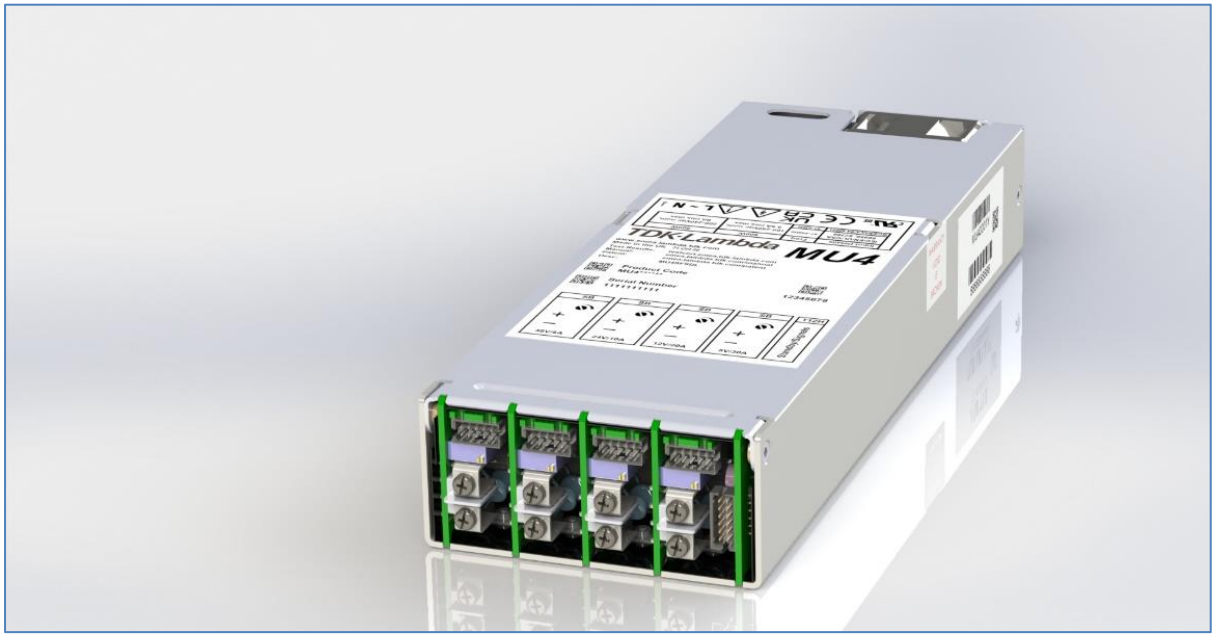
TDK·Lambda

MU

AC/DC Modular Power Supply Series

PMBus APPLICATION NOTES



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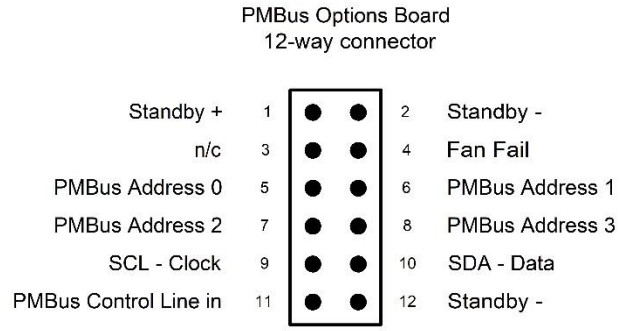
Reading operating time and power cycle count

On/Off control of the module outputs by PMBus Command, PMBus Control Pin, or a combination of both

Up to 8 units may be connected to a single PMBus controller

2. Hardware Interface



Pin #	Function	Notes
J5-1	Standby +	Standby Voltage Supply Output (+ve)
J5-2	Standby -	Standby Voltage Supply Output (-ve)
J5-3	n/c	Not Connected
J5-4	Fan Fail	Open Drain, see below
J5-5	PMBus Address 0	These lines are pulled high internally. Pull to 0V (pin 12) to select different PMBus addresses. See Section 3 below.
J5-6	PMBus Address 1	
J5-7	PMBus Address 2	
J5-8	PMBus Address 3	
J5-9	SCL – Clock	Logic 0/1 – GND/3v3
J5-10	SDA - Data	Logic 0/1 – GND/3v3
J5-11	PMBus Control Line In	Logic 0/1 – GND/3v3
J5-12	Standby -	Reference for J5-4 to J5-11

