>
<td>32</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0178</td>
<td>32</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0183</td>
<td>32</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0184</td>
<td>32</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0185</td>
<td>32</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0186</td>
<td>32</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0187</td>
<td>32</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0188</td>
<td>33</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0189</td>
<td>33</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0190</td>
<td>33</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0191</td>
<td>33</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0192</td>
<td>33</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0193</td>
<td>33</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0194</td>
<td>33</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0195</td>
<td>33</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0196</td>
<td>33</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0197</td>
<td>33</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0198</td>
<td>33</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0199</td>
<td>33</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0200</td>
<td>34</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0201</td>
<td>34</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0202</td>
<td>34</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0203</td>
<td>34</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0204</td>
<td>34</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0205</td>
<td>34</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0206</td>
<td>34</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0207</td>
<td>34</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0208</td>
<td>34</td>
</tr>
</tbody>
</table>
D16.19 – Power drive electronics modules specification

A2015-D16_19_PDE_0208 .................................................. 34
A2015_D16_19_PDE_0209 .................................................. 34
A2015_D16_19_PDE_0210 .................................................. 34
A2015_D16_19_PDE_0211 .................................................. 34
A2015_D16_19_PDE_0212 .................................................. 35
A2015_D16_19_PDE_0213 .................................................. 35
A2015_D16_19_PDE_0214 .................................................. 35
A2015_D16_19_PDE_0215 .................................................. 35
A2015_D16_19_PDE_0216 .................................................. 35
A2015_D16_19_PDE_0217 .................................................. 35
A2015_D16_19_PDE_0218 .................................................. 35
A2015_D16_19_PDE_0219 .................................................. 35
A2015_D16_19_PDE_0220 .................................................. 35
A2015_D16_19_PDE_0221 .................................................. 35
A2015_D16_19_PDE_0222 .................................................. 35
A2015_D16_19_PDE_0223 .................................................. 35
A2015_D16_19_PDE_0224 .................................................. 36
A2015_D16_19_PDE_0225 .................................................. 36
A2015_D16_19_PDE_0226 .................................................. 36
A2015_D16_19_PDE_0227 .................................................. 37
A2015_D16_19_PDE_0228 .................................................. 37
A2015_D16_19_PDE_0229 .................................................. 37
A2015_D16_19_PDE_0230 .................................................. 37
A2015_D16_19_PDE_0231 .................................................. 37
A2015_D16_19_PDE_0232 .................................................. 38
A2015_D16_19_PDE_0233 .................................................. 38
A2015_D16_19_PDE_0234 .................................................. 38
A2015_D16_19_PDE_0235 .................................................. 38
A2015_D16_19_PDE_0236 .................................................. 38
A2015_D16_19_PDE_0237 .................................................. 38
A2015_D16_19_PDE_0238 .................................................. 38
A2015_D16_19_PDE_0239 .................................................. 38
A2015_D16_19_PDE_0240 .................................................. 38
A2015_D16_19_PDE_0241 .................................................. 38
A2015_D16_19_PDE_0242 .................................................. 38
A2015_D16_19_PDE_0243 .................................................. 38
A2015_D16_19_PDE_0244 .................................................. 38
A2015_D16_19_PDE_0245 .................................................. 38
A2015_D16_19_PDE_0246 .................................................. 38
A2015_D16_19_PDE_0247 .................................................. 38
A2015_D16_19_PDE_0248 .................................................. 38
A2015_D16_19_PDE_0249 .................................................. 38
A2015_D16_19_PDE_0250 .................................................. 39
D16.19 – Power drive electronics modules specification

