12V 33A Digital Quarter Brick Converter

Features

- High efficiency 95.5% (12V/33A)
- Fully regulated output voltage
- Industry standard footprint and pin out
- Excellent thermal performance
- Input OVLO&UVLO, Output OVP,OCP,OTP and short-circuit protection
- Designed to meet UL 60950-1 2nd
- Digital Interface with PMBus Revision 1.2 compliance
- Configurable enable logic
- Configurable precision delay and ramp-up
- Configurable soft start
- Configurable output voltage
- Configurable fault response
- Output voltage margin and trim
- Voltage/Current/Temperature monitoring
- 2,250Vdc input-to-output isolation

Applications

- Wireless Networks
- Telecom / Data Communication
- Electronic Data Process / Servers
- Distributed Power Architectures

Options

- Baseplate
- Case ground pin
- Various lead lengths
- Without digital interface
- Droop current sharing
- Secondary remote control

Part Numbering System

QDS	4	120	□□		033	□	□	□	□
Series Name	**Input Voltage**	**Output Voltage (Default)**	**Enable Logic***		**Output Current**	**Pin Style Option**	**Electrical Options**	**Mechanical Options**	**PMBus Options**
			Primary	**Secondary**				**Lead-free**	
QDS	**4:** 36-75V	**Unit:**0.1V **120:** 12V	**N:** negative **P:** positive **U:** control pin deactivated	**N:** negative **P:** positive **U:** control pin deactivated	**Unit:** A **033:**33A	**Regular** **K:** 0.110" **N:** 0.145" **R:** 0.180" **S:** SMT**	**0:** latch-up, no droop **1:** latch-up, droop **2:** auto-restart, no droop **A:** auto-restart, with droop	**5:** open frame **6:** baseplate **8:** case pin with baseplate	**Omit:** With PMBus interface; **A**: Without PMBus interface

**: Options specified by part number are default configuration. These options can be reconfigured later by PMBus commands.*

***: SMT pins are metal block pins at the same locations as the through-hole pins. The recommended diameter for pad/stencil opening and solder mask opening for these pins is 0.12".*

Absolute Maximum Ratings

Excessive stresses over these absolute maximum ratings can cause damage to the converter. Operation should be limited to the conditions outlined under the Electrical Specification Section.

Parameter	Symbol	Min	Max	Unit
Input Voltage (continuous)	Vi	-0.5	80	Vdc
Input Voltage (< 100ms, operating)	Vi	-	100	Vdc
Input Voltage (continuous, non-operating)			100	Vdc
Operating Ambient Temperature (See Thermal Consideration section)	To	-40	85*	˚C
Storage Temperature	Tstg	-55	125	˚C
Remote Control pin voltage	V_{RC}	-0.3	15	V
CTRL, SALERT, SCL, SDA	V_{Logic}	-0.3	3.6	V

* *Derating curves provided in this datasheet end at 85ºC ambient temperature. Operation above 85ºC ambient temperature is allowed provided the temperatures of the key components or the baseplate do not exceed the limit stated in the Thermal Considerations section.*

Electrical Specifications

These specifications are valid over the converter's full range of input voltage, resistive load, and temperature unless noted otherwise.

Input Specifications

Parameter	Symbol	Min	Typ	Max	Unit
Input Voltage	Vi	36	48	75	Vdc
Input Current	Ii,max	-	-	15	A
Quiescent Input Current (Typical Vin)	Ii,Qsnt	-	100	120	mA
Standby Input Current	Ii,stdby	-	30	40	mA
Input Reflected-ripple Current, Peak-to-peak (5 Hz to 20 MHz, 12 μH source impedance)	-	-	30	-	mA
Input Ripple Rejection (120 Hz)	-		60	-	dB
Input Turn-on Voltage Threshold (Default)	-	34	35	36	V
Input Turn-off Voltage Threshold (Default)	-	32	33	34	V
Input Voltage ON/OFF Hysteresis	-	-	2	-	V

Output Specifications

Parameter	Symbol	Min	Typ	Max	Unit
Output Voltage Set Point (non-droop option)** (Typical Vin; Io = Io,max; Ta = 25°C)	-	11.8	12.0	12.2	Vdc
Output Voltage Set Point (over all conditions)	-	11.7	-	12.3	Vdc
Output Regulation:					
Line Regulation (Over full input range, Io = 1/2 of load)	-	-	0.05	0.2	%Vo
Load Regulation (Non-droop option, Io = Io,min to Io,max, typical Vin)	-	-	0.2	0.5	%Vo
Temperature (Ta = -40°C to 85 °C)	-	-	15	50	mV
Output Ripple and Noise Voltage					
RMS	-	-	-	50	mVrms
Peak-to-peak (5 Hz to 20 MHz bandwidth, Vin = 48V)				120	mVp-p
External Load Capacitance	-	-	-	10,000	μF
Output Current	Io	0	-	33	A
Output Power	Po	0		396	W
Output Voltage Adjustment Range		4.0		12.8	Vdc

**: Default output voltage set points with droop option are 12.2V at zero load and 11.6V at full load.

Output Specifications (Continued)