Refer general MU Application notes document 360040 for mating connector details

The Fan Fail signal (J5-4)

Provided by an internal FET which is referenced to pin 12 of the option connector. Pin 4 is the FET drain (+) and pin 12 the source (-). This signal provides a warning that the MU fan has stopped or the fan speed is slowing and should be replaced. The FET will be on when the fan is running much slower than expected.

Refer general MU Application notes document 360040 for signal ratings and example connection details.

Note that the Fan Fail signal may be generated by the slow running of either fan 1 or fan2 (if fitted). The Fan Fail indication is latching, and remains indicating until reset by PMBus command (81h), or cycling the power to the unit.

3. Setting the PMBus Address

Each unit in a system sharing a common Bus must use a unique PMBus address. The address may be set by grounding (connect to standby -) the address pins on the connector. The address of the unit is then given by the following table:

A3 Grounded	A2 Grounded	A1 Grounded	A0 Grounded	Address (decimal)
✓	✓	✓	✓	100
✓	✓	✓	×	101
✓	✓	×	✓	102
✓	✓	×	×	103
✓	×	✓	✓	104
✓	×	✓	×	105
✓	×	×	✓	106
✓	×	×	×	107
×	✓	✓	✓	108
×	✓	✓	×	109
×	✓	×	✓	110
×	✓	×	×	111
×	×	✓	✓	112
×	×	✓	×	113
×	×	×	✓	114
×	×	×	×	115

By default the address lines are pulled high internally (via 10Kohm resistor to internal +3v3 voltage), giving a default PMBus address of 115.

4. Supported PMBus Commands

See references [1], [2], and [3] for details of the PMBus command structure and transaction types.

Command Name	Command Code	Transaction Type(s)	Notes
OPERATION	01h	Read/Write Byte	
ON/OFF CONFIG	02h	Read/Write Byte	
CLEAR FAULTS	03h	Send Byte	
CAPABILITY	19h	Read Byte	
STATUS BYTE	78h	Read/Write Byte	General unit status
STATUS CML	7Eh	Read/Write Byte	Comms Status
STATUS_FANS_1_2	81h	Read/Write Byte	Fan faults or warnings
READ VIN	88h	Read Word	LINEAR11 format
READ VCAP	8Ah	Read Word	LINEAR11 format
READ TEMPERATURE	8Dh	Read Word	LINEAR11 format
READ FANSPEED 1	90h	Read Word	LINEAR11 format
READ FANSPEED 2	91h	Read Word	LINEAR11 format
PMBus REVISION	98h	Read Byte	
MANUFACTURER ID	99h	Read Block	ASCII string – “TDK_LAMBDA”
MANUFACTURER MODEL	9Ah	Read Block	ASCII String – 20 characters
MANUFACTURE DATE	9Dh	Read Block	Special format
SERIAL NUMBER	9Eh	Read Block	ASCII string – 10 characters
USER DATA 00 - 15	B0h - BFh	Read/Write Block	16 bytes per command
RUNTIME	C4h	Read Block	Special format
POWER CYCLE COUNT	C5h	Read Block	Special format
SOFTWARE VERSION NUMBER	C6h	Read Block	Special format
INDIVIDUAL CHANNEL CONTROL	CAh	Read/Write Word	Special format *Only applicable when unit in Individual Channel Control Mode*
INDIVIDUAL CHANNEL CONTROL DEFAULT STATE	CBh	Read/Write Word	Special format

More details for each command are given in the sections below.

