Flight 300W Power Supply – Technical Description

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1 Introduction

The Flight 300W Power Supply is a 300W power supply, converting a 28V aircraft supply voltage from one of three sources to five regulated output voltages of nominally 14V (other factory voltage configuration options available on request).

The three input sources are:

- DC1
- DC2
- DC Essential

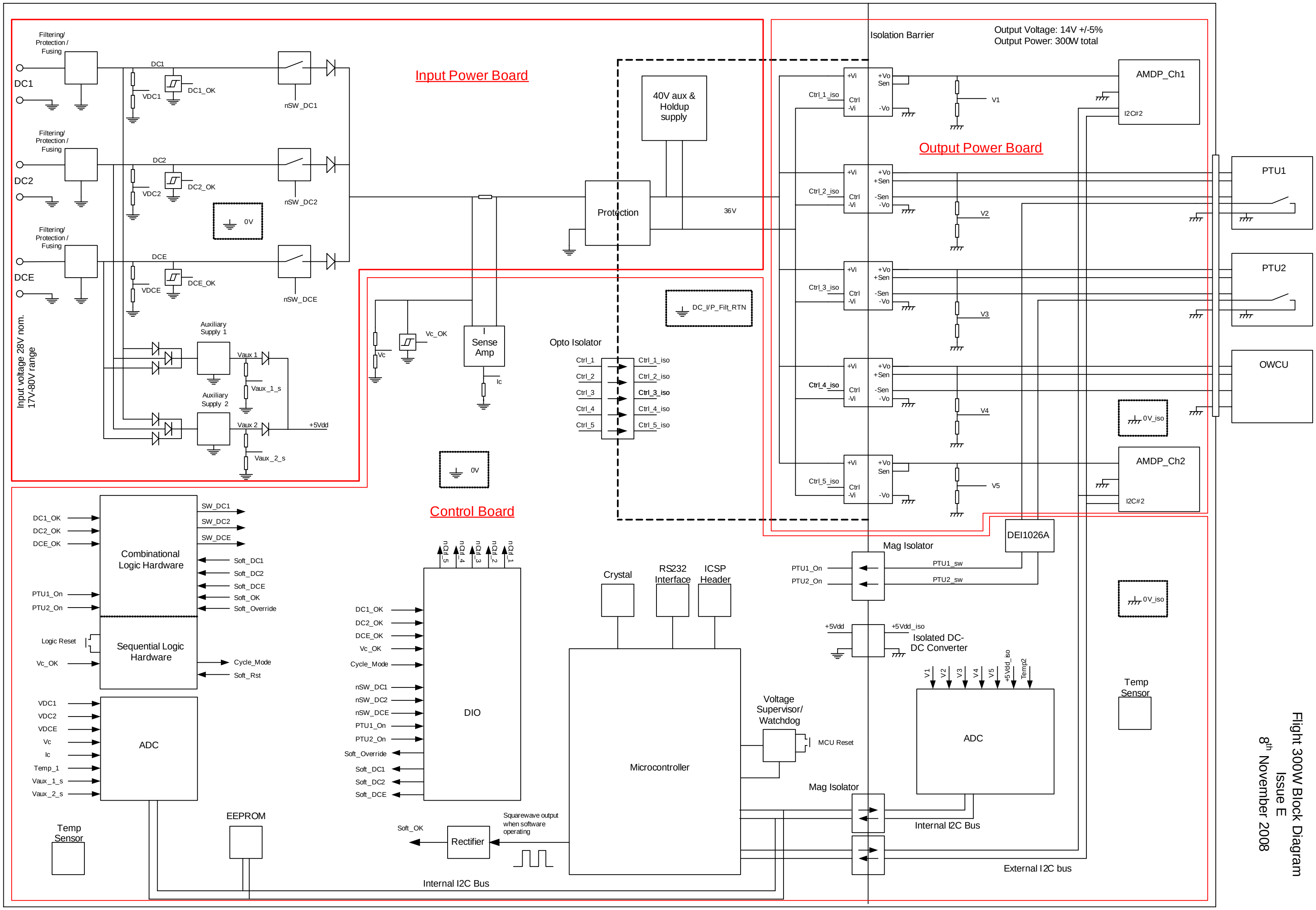
The five outputs are:

- AMDP Channel 1
- PTU 1
- PTU 2
- OWCU
- AMDP Channel 2

It comprises three modules:

- Input Power Board – input voltage switching, auxiliary supply generation, protection/filtering, hold-up storage.
- Output Power Board – DC-DC converters, output enabling/disabling.
- Control Board – input selection, output enabling control, PTU Discrete control, I2C interface, BITE.

Figure 1 shows the block diagram of the Flight 300W and the interaction between the constituent modules.



Input Power Board
Output Power Board
Control Board
Isolation Barrier
Output Voltage: 14V +/-5%
Output Power: 300W total
Filtering/ Protection / Fusing
DC1
DC2
DCE
Input voltage 28V nom.
17V-80V range
40V aux & Holdup supply
Protection
36V
Auxiliary Supply 1
Auxiliary Supply 2
+5Vdd
Sense Amp
Opto Isolator
AMDP_Ch1
AMDP_Ch2
PTU1
PTU2
OWCU
DEI1026A
Mag Isolator
Isolated DC-DC Converter
Combinational Logic Hardware
Sequential Logic Hardware
ADC
DIO
Crystal
RS232 Interface
ICSP Header
Microcontroller
Voltage Supervisor/ Watchdog
MCU Reset
Temp Sensor
EEPROM
Rectifier
Squarewave output when software operating
Internal I2C Bus
External I2C bus
Flight 300W Block Diagram
Issue E
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Figure 1

2 Redundancy

The Power Supply incorporates a number of features to ensure the reliability of the output voltage supplies in the event of short-term or long-term failures of the input voltage supplies.

2.1 Hold-up

The Input Power Board contains a bank of pre-charged capacitors which are switched in to supply power to the Output Power Board in the event of the input voltage failing. This enables the Flight 300W to supply full output power for short-term interruptions of up to 20ms.
After the hold-up capacitors have been switched in, it will take up to 4s for them to be fully re-charged.

2.2 Input selection

The power supply automatically selects an active input in order of preference (DC1 > DC2 > DC Essential). It has two automatic modes of operation: hardware and software.

Software Control:
If the voltage on the currently selected input falls below 17V for longer than 20ms, the circuit automatically switches over to the next input in the priority list. When the higher-priority input has been restored for 1s or more, it is considered to be sufficiently stable again, and the circuit switches back to use this input.

Hardware Control:
This is a back-up mode of operation which automatically takes over if, for some reason, the software fails to operate correctly.
If the voltage on the currently selected input falls below 17V for longer than approximately 3-4ms, the circuit automatically switches over to the next input in the priority list. When the higher-priority input has been restored for approximately 3-4ms, the circuit switches back to use this input.

2.3 Input switching control

The input switches are controlled by software by default. In the event of the software or microcontroller circuit failing, a hardware logic circuit automatically takes over.

3 Module Description

3.1 Input Power Board

The Input Power Board accepts power from three sources referred to as DC_1, DC_2 and DC_Essential. These are nominally 28V, but may vary between 17V and 32.5V steady state limits.
Each input is independently fuse protected and applied to a series MOSFET switch and low-loss OR-ing Switch combination to feed the input voltage to a common point. This configuration not only allows the PSU to select which input supply it operates from but the OR-ing switch and in-line fuse on each input also provides double assurance that current cannot reverse feed back to any of the input sources, including in the event of a failure.

These three switch combinations are controlled by signals from the input-selection function on the Control Board. The common point voltage is then applied to a dual-redundant surge & transient protection circuit which provides protection against over-voltage surges and spikes, in accordance with RTCA/DO-160F. In doing so, the circuit limits the supply voltage to the downstream PSU circuitry during input surges, up to and including those of Category Z (80V, 100ms surge), to 36Vdc.