Parameter	Symbol	Min	Typ	Max	Unit
Startup Delay (from Vin connection to Vo reaching 10% of set point. Typical Vin, Io=Io,max, Ta = 25ºC, ON/OFF set to on)			22		ms
Startup Time (Vo from 10% to 90% of output set point. Io = Io, min. Ta = 25ºC, ton rise = 15mS)			13		ms
Default Output Over Current Protection trip point (programmable)	Io,cli	35	38	41	A
Default Output Over Voltage trip point (programmable)		15.2	15.6	16	V
Default switch frequency (programmable)	-	133	140	147	kHz
Dynamic Response (Typical Vin; Ta = 25°C; Load transient 0.1A/µs,Co=220µF) Load step from 50% to 75% of full load: Peak deviation Settling time (to 10% band of Vo deviation) Load step from 50% to 25% of full load Peak deviation Settling time (to 10% band of Vo deviation)			 3 250 3 250		 %Vo µs %Vo µs

General Specifications

Parameter	Symbol	Min	Typ	Max	Unit
Remote Enable Logic Low: ION/OFF = 1.0mA VON/OFF = 0.0V Logic High: ION/OFF = 0.0µA Leakage Current	 VON/OFF ION/OFF VON/OFF ION/OFF	 0 - 2.6 -	 - - - -	 1.2 1.0 13 50	 V mA V µA
Output Voltage Trim Range(via PMBus interface)	-	80	-	110	%Vo
Isolation Capacitance	-	-	1500	-	pF
Isolation Resistance	-	10	-	-	MΩ
Calculated MTBF (Telecordia SR-332, 2011, Issue 3), full load, 40°C, 60% upper confidence level, typical Vin			5.9		10^6 -hour

Digital Interface Specifications

Parameter	Conditions		Min	Typ	Max	Unit
Logic Input/ Output Characteristics						
Logic Input Low (V_{IL})	SCL, SDA, CTRL		0	-	1.1	V
Logic Input High (V_{IH})			2.1	-	3.3	V
Logic Output Low (V_{OL})	SCL, SDA, SALERT, MULTI; Iol = 4mA		-	-	0.25	V
Logic Output High (V_{OH})	SCL, SDA, SALERT, MULTI; Ioh = -4mA		2.7	-	-	V
PMBus Operating Frequency Range			100	-	400	KHz
PMBus Monitoring Accuracy						
Output Voltage	VI = 48V		-	±0.2	±1	%
Output Current	VI = 48V, 50-100% of max IO		-	±3	±6	%
Output Current	VI = 48V, 10% of max IO		-	±0.5	±1.0	A
Input Voltage	Not operating		-	±2	±3	%
Temperature			-	-	±2	℃
Fault Protection Characteristics						
Input Under Voltage Lockout (UVLO)	VIN_ON	Factory Default	-	35.0	-	V
		Configurable via PMBus	35.0	-	75.0	V
	VIN_OFF	Factory Default		33.0		V
		Configurable via PMBus	33.0	-	73.0	V
	Set-point Accuracy		-3	-	3	%
	Hysteresis		-	2.0	-	V
	Response Time		-	200		μs
Input Over/Under Voltage Protection (Vin OVP/Vin UVP)	VIN_OV_FAULT_LIMIT	Factory Default	-	85.0	-	V
		Configurable via PMBus	41.0	-	90.0	V
		Response Time	-	100	-	ms
	VIN_UV_FAULT_LIMIT	Factory Default	-	34.0	-	V
		Configurable via PMBus	33.0		75.0	V
		Response Time	-	200		μs
Output Over/Under Voltage Protection (OVP/UVP)	VOUT_OV_FAULT_LIMIT	Factory Default	-	15.6	-	V
		Configurable via PMBus	0.0	-	16.0	V
		Response Time	-	5	-	μs
	VOUT_UV_FAULT_LIMIT	Factory Default	-	0.0	-	V
		Configurable via PMBus	0.0	-	16.0	V
		Response Time	-	200		μs
Over Current Protection (OCP)	IOUT_OC_FAULT_LIMIT	Factory Default	-	38.0	-	A
		Configurable via PMBus	0.0	-	100.0	A
		Response Time	-	200	-	μs
	Set-point Accuracy		-5	-	5	%
Over/Under Temperature Protection (OTP/UTP)	OT_FAULT_LIMIT	Factory Default	-	120	-	˚C
		Configurable via PMBus	-40	-	130	˚C
	UT_FAULT_LIMIT	Factory Default	-	-45	-	˚C
		Configurable via PMBus	-50	-	130	˚C
	Temp Hysteresis	Factory Default	-	20	-	˚C
		Configurable via PMBus	5	-	50	˚C
	Response Time		-	200		μs

Characteristic Curves

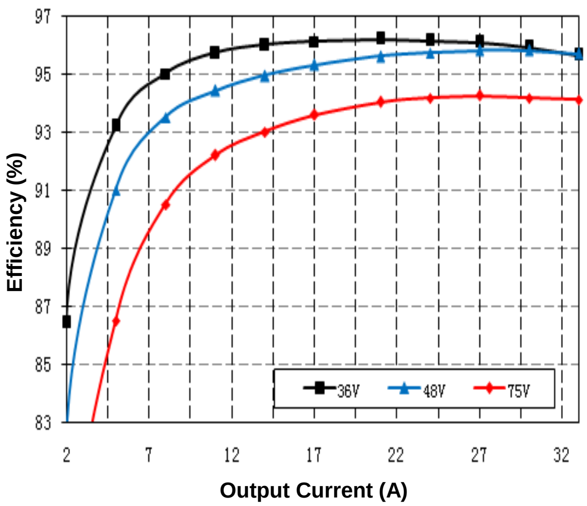

Figure 1. Efficiency vs. Load Current (25℃)