5. Controlling the Module Outputs of the Unit

Modes of Operation

There are 7 distinct modes of operation:

1. Module outputs enabled when Input Power is present
2. Module outputs enabled when commanded to by the PMBus Operation Command
3. Module outputs enabled when the PMBus Control Pin is HIGH
4. Module outputs enabled when the PMBus Control Pin is LOW
5. Module outputs enabled when commanded to by the PMBus Operation Command AND the PMBus Control Pin is HIGH
6. Module outputs enabled when commanded to by the PMBus Operation Command AND the PMBus Control Pin is LOW
7. Individual Channel Control Mode

The active mode of operation is selected using the On/Off Configuration Command (02h) described below.

IMPORTANT NOTE

In modes 1-6 above, the output state of all modules fitted in a MU unit are switched together. In these modes individual control of the separate channels within a MU unit is not possible.

In mode 7 above "Individual Channel Control Mode", the output state of each channel is controllable individually using the Individual Channel Control Command (CAh) described below.

If multiple MU units (maximum of 8) are connected to the bus, each unit is controlled independently, and may operate in different modes.

On/Off Configuration – Command 02h

This command is used to configure the mode of operation of the unit. The read and write byte transaction types are supported. The following table shows the data bytes sent /read that indicate the available modes of operation.

Mode	Data Byte
All Module outputs enabled when Input Power is present (factory default)	01h or 03h
All Module outputs enabled when commanded to by the PMBus Operation Command	19h or 1Bh
All Module outputs enabled when the PMBus Control Pin is HIGH	17h
All Module outputs enabled when the PMBus Control Pin is LOW	15h
All Module outputs enabled when commanded to by the PMBus Operation Command AND the PMBus Control Pin is HIGH	1Fh
All Module outputs enabled when commanded to by the PMBus Operation Command AND the PMBus Control Pin is LOW	1Dh
Individual Channel Control Mode	E0h

Note that the operating mode is persistent across a power cycle of the MU unit.

Operation – Command 01h

When a unit is in an operating mode dependent upon the PMBus Command (modes 2, 5 and 6 above), this command is used to control the unit's module outputs (in combination with the Control Line if required). MU units only support bit 7 of this command (On/Off State). If any other bit is set in the command data byte, the command is ignored, and a communication error is generated. The only legal commands are as follows:

Commanded State	Data Byte
All Module Outputs ENABLED (ON)	80h
All Module Outputs DISABLED (OFF)	00h

The commanded On/Off state is not persistent across a power cycle, and will default to OFF when input power is restored to the unit.

Note that the Operation command (01h) has no affect when operating in Individual Channel Control mode.

Control Line Operation

When a unit is in an operating mode dependent upon the PMBus Control Line (modes 3, 4, 5 and 6 above), the Control pin should be set HIGH or LOW as required to control the module outputs (in combination with the PMBus Operation Command if required).

Individual Channel Control – Command CAh

When a unit is in the Individual Channel Control mode, this command is used to control the unit's channel outputs individually. The command number is CAh, and the transaction types supported are Read and Write Word. The Command Word represents the requested state of the individual channel outputs as follows:

Command Word Bit #	Controlled Output Channel
0	Not used, set to zero
1	Module Slot 1, Channel 1
2	Module Slot 1, Channel 2
3	Module Slot 2, Channel 1
4	Module Slot 2, Channel 2
5	Module Slot 3, Channel 1
6	Module Slot 3, Channel 2
7	Module Slot 4, Channel 1
8	Module Slot 4, Channel 2
9	Module Slot 5, Channel 1 – Wide units only
10	Module Slot 5, Channel 2 – Wide units only
11	Module Slot 6, Channel 1 – Wide units only
12	Module Slot 6, Channel 2 – Wide units only
13	Not used, set to zero
14	Not used, set to zero
15	Not used, set to zero

1 = ENABLE, 0 = DISABLE. For slots occupied by a single output module, use only the channel 1 enable.

E.g. A command word of 1092h (0b0001000010010010) would enable channel 1 in slot 1, channel 2 in slot 2, channel 1 in slot 4, and channel 2 in slot 6.

A read of this command returns the current state of the outputs, with 1 indicating the channel is enabled, 0 indicating disabled using the bit ordering in the above table.

When the unit is first switched to Individual Channel Control mode, or when the unit starts up in Individual Channel Control mode, the channels are enabled dependent on the setting of the Individual Channel Control Default Output State, as set with Command CBh (see next section).