A2015 – FP7-284915

A2015_D16_19_PDE_0251........................................................................................................... 39
A2015_D16_19_PDE_0252........................................................................................................... 39
A2015_D16_19_PDE_0253........................................................................................................... 39
A2015_D16_19_PDE_0254........................................................................................................... 39
A2015_D16_19_PDE_0255........................................................................................................... 39
A2015_D16_19_PDE_0256........................................................................................................... 39
A2015_D16_19_PDE_0257........................................................................................................... 39
A2015_D16_19_PDE_0258........................................................................................................... 39
A2015_D16_19_PDE_0259........................................................................................................... 39
A2015_D16_19_PDE_0260........................................................................................................... 39
A2015_D16_19_PDE_0261........................................................................................................... 39
A2015_D16_19_PDE_0262........................................................................................................... 39
A2015_D16_19_PDE_0263........................................................................................................... 39
A2015_D16_19_PDE_0264........................................................................................................... 40
A2015_D16_19_PDE_0265........................................................................................................... 40
A2015_D16_19_PDE_0266........................................................................................................... 40
A2015_D16_19_PDE_0267........................................................................................................... 40
A2015_D16_19_PDE_0268........................................................................................................... 40
A2015_D16_19_PDE_0269........................................................................................................... 40
A2015_D16_19_PDE_0270........................................................................................................... 40
A2015_D16_19_PDE_0271........................................................................................................... 40
A2015_D16_19_PDE_0272........................................................................................................... 40
A2015_D16_19_PDE_0273........................................................................................................... 41
A2015_D16_19_PDE_0274........................................................................................................... 41
A2015_D16_19_PDE_0275........................................................................................................... 41
A2015_D16_19_PDE_0276........................................................................................................... 41
A2015_D16_19_PDE_0277........................................................................................................... 41
A2015_D16_19_PDE_0278........................................................................................................... 41
A2015_D16_19_PDE_0279........................................................................................................... 41
A2015_D16_19_PDE_0280........................................................................................................... 41
A2015_D16_19_PDE_0281........................................................................................................... 41
A2015_D16_19_PDE_0282........................................................................................................... 42
A2015_D16_19_PDE_0283........................................................................................................... 42
A2015_D16_19_PDE_0284........................................................................................................... 42
A2015_D16_19_PDE_0285........................................................................................................... 42
A2015_D16_19_PDE_0286........................................................................................................... 42
A2015_D16_19_PDE_0287........................................................................................................... 42
A2015_D16_19_PDE_0288........................................................................................................... 42
A2015_D16_19_PDE_0289........................................................................................................... 42
A2015_D16_19_PDE_0290........................................................................................................... 42
A2015_D16_19_PDE_0291........................................................................................................... 43
A2015_D16_19_PDE_0292........................................................................................................... 43
A2015_D16_19_PDE_0293........................................................................................................... 43
<table>
<thead>
<tr>
<th>File Name</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2015_D16_19_PDE_0375</td>
<td>55</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0376</td>
<td>55</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0377</td>
<td>55</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0378</td>
<td>56</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0379</td>
<td>56</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0380</td>
<td>56</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0381</td>
<td>56</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0382</td>
<td>56</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0383</td>
<td>56</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0384</td>
<td>56</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0385</td>
<td>56</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0386</td>
<td>56</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0387</td>
<td>57</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0388</td>
<td>57</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0389</td>
<td>57</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0390</td>
<td>57</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0391</td>
<td>57</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0392</td>
<td>57</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0393</td>
<td>57</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0394</td>
<td>57</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0395</td>
<td>58</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0396</td>
<td>58</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0397</td>
<td>58</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0398</td>
<td>58</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0399</td>
<td>58</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0400</td>
<td>58</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0401</td>
<td>58</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0402</td>
<td>58</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0403</td>
<td>59</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0404</td>
<td>59</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0405</td>
<td>59</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0406</td>
<td>59</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0407</td>
<td>59</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0408</td>
<td>59</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0409</td>
<td>59</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0410</td>
<td>59</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0411</td>
<td>59</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0412</td>
<td>59</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0413</td>
<td>60</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0414</td>
<td>60</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0415</td>
<td>60</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0416</td>
<td>60</td>
</tr>
<tr>
<td>A2015_D16_19_PDE_0417</td>
<td>60</td>
</tr>
</tbody>
</table>