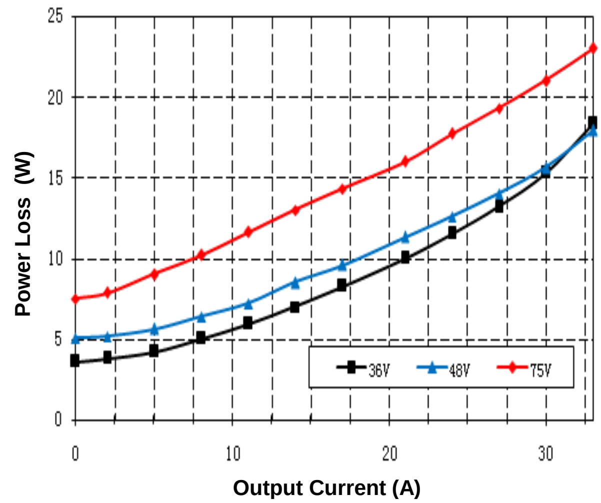

Figure 2. Power Loss vs. Load Current (25℃)

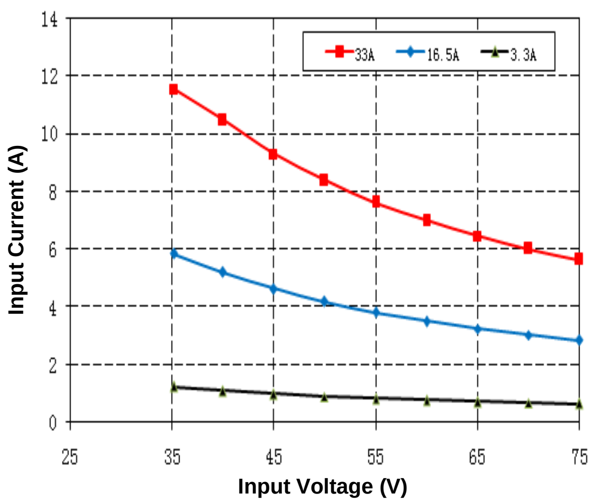

Figure 3. Input Characteristics

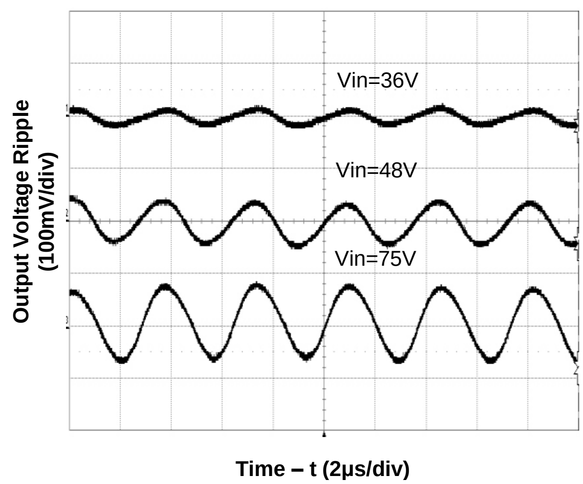

Figure 4. Output Ripple Voltage at Full Load

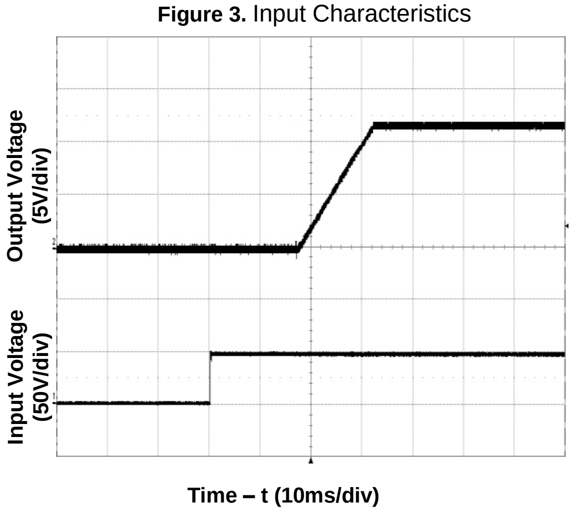

Figure 5. Start-Up from Vin (Zero load)
Typical Vin; Ton delay=0; ON/OFF Enabled

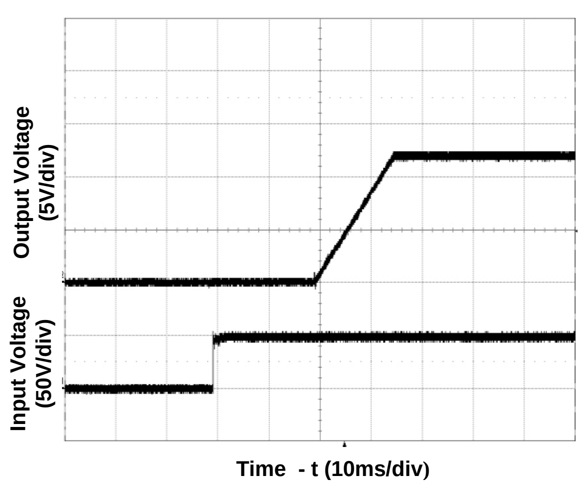

Figure 6. Start-Up from Vin (Full load)
Typical Vin; Ton delay=0, ON/OFF Enabled

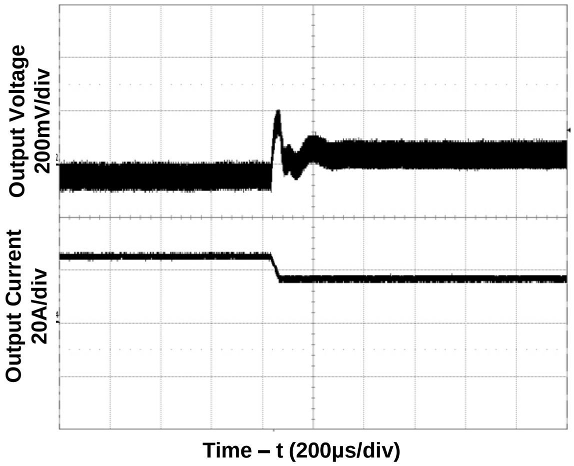

Figure 7. Transient Load Response
(Typical Vin; Co=220µF) Load current step 50% full load ⇒25% full load; Slew rate 0.1A/µs;