Notes

1. When the unit is operating in Individual Channel Control mode, the Converter is always enabled, and the fans (if fitted) spin continuously. This is to allow rapid enabling of the individual channels using the Individual Channel Control command CAh.
2. To completely disable the unit when operating in Individual Channel Control mode it is necessary to switch control mode to PMBus Operation Control Mode. This will then disable the Converter and fans.
3. A communication error is generated if the Individual Channel Control command is issued when the system is not in the Individual Channel Control Mode.

Individual Channel Control Default Output State – Command CBh

PMBus command CBh is available to set the default output state for each channel. This setting is then applied at start-up when the unit boots into the Individual Channel Control mode, and also on mode changes when changing to the Individual Channel Control mode. The transaction types supported are Read and Write Word. The Command Word will represent the requested default state of the individual channel outputs as follows:

Command Word Bit #	Controlled Output Channel
0	Not used, set to zero
1	Module Slot 1, Channel 1
2	Module Slot 1, Channel 2
3	Module Slot 2, Channel 1
4	Module Slot 2, Channel 2
5	Module Slot 3, Channel 1
6	Module Slot 3, Channel 2
7	Module Slot 4, Channel 1
8	Module Slot 4, Channel 2
9	Module Slot 5, Channel 1 – Wide units only
10	Module Slot 5, Channel 2 – Wide units only
11	Module Slot 6, Channel 1 – Wide units only
12	Module Slot 6, Channel 2 – Wide units only
13	Not used, set to zero
14	Not used, set to zero
15	Not used, set to zero

1 = ENABLE, 0 = DISABLE. For slots occupied by a single output module, use channel 1 enable only.

A read of this command will return the default state, with 1 indicating the channel is enabled, 0 indicating disabled using the bit ordering in the above table.

This setting is persistent over a power cycle.

6. Reading Status from the Unit - Errors and Warnings

The status of a unit can be determined through a hierarchy of status bytes. Interrogation of a unit starts with reading the Status Byte. Read and Write transactions are supported to the status bytes – writes are used to clear status indicators. If a condition is persistent, a cleared indicator will immediately re-indicate. Bits for unsupported features are always returned as 0.

Status Byte – Command 78h

The following bits of the Status Byte are supported:

Bit Number	Meaning when Bit Set
7	Not Supported
6	Module Outputs are OFF
5	Output OV
4	Not Supported
3	UV Fault
2	Over Temperature Fault
1	PMBus Communication Fault – Read CML Status for further details
0	None of the above (this indicates a Fan Fault or Warning has been generated – Read the STATUS_FANS_1_2 status byte for further details)

Read and write byte transactions are supported. To clear an indicator, write a 1 to the relevant bit. Clearing bit 0 will clear all bits in the STATUS_FANS_1_2 byte. Clearing bit 1 will clear all bits in the STATUS CML byte.

When operating in Individual Channel Control Mode, bit 6 is always read as clear. For the enable states of the individual channels read Individual Channel Control (CAh).

CML Status Byte – Command 7Eh

The following bits of the CML Status byte are supported:

Bit Number	Meaning when Bit Set
7	Invalid or Unsupported Command Received
6	Invalid or Unsupported Data Received
5	PEC Error
4	Memory Fault – Not Supported
3	Processor Fault - Not Supported
2	Reserved
1	Other Comms Error (Timeout/Overflow or Bus Error)
0	Other Memory or Logic Error (*)

(*) The “Other Memory or Logic Error” (bit 0) is generated when the Individual Channel Enable Control Command is received when not in Individual Channel Control Mode.

Read and write byte transactions are supported. To clear an indicator, write a 1 to the relevant bit. If all bits are clear, bit 1 of the main status byte (command 78h) is also cleared.