A voltage detector monitors the common voltage point, and uses a MOSFET switch to switch in the Hold-up/storage capacitors in the event of the common voltage falling below 17V. The storage capacitors are capable of providing 300W of power to the downstream DC-DC converters on the Output Power Board for 20ms to meet the PSU Hold-up requirements. When the supply voltage has been restored (on any of the inputs), the storage capacitors will re-charge within 4s.
An in-line sense resistor is placed at the common voltage point and sense lines fed to the Control Board so that the total input current may be monitored for the purposes of detecting light load conditions which may indicate an open load state on the PSU output.

The filtered DC supply of the Input Power Board is used to apply power to the Output Power Board.

The Input Power Board also contains two, dual-redundant, Auxiliary Converter Circuits each generating +5Vdc to power the internal control and logic of the PSU. Each of the Auxiliary circuits are independently protected and powered from DC_1, DC_2 and DC_Essential input supplies, ensuring control power is always maintained as long as there are one or more input supplies connected (irrespective of the state of the main input power control MOSFET switches). In this way the user is able to maintain control of the PSU in the instance where the external PTU Discrete commands all power inputs and outputs off.

As the Auxiliary Converter Circuits work independently of each other, failure of either converter does not affect the operation of the PSU and the PSU will continue to supply power.

3.2 Output Power Board

The filtered and protected voltage from the Input Power Board is fed to five DC-DC converters on the Output Power Board. Each of these converters share a common input return and provide ground loop input-output isolation, with a common output return. They also incorporate independent current limit and short circuit protection on each of their outputs.
The converters have an output enable/disable input which is controlled via an isolated interface from the Control Board. This enables each of the outputs to be individually turned on or off.
Connections are provided to the Control Board to enable it to monitor each of the five output supplies.
The PTU1, PTU2 and OWCU converters have sense lines that enable the supplies to automatically adjust for any voltage drop in the supply lines to the load. The Sense+ line and the Vout+_ lines should be connected together at the load. Similarly, the Sense- and the Vout- lines should be connected together at the load.

3.3 Control Board

The Control Board contains the input hardware switching logic, PTU On/Off Discrete Control, input-monitoring circuit, analog-to-digital conversion, microcontroller and external I2C interface circuits.

The input voltages from the Input Power Board are monitored and applied to voltage comparators and also to an analog-to-digital circuit.

Isolated interfaces to the Output Power Board are provided to monitor the output voltages, and to enable/disable the five outputs.

A hardware switching control circuit constantly monitors the input voltage status, and switches in the highest priority input that is currently available.

A software-OK detect circuit checks that the microcontroller software is operating correctly and overrides the hardware switching control circuit, bringing the input switching under software control.

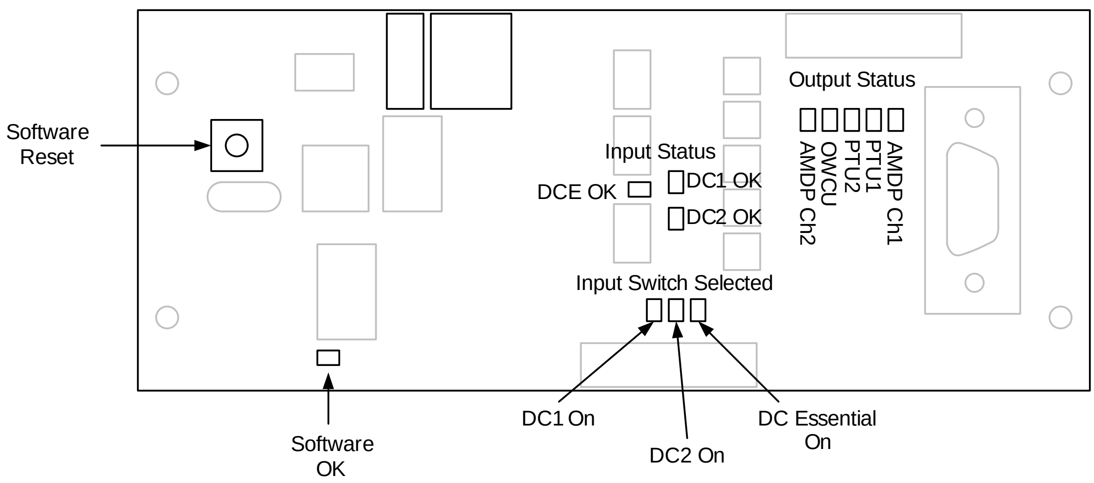
An I2C interface allows the user to monitor and control various aspects of the operation of the Flight 300W:

- Monitor input voltages
- Monitor output voltages
- Monitor common voltage and current
- Monitor temperature
- Monitor input-voltage status (OK/Not OK)
- Control output voltages (On/Off)
- Control input switches (Change between automatic and manual control)
- Monitor the number of input-voltage-fail and output-voltage-fail events
- Reset the event counters

Refer to Section 4 that describes the use of the I2C interface in detail.

3.3.1 Control Board LEDs

The Control Board contains a number of LEDs that indicate the operational state of the Power Supply.



3.3.2 PTU Discrete Control

The PTU Discrete control circuitry is designed to act in response to the PTU Discrete inputs to the PSU. The PTU control is dual redundant in that it operates by default in Software Mode but reverts to Hardware Control Mode should the software or any part of the microprocessor control logic fail. As the PSU only reverts to Hardware Control mode during an abnormal or failure state, the PTU control has limited functions during this state. These differences are explained by the following truth tables:-

PTU in Software Control Mode (Default Operation of PSU):

PTU 1 Discrete Switch	PTU 2 Discrete Switch	PTU 1 Output	PTU 2 Output	AMDP Channel 1, AMDP Channel 2 and OWCU Outputs	DC1, DC2 and DC Essential Power Inputs
Disabled	Disabled	Off	Off	Off	Off
Disabled	Enabled	Off	On	On	On
Enabled	Disabled	On	Off	On	On
Enabled	Enabled	On	On	On	On

PTU in Hardware only Control Mode (PTU operating in abnormal state):

PTU 1 Discrete Switch	PTU 2 Discrete Switch	PTU 1 Output	PTU 2 Output	AMDP Channel 1, AMDP Channel 2 and OWCU Outputs	DC1, DC2 and DC Essential Power Inputs
Disabled	Disabled	Off	Off	Off	Off
Disabled	Enabled	On	On	On	On
Enabled	Disabled	On	On	On	On
Enabled	Enabled	On	On	On	On

4 I²C Interface Description

4.1 Introduction

The Flight 300W has an I2C interface that allows the user to monitor the performance of the equipment, and also to configure and control the equipment.

The control circuit contains a number of data registers. Some of these are used to store BITE results and other to hold commands or settings to control the Flight 300W PSU. In addition, there is a command/address register that is used to point to a particular data register.

4.2 I2C Configuration

The I2C interface conforms to the Philips/NXP standard. It may be addressed by any master also conforming to the standard.

Interface connector: 9-Dsub female

Interface connections:

Pin 5 – Ground

Pin 4 – Serial Clock, SCL

Pin 3 – Serial Data, SDA

Speed: 100kb/s

I2C Level: 3.3V

Pull-up resistors: 1k fitted to SCL and SDA

Address: 0x60 (b0110000)

4.3 I2C Commands

To set up the Flight 300W for a subsequent read of 2 bytes:

S <0x60> /W sACK <Address Reg.> sACK S <0x60> R mACK <Read Byte 1> mACK <Read Byte 2> mNACK P

To write 1 byte of data to the Flight 300W:

S <0x60> /W sACK <Address Reg.> sACK <Data 1> sACK P

S = Start

sACK = ACK from slave (Flight 300W)

mACK = ACK from the master

P = Stop

/W = 0 for Write command

R = 1 for Read command

4.4 Register Structure

4.4.1 Command/Address Register

The first byte of every write operation is automatically written to the Command/Address Register. The CAR is an 8-bit register, and is used to store an address that points to one of the data registers. On power-up, the CAR contains all 0s, pointing to the ADC Result Register.