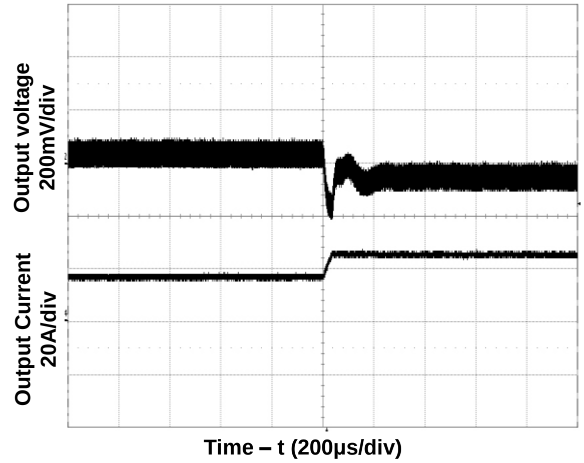

Figure 8. Transient Load Response
(Typical Vin; Co=220µF)
Load current step 50% full load ⇒75% full load; Slew rate

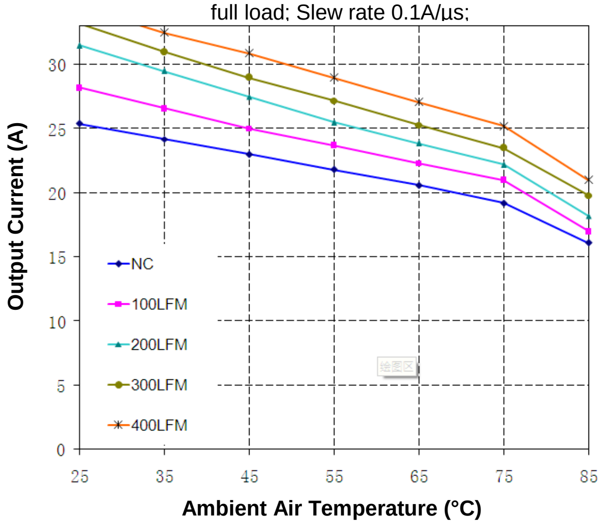

Figure 9. Derating Curve for Airflow Direction 3
Typical Vin, Open frame unit using soldering interface
(Ref. to Figure 10 for Airflow Direction)

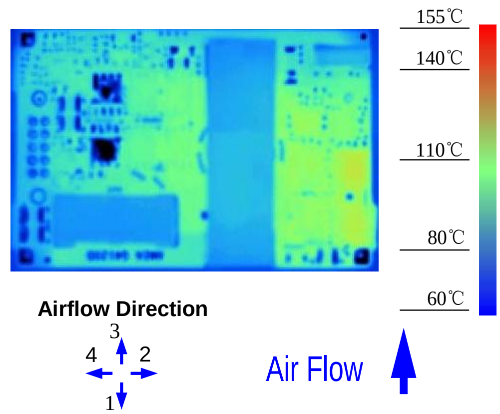

Figure 10. Thermal Image for Airflow Direction 3
(23.5A output, 55°C ambient, 200 LFM, typical Vin, open frame unit using soldering interface)

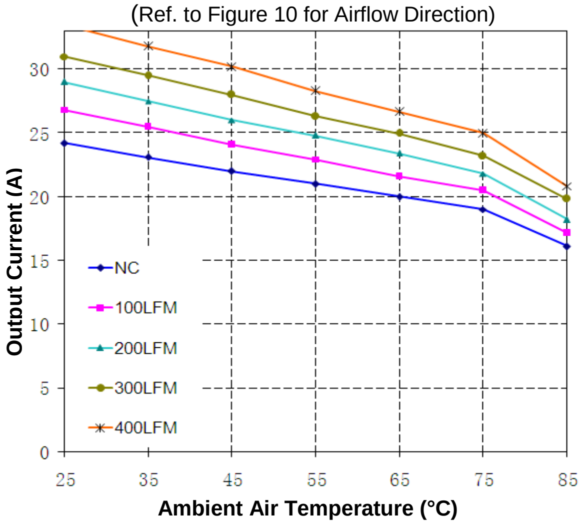

Figure 11. Current Derating Curve for Airflow Direction 4
Typical Vin, Open frame unit using soldering interface
(Ref. to Figure 10 for Airflow Direction)