STATUS_FANS_1_2 Status Byte – Command 81h

The following bits of the STATUS_FANS_1_2 status byte are supported:

Bit Number	Meaning when Bit Set
7	Fan1 Fault – Fan 1 running too slow or stopped
6	Fan2 Fault – Fan 2 running too slow or stopped
5	Fan1 Warning – Fan 1 running too fast – check for blockage
4	Fan2 Warning – Fan 2 running too fast - check for blockage
3	Not Supported
2	Not Supported
1	Not Supported
0	Not Supported

Read and write byte transactions are supported. To clear an indicator, write a 1 to the relevant bit. If all bits are clear, bit 0 of the main status byte (command 78h) is also cleared.

Clear Faults – Command 03h

Send byte transaction type. This command is used to clear all fault or warning indications in a single transaction. If conditions are persistent, the errors or warnings will immediately re-indicate.

7. Reading Data from the Unit

Read VIN – Command 88h

Read word transaction type. The input voltage (RMS) is returned in LINEAR11 format. The value is in Volts. N .B. This assumes a sinusoidal input voltage. For DC inputs, the returned value must be multiplied by SQRT(2) to get the true DC input voltage.

Read VCAP – Command 8Dh

Read word transaction type. The boost capacitor voltage is returned in LINEAR11 format. The value is in Volts.

Read Temperature – Command 8Dh

Read word transaction type. The temperature is returned in LINEAR11 format. The temperature value is in Celsius.

Read Fan speed 1 – Command 90h

Read word transaction type. The fan speed is returned in LINEAR11 format. The value is in units of RPM. If fan 1 is not fitted this will return 0.

Read Fan speed 2 – Command 91h

Read word transaction type. The fan speed is returned in LINEAR11 format. The value is in units of RPM. If fan 2 is not fitted this will return 0.

Manufacturer ID – Command 99h

Read Block transaction type. The value is returned as an ASCII string, and is always equal to "TDK_LAMBDA".

Model ID – Command 9Ah

Read Block transaction type. The value is returned as a 20 character ASCII string.

Manufacture Date – Command 9Dh

Read Block transaction type. The value is returned in 3 bytes as follows:

Byte 1 = Day of Month (1-31)

Byte 2 = Month of Year (1-12 representing January to December)

Byte 3 = Year (16-99 representing 2016 – 2099)

Serial Number – Command 9Eh

Read Block transaction type. The value is returned as a 10 character ASCII string.

Runtime – Command C4h

Read Block transaction type. The data is returned as a 32-bit unsigned value as follows:

Byte 1 = Least Significant Byte

Byte 2 = 2nd Least Significant Byte

Byte 3 = 2nd Most Significant Byte

Byte 4 = Most Significant Byte

Note that he value represents the time the unit has been powered up, which may not equal the time that module outputs have been enabled. The value is in units of ¼ hours e.g. a value of 13 represents 3.25 hours.

Power Cycle Count – Command C5h

Read Block transaction type. The data is returned as a 32-bit unsigned value as follows:

Byte 1 = Least Significant Byte

Byte 2 = 2nd Least Significant Byte

Byte 3 = 2nd Most Significant Byte

Byte 4 = Most Significant Byte

Note that he value represents the number of times that power has been cycled to the unit.

S/W Version Number – Command C6h

Read Block transaction type (length = 4). The version numbers of the Options Board and Converter Board expressed as major and minor pairs are returned as follows:

Byte 1 = Major version number of Options Board Firmware (unsigned value 0-255)

Byte 2 = Minor version number of Options Board Firmware (unsigned value 0-255)

Byte 3 = Major version number of Converter Firmware (unsigned value 0-255)

Byte 4 = Minor version number of Converter Firmware (unsigned value 0-255)

The version numbers are usually expressed as “<major>.<minor>”.

8. Miscellaneous Commands

Capability – Command 19h

Read byte transaction type. The value returned represents the capability of the PMBus implementation. A fixed value is returned by MU units of A0h. This indicates:

- PEC Supported
- 400kHz Operation
- SMBAlert Not Supported
- Numeric Format LINEAR11
- AVSBus Not Supported

PMBus Revision – Command 98h

Read byte transaction type. The value returned represents the PMBus revision supported. A fixed value is returned by MU units of 33h. This indicates that the units support PMBus version 1.3.