The following table lists the data registers for each valid CAR value.

CAR Value		**Data Register**
Hex	**Binary**	
00	00000000	ADC Results
01	00000001	Digital Status
02	00000010	Input Control
03	00000011	Output Control
04	00000100	Counts Reset
05	00000101	Event Counters

4.4.2 ADC Results Register (Address = 00), Read only

The ADC results register contains the results of the ADC conversions on various analog voltages within the Flight 300W equipment. There are two 8-channel Analog to Digital Converters within the Flight 300W. Each channel produces a 2-byte result. Therefore it is necessary to read out 32 bytes to obtain all of the information from the Flight 300W ADCs.

Each conversion is 2 bytes in length. The contents of each byte are as follows:

First byte:

D15	D14	D13	D12	D11	D10	D9	D8
0	Channel ID bit 2	Channel ID bit 1	Channel ID bit 0	MSB B9	B8	B7	B6

Second byte:

D7	D6	D5	D4	D3	D2	D1	D0
B5	B4	B3	B2	B1	B0	0	0

The following table shows what data each pair of bytes represents:

1st Byte No.	2nd Byte No.	Channel ID	Measured parameter	Conversion Factor
0	1	0	Input voltage DC1	x24.256
2	3	1	Input voltage DC2	x24.256
4	5	2	Input voltage DC Essential	x24.256
6	7	3	Combined Voltage	x24.256
8	9	4	Current	x10
10	11	5	Internal 5V supply 1	x2
12	13	6	Internal Temperature 1	See table
14	15	7	Internal 5V supply 1	x2
16	17	0	V1 - AMDP Ch 1 Voltage	x5.667

18	19	1	V2 – PTU 1 Voltage	x5.667
20	21	2	V3 – PTU 2 Voltage	x5.667
22	23	3	V4 – OWCU Voltage	x5.667
24	25	4	V5 – AMDP Ch 2 Voltage	x5.667
26	27	5	Internal +5V supply 3	x2
28	29	6	Internal Temperature 2	See table
30	31	7	Not used	-

Conversion Method

To convert the bytes to real data, the following routine should be followed:

Mask the first byte of each channel with 0x0F to remove the channel ID number which would otherwise corrupt the conversion result.

The two separate bytes for each channel should then be combined, and then bit-shifted to the right by 2 places to remove the un-wanted data in bit positions D0 and D1.

The ADCs are 10-bit, resulting in 2^10=1024 levels. The voltage reference for the ADCs is 4.096V. Therefore, the combined, bit-shifted data should be divided by 1024, and multiplied by 4.096 to determine the analog voltage at the ADC input.

Now, the ADC voltage may be multiplied by the relevant Conversion Factor for each channel shown in the table above.

Example:

We wish to know the value of the input voltage on the DC-Essential input.

1. We read the values of Byte 4 = 0x23 and Byte 5 = 0xC8.
2. We AND the value of Byte 4 with 0x0F to remove the channel ID:
   0x23 & 0x0F = 0x03
3. We combine Bytes 4 & 5
   0x03C8
4. We shift the word to the right by 2 bits to remove the irrelevant data:
   0x03C8 >> 2 = 0xF2 = d242 (same as dividing by 4)
5. Divide the shifted data by 1024, and multiply by 4.096 (or just multiply by 0.004):

d2428 / 1024 * 4.096 = 0.968V
This is the voltage at the ADC input.