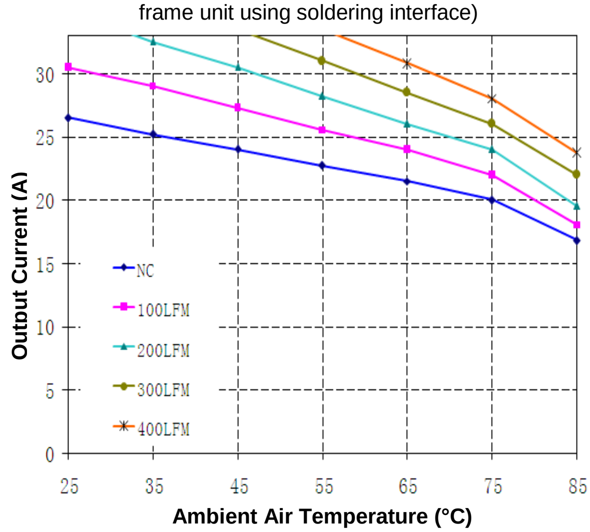

Figure 12. Current Derating Curve for Airflow Direction 4
Typical Vin, Unit with baseplate; Using soldering interface
(Ref. to Figure 10 for Airflow Direction)

Design Considerations

Input Source Impedance

The stability of the QDS4 converters, as with any DC/DC converter, may be compromised if the source impedance is too high or too inductive. It's desirable to keep the input source impedance as low as possible. The converters are designed to be stable without additional input capacitors for typical source impedance. However, it is recommended to use 100μF low ESR electrolytic capacitor at the input of the converter to reduce the potential impact of the source impedance. This electrolytic capacitor should have sufficient RMS current rating over the operating temperature range to avoid overheating.

Safety Considerations

The QDS4 Series of converters is designed in accordance with EN 60950 Safety of Information Technology Equipment Including Electrical Equipment.

Thermal Considerations

The QDS4 Series of converters can operate in various thermal environments. Due to the high efficiency and optimal heat distribution, these converters exhibit excellent thermal performance. Most heat-generating components are mounted on the top side of the converter, so the heat can be easily removed by conduction, convection, and radiation. Proper cooling can be verified by monitoring the temperature of the key components. Figure13 shows recommended temperature monitoring point(s) for open frame converters. The temperature at the measuring point(s) should not exceed 120 ℃ continuously. For a converter with a base-plate, the base-plate temperature should not exceed 105℃ continuously if the load current is more than 15A, or 110℃ if the load current is less to 15A.

The maximum allowable output power of any power converter is usually determined by the electrical design and the maximum operating temperature of its components. The QDS4 Series of converters have been tested under various conditions in a laboratory wind-tunnel to generate the derating curves.

Thermal derating curves are highly influenced by derating guidelines, the test conditions and the test setup, including the interface method between the converter and fixture board (soldered or sockets), the design of the fixture board (especially copper weight, holes and openings), temperature measurement method, and the ambient temperature measurement point, etc. One of the critical variables is the interface method between the converter and the test fixture board. There is no standard method in the industry for the derating tests. Some suppliers use sockets to plug in the converter, while others solder the converter into the fixture board. It should be noticed that these two methods produce significantly different results for a given converter. When the converter is soldered into the fixture board, the thermal performance of the converter is significantly improved compared to using sockets due to the reduction of the contact loss and the thermal impedance from the pins to the fixture board.

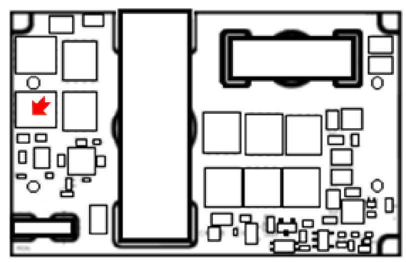

Figure 13. Temperature Monitoring Location

Thermal derating curves of QDS4 converters are obtained with thermal tests in a wind-tunnel at 25℃, 55℃, 75℃, and 85℃. The converter's power pins are soldered into a 2-layer test fixture board. The space between the test board and a spacing board is 1 inch.

It's important to note that many variables are different between a real system and the above described test setup. In addition, different power module vendors use different ways to generate the derating curves, and derating curves from different power vendors are often not based on the same test conditions, therefore, don't offer a fair comparison. It is strongly advised to conduct careful system thermal testing in the qualification process.

Note that the natural convection condition was measured at 0.05 m/s to 0.15 m/s (10ft./min. to 30 ft./min).

Heat Transfer with a Baseplate

The QDS4 series of converters can use a baseplate to further enhance their thermal performance. The maximum height of a QDS4 converter with a baseplate is 0.50''. A baseplate works as a heat spreader, and thus can improve the heat transfer between the converter and its ambient.

An additional heatsink or cold-plate can be attached to the baseplate using M3 screws. The heatsink/cold plate further improves the thermal performance of the converter.

An optional case pin is available with the baseplate and heatsink options.

EMC Considerations

The EMC performance of the converter is related to the EMI filter design and its layout on the system board. Customers shall use common practices in EMI filter designs for DC/DC converters to minimize both differential-mode and common mode noises. EMI is largely a system issue and proper system design (filtering and shielding) is often the most important means to meet conducted and radiated EMI standards.

Feature Descriptions (General)

On/off Control

On/off control function is configurable for the QDS4 Series of converters. The on/off control of the converter can be implemented through three inputs: primary side remote control RC (Pin2), secondary side remote control CTRL (Pin15) and on/off command from PMBus interface. The relationship between primary RC and secondary CTRL can be configured using command MFR_REMOTE_CTRL.

a) Primary Side RC On/off

The converter can be turned on and off by changing the voltage between the RC pin and Vin(-) pin. The primary RC on/off logic can be configured through a PMBus command.

With an internal pull-up resistor, a simple external switch between the RC pin and Vin(-) pin can produce logic high or logic low at RC pin. A few examplary circuits for controlling the RC on/off are shown in Figure 14, 15 and 16. When the primary RC on/off function is deactivated, the status at the RC pin is ignored.

Users can configure the primary side RC on/off with MFR_REMOTE_CTRL [E3h] command.

b) Secondary Side CTRL On/off

The secondary CTRL pin (pin 15) can be configured as remote on/off control through PMBus command MFR_MULTI_PIN_CONFIG[F9h]. The secondary on/off logic can be positive or negative.

When CTRL pin is configured to be secondary remote on/off, it is internally connected to a 3.3V source through a pull-up resistor to ensure the logic high when it is left open. Users can connect this pin to a logic signal, or simply connect an enable circuit between this pin and Vo(-) pin. When the CTRL function is deactivated, the status at the CTRL pin is ignored.

The logic low level at CTRL is from 0V to 1.1V and the maximum sink current during logic low is 1mA. The external switch must be capable of maintaining a logic low level while sinking up to this current. The logic high level is from 2.1V to 3.3V.

Users can configure the secondary side CTRL on/off through ON_OFF_CONFIG [02h] command.

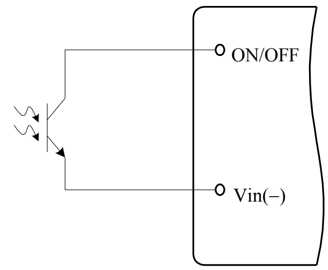

Figure 14. Opto-coupler Enable Circuit

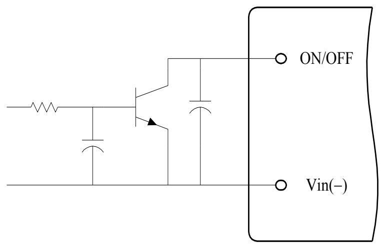

Figure 15. Open Collector Enable Circuit

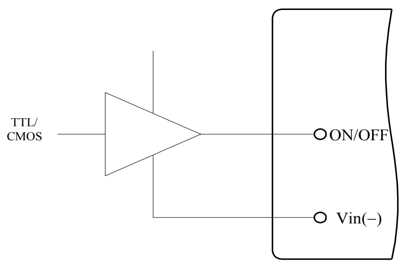

Figure 16. Direct Logic Drive

Remote SENSE

The remote sense pins are used to sense the voltage at the load point to accurately regulate the voltage at the load and eliminate the impact of the voltage drop in the power distribution path.

SENSE(+) and SENSE(-) pins should be connected between the points where voltage regulation is desired. The voltage between the SENSE pins and the output pins must not exceed the smaller of 0.5V or 10% of typical output voltage.

[Vout(+) - Vout(-)] - [SENSE(+) - SENSE (-)] < MIN{0.5V, 10%Vo}

When remote sense is not used, the SENSE pins should be connected to their corresponding output pins. If the SENSE pins are left floating, the converter will deliver an output voltage slightly higher than its specified typical output voltage.

Output Voltage Configuration and Adjustment

The output voltage of QDS4 Serials of converters can be dynamically reconfigured using PMBus commands. Using OPERATION command, the output voltage of the converter can be selected from three voltages set with VOUT_COMMAND, VOUT_MARGIN_HIGH and VOUT_MARGIN_LOW commands. Since the output voltage can be trimmed with PMBus commands, there is no need of a trim pin. The trimmed output voltage can not exceed 12.8V.

As the voltage at the converter output terminals can be higher than the specified typical level when the trim up and/or remote sense functions are used, it is important to make sure that the output power doesn't exceed the maximum power rating of the converter as given in the Specifications table.

Start-up Process

Several parameters or functions affect start-up process: delay before start-up, pre-bias setting, start-up speed, and over current protection while starting up. If the module is enabled using RC, CTRL, or on/off command, a start-up delay time set with TON_DELAY will present. After the delay time, the output voltage begins to rise from the pre-bias voltage. The pre-bias start-up feature helps to avoid energy in the capacitors across the output terminals being discharged back into the module and causing damages, and prevents glitches at the output voltage during start-up. The output voltage rise time is set with TON_RISE. This rise time is for the output voltage to go from 0V to its set point. Therefore, different pre-bias voltage will lead to different actual rise time. During this start-up process, the over current protection could be triggered in case of excessive current drawn by the load. Therefore, properly configuring the rise time is important for a smooth start up.

Power Good (PG)

The default function of the multi-function pin MULTI is Power Good and the polarity is defined with command MFR_PGOOD_POLARITY. By default, logic low represents the output voltage is good.

The MULTI pin can also be reconfigured to an open drain Power Good signal regardless of MFR_PGOOD_POLARITY to allow parallel option of multiple converters.

Parallel Operation

QDS4 series of converters with the droop option can be directly connected in parallel to meet higher system power demands. By default, a module with the droop option has a set point of 12.2V at zero load and

11.6V at its full rating (33A). The 0.6V droop allows the converters in parallel to share the load current within 10% of the rated current. Users can reconfigure the droop with VOUT_DROOP[0x28] command.

It's desirable to have impedance balance among all converters' output power traces for better current sharing. If converters with the droop option are directly connected in parallel at their output terminals without using ORing devices, these converters should all have the optional latch-off protection feature and receive synchronized enable signals to ensure synchronized start-up.

Input Under-Voltage Lockout

This feature prevents the converter from starting until the input voltage reaches the turn-on voltage threshold (VIN_ON), and shuts the converter off when the input voltage falls below the turn-off voltage threshold (VIN_OFF). The hysteresis (minimum 2V) prevents oscillations. Both thresholds can be programmed through PMBus interface.

Input Over/Under Voltage Protection (OVP/UVP)

The input OVP feature shuts off the converter when the input voltage goes above the threshold set with VIN_OV_FAULT_LIMIT. When the input voltage is higher than VIN_OV_FAULT_LIMIT yet lower than or equal to 100V, it has a 100ms delay before shutting off the converter to meet the NEBS requirement of riding through 100V, 100ms surges. When the input voltage exceeds 100V, the input OVP will immediately turn off the converter.

The converter also features input UVP. When the input voltage is lower than VIN_UV_FAULT_LIMIT, the converter will be immediately turned off if the UVP is enabled.

The thresholds and fault response of input OVP and UVP can be reconfigured via the PMBus interface.

Output Over-Current Protection (OCP)

This feature protects the converter against over load. This OCP feature is configurable. There are three protection modes available: latch-off, restart/latch-off, and auto-restart.
With the latch-off mode, the converter will latch off once the output current exceeds the limit set with IOUT_OC_FAULT_LIMIT. The converter can be restarted by recycling ON/OFF control or the input voltage.

With the restart/latch-off mode, the converter will try to restart after it shuts off due to the output current exceeding the limit (IOUT_OC_FAULT_LIMIT). The number of restarting attempts is configurable. If the over current condition remains after the configured number of restarting, the module will then enter latch-off mode.

With the auto-restart mode, the converter will continue its restarting attempts until the over current condition is cleared and the converter successfully restarts.

Users can reconfigure OCP level and the protection mode using PMBus commands.

Output Over-Voltage Protection (OVP)

This feature protects the converter against output over voltage. This output OVP feature is configurable. There are three protection modes available: latch-off, restart/latch-off, and auto-restart.

With the latch-off mode, the converter will latch off once the output voltage exceeds the limit (VOUT_OV_FAULT_LIMIT). The converter can be restarted by recycling the ON/OFF control or the input voltage.

With the restart/latch-off mode, the converter will try to restart after it shuts off due to the output voltage exceeding the limit (VOUT_OV_FAULT_LIMIT). The number of restarting attempts is configurable. If the over voltage condition remains after the configured number of restarting, the module will then enter latch-off mode.

With the auto-restart mode, the converter will continue its restarting attempts until the over voltage condition is cleared and the converter successfully restarts.

Users can reconfigure output OVP level and the protection mode using PMBus commands.

Output Under-Voltage Protection (UVP)

The output UVP feature is configurable. There are three protection modes available: latch-off, restart/latch-off, and auto-restart.

With the latch-off mode, the converter will latch off once the output voltage is lower than the limit (VOUT_UV_FAULT_LIMIT). The converter can be restarted by recycling the ON/OFF control or the input voltage.

With the restart/latch-off mode, the converter will try to restart after it shuts off due to the output voltage being lower than the limit (VOUT_UV_FAULT_LIMIT). The number of restarting attempts is configurable. If the under voltage condition remains after the configured number of restarting, the module will then enter latch-off mode.

With the auto-restart mode, the converter will continue its restarting attempts until the under voltage condition is cleared and the converter successfully restarts.

Users can reconfigure output UVP level and the protection mode using PMBus commands.

Thermal Shutdown (OTP/UTP)

The converter has a built-in temperature sensor that detects the temperature of the converter. The converter will shut off when the sensed temperature reaches above the over temperature limit set with TEMP_OT_FAULT_LIMIT or the under temperature limit set with TEMP_UT_FAULT_LIMIT, and will resume operation when the temperature at the sensor comes back to the specified operational temperature range. The hysteresis set using command MFR_TEMP_HYSTERESIS prevents OTP or UTP oscillation.

Switching Frequency Adjustment via PMBus

The default value of switching frequency is 140KHZ. Users can reconfigure the switching frequency in the range of 125KHZ-150KHZ through the PMBus interface. However, the output performance is not optimized if the frequency is not at the default value.

When receiving the command to adjust the switching frequency, the switching frequency is gradually changed to the new frequency to avoid output voltage glitches.

Feature Descriptions (Digital)

QDS4 Series digital converters have almost all the control functions implemented with digital circuits and software, including signal acquisition, PWM, and close-loop control.

The key digital features include:

- *Digital PWM generator*
- *Digital signal acquisition and processing*
- *Digital control loops*
- *Digital faults protection*
- *PMBus communication interface*

Users can monitor the status of the converter and dynamically change the converter parameters and/or some functions. **Caution: changing parameters while a converter is operating may result in abnormal converter behaviors and possible damages to the converter and/or the load. Read this datasheet carefully and understand the functions and effects of the commands prior to power up this converter.**

PMBus Interface

The Power Management Bus (PMBus) is an open-standard power management protocol. It is used to configure and monitor power converters and communicate with system controllers or host computers. QDS4 Series of converters comply with PMBus revision 1.2, and support Packet Error Checking (PEC) and clock stretching function. Please refer to CAPABILITY command for the capabilities. Since QDS4 Series of converters support only partial commands of PMBus 1.2; please refer to the Table 3 in this datasheet for supported commands. When a certain fault or warning occurs, the PMBus Alert signal will be pulled low to inform the system controller. Alert signal can be cleared through CLEAR_FAULTS command.

Users can modify some parameters of the converter while the converter is in operation, and these modifications will be lost once the converter is turned off. Users can save these modifications to the internal non-volatile memory using STORE_USER_ALL command. The users can restore the converter to the factory default configuration using RESTORE_DEFAULT_ALL command.

PMBus Address

Since multiple converters might be connected to the same bus, each should have its own address. There are two methods for configuring the PMBus address: using command MFR_PMBUS_ADDRESS_CONFIG or using address-configure resistors. The default method is address-configure resistors.

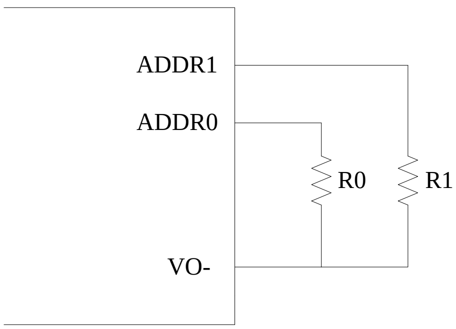

Figure17. Address-configure resistors

Table 1. Address Digit Values vs. Resistor Values

ADDR0/ADDR1	R0/R1(kΩ)
0	10
1	22
2	33
3	47
4	68
5	100
6	150
7	220

With the address-configure resistors method, two resistors should be used connecting ADDR0 pin and ADDR1 pin to Vout(-) as shown in Figure 17. Each resistor stands for an octonary digit (0-7), and together configures 64 (0~63) addresses. Addresses from 64 to 127 can only be defined with MFR_PMBUS_ADDRESS_CONFIG command. The suggested resistor values and the corresponding digits are listed in Table 1. The suggested resistors' accuracy is 1%. The address value can be obtained from below equation.

PMBus Address = $8 \times$ ADDR1 + ADDR0

Total addresses defined in PMBus 1.2 protocol is 128 (use 7 bits). But not all of them are available to users. Addresses 0-12, 40, 44, 55, 97, 120-127 are reserved in the protocol. If improper resistors are detected or the resulted address is reserved, the default address 127 is assigned. For instance, when the address-configure resistors are not connected, the active address is 127.

PMBus Data Format

Different units and data formats are used in PMBus commands for usability and operational efficiency.

VOUT Linear format

For some commands that set or monitor output voltage related parameters, including VOUT_COMMAND, VOUT_MARGIN_HIGH/LOW, VOUT_MAX, READ_VOUT, POWER_GOOD_ON/OFF, etc., their active data formats are the same, and are defined with command VOUT_MODE. Among the three data formats (linear format, VID format and direct format), this QDS4 design uses linear data format, renamed as VOUT Linear, and the other 2 data formats are not supported. VOUT Linear is a float point data format with 16 binary significant digits. The mantissa is saved as a 16 bits unsigned integer, and the data format and the exponent are defined using VOUT_MODE command, as described in Table 2. Therefore, for a certain data, only mantissa should be saved. VOUT_MODE command is not writable, and its default value is 0x17 for QDS4 Series of converters, which means linear float point data format is used (bit7:5 is 0b000), and the exponent is -9 (bit4:0 is 0b10111,which is -9 as 5 bits two's complement). So, the actual value is

$$\text{Value} = \text{mantissa} \times 2^{-9}$$

Table 2. VOUT_MODE

Bit 7:5	Bit 4:0
0b000	0b10111
Mode(linear)	Exponent(-9)

Linear format

For other commands that set thresholds or report measurements, Linear data format is used, which is a two byte value made up of an 5 bit exponent of two's complement, and 11 bit mantissa of two's complement, as shown in Figure 18.

Value = mantissa × $2^{exponent}$

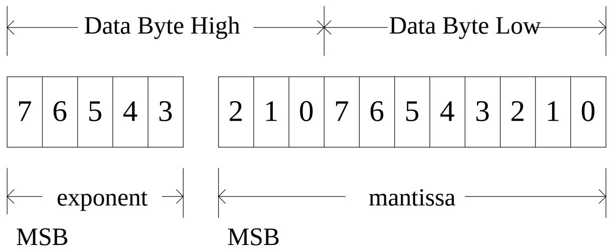

Figure 18. Linear Data Format

Bit Field format

This format is specially defined according to each command. The data is usually divided into several bit fields, and each of the bit fields is defined separately.

Bytes format

The data comprise series of bytes and each byte stands for an integer number or an ASCII code and so on.

PMBus Commands

PMBus protocol revision 1.2 is based on SMBus protocol revision 2.0. So the format of PMBus commands is similar to that of SMBus commands except for some extensions. Please refer to the PMBus and SMBus protocol documents for more detailed descriptions of the commands.

Only supported commands or features are described in the below table. All reserved bits or bits combinations are not used in this design. If users write any reserved bits or bits combinations, the module will not react. 'Reserved' means it is reserved for future version but not defined in this version of protocol.

Table 3: Supported PMBus commands

Cmd Name	Cmd Code	Transfer Type	Data Format	Min	Default Value	Max	Data Unit	Note
Standard PMBus Commands								
OPERATION	01h	R/W byte	Bit field	-	0x00	-	-	
ON_OFF_CONFIG	02h	R/W byte	Bit field	-	Option	-	-	
CLEAR_FAULTS	03h	Send byte	-	-	-	-	-	
WRITE_PROTECT	10h	R/W byte	Bit field	-	0x00	-	-	
RESTORE_DEFAULT_ALL	12h	Send byte	-	-	-	-	-	
STORE_USER_ALL	15h	Send byte	-	-	-	-	-	
RESTORE_USER_ALL	16h	Send byte	-	-	-	-	-	
CAPABILITY	19h	Read byte	Bit field	-	0xB0	-	-	PEC, max bus speed is 400k, SMBAlert