User Data – Commands B0h – BFh

Users may store data on the unit using commands B0h to BFh. These commands support read/write block transactions. Each command supports the reading or writing of 16 bytes, for a total storage of 256 Bytes across all 16 commands. All transactions must be of a block length of 16 bytes, either reading or writing all 16 bytes in one go.

Due to the expected life of the underlying non-volatile memory used to store this data, the User Data should not be updated more than 10000 times during the product lifetime.

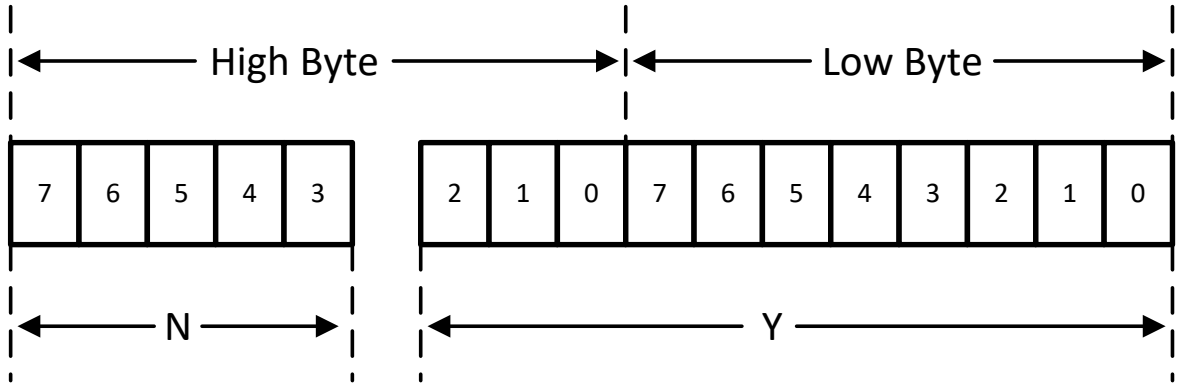
9. LINEAR11 Data Format

Temperature and Fan Speed queries use the LINEAR11 format described below:

The LINEAR11 format is a two byte value with:

- An 11-bit two's complement mantissa (Y)
- A 5-bit two's complement exponent (N)

The format is as follows:



The value represented by the format is given by: Value = Y x 2^N

10. Recommended Operation

It is always recommended that PEC is used for all transactions. Following a command or query to a unit, the Status Byte should be read to determine if a communication error occurred during the transaction. If a communication error occurred (as indicated by Bit 1 of the Status Byte being set) it should be assumed that the command was not actioned, or the data returned is not valid. The communication error status should then be cleared by writing a 1 to Bit 1 of the Status Byte, followed by a read of the Status Byte to check that it's clear. The command or query should then be repeated and the Status Byte rechecked until no error is reported during the transaction. If further information regarding the communications error is required, it can be found by reading the CML status byte before the Status byte bit is cleared.

11. General Notes

SMBAlert is not supported.

PEC (Packet Error Checking) is supported and should be used at all times.

If simultaneous control of the outputs from multiple MU units is required, this may be achieved using the PMBus Control Pin which may be routed to all units. It should be noted that due to differences in module output start-up times, precise synchronisation cannot be guaranteed.

MU units operate as a slave in single master systems only.

A maximum of 8-units may be connected to the bus, each unit must have a unique PMBus address.

12. Recommended PMBus Interface Adapter

The following USB to PMBus adapter is recommended:

Manufacturer: Texas Instruments

Manufacturer Part Number: USB-TO-GPIO

This is available from many suppliers, for example:

Farnell order Code: 1901883

Digi-Key Part Number: 296-23114-ND

RS Stock Number: 819-7562

Mouser Part Number: 595-USB-TO-GPIO

13. References

Ref[1]: System Management Bus (SMBus) Specification. Version 3.1, 19 Mar 2018.

Ref[2]: PMBus Power System Management Protocol Specification Part 1 – General Requirements, Transport And Electrical Interface. Revision 1.3.1, 13th March 2015.

Ref[3]: PMBus Power System Management Protocol Specification Part II – Command Language. Revision 1.3.1, 13th March 2015.