6. Now multiply the ADC voltage by the Conversion Factor (in this case 24.256):
Voltage on DC-Essential = 0.968 * 24.256 = 23.48V

Temperature Conversion

Having calculated the voltage at the ADC input, it is possible to calculate the temperature:

$$T = -1481.96 + \sqrt{2.1962x10^{6} + \frac{(1.8639 - Vadc)}{3.88x10^{-6}}}$$

4.4.3 Digital Status Register (Address = 01), Read only

One-byte result showing the status of various functions within the Flight 300W.

D7	D6	D5	D4	D3	D2	D1	D0
Under-current alarm	DC1 Status	DC2 status	DC E status	Combined voltage status	PTU1 switch	PTU2 switch	Software status
1 = under-current	1 = voltage within range	1 = voltage within range	1 = voltage within range	1 = voltage within range	1 = switch is on	1 = switch is on	1 = software is OK

4.4.4 Input Control Register (Address = 02), Read & Write

One-byte word allowing user to set the operating mode of the Flight 300W. The following table describes the functions of each bit together with the default setting on power-up.

D7	D6	D5	D4	D3	D2	D1	D0
Not used	Not used	Not used	DC1 switch	DC2 switch	DC E switch	Software Override	Automatic Mode
-	-	-	1 = Switches on DC 1	1 = Switches on DC 2	1 = Switches on DC E	1 = Switches on DC E	1 = Auto mode
0	0	0	1	0	0	1	1

Example settings:

0x13 – default value on power-up. When bits D0 and D1 are set, the Flight 300W is in fully automatic mode.

0x10 – Forces hardware mode. Software has no involvement in input switching. All switching controlled by hardware logic circuit.

0x1E – Manual mode with all inputs on. Setting bit D1, and clearing bit D0 puts the Flight 300W into manual mode. By setting or clearing bits D2, D3, D4, the user can operate the input voltage switches directly.

0x12 – Manual mode. DC1 on. DC2 & DCE off.

0x0A – Manual mode. DC2 on. DC1 & DCE off.

0x06 – Manual mode. DCE on. DC1 & DC2 off.

4.4.5 Output Control Register (Address = 03), Read & Write

One byte word allowing user to control the five outputs.

The following table describes the functions of each bit together with the default setting on power-up.

D7	D6	D5	D4	D3	D2	D1	D0
Not used	Not used	Override PTU Switch	AMDP Ch 2 output	OWCU output	PTU 2 output	PTU 1 output	AMDP Ch 1 output
-	-	1 = override PTU switch control	1 = On	1 = On	1 = On	1 = On	1 = On
0	0	0	1	1	1	1	1

Example settings:

0x1F – default power-up setting. All switches on. PTU switches operate as follows:

	PTU 1 switch on	PTU 1 switch off
PTU 2 switch on	All outputs on	PTU 1 output off. All other outputs on.
PTU 2 switch off	PTU 2 output off. All other outputs on.	All input switches switched off. No output.

0x21 – AMDP Ch 1 on. All others off.

0x22 – PTU 1 on. All others off.

0x24 – PTU 2 on. All others off.

0x28 – OWCU on. All others off.

0x30 – AMDP Ch 2 on. All others off.

4.4.6 Counter Reset (Address = 04), Write only

One byte word used to reset the event counters.

The following table describes the functions of each bit together with the default setting on power-up.

D7	D6	D5	D4	D3	D2	D1	D0
Not used	Not used	Not used	Not used	Not used	Not used	Not used	Reset counters
-	-	-	-	-	-	-	1 = reset counters
0	0	0	0	0	0	0	0

Cleared by software after the counters have been successfully reset.

4.4.7 Event Counters (Address = 05), Read only

Eight bytes, each one counting the number of failures in an input or an output channel since power-up or the last reset command.

Byte No.	Counter
1	DC1 count
2	DC2 count
3	DCE count
4	AMDP Ch 1 count
5	PTU 1 count
6	PTU 2 count
7	OWCU count
8	AMDP Ch 2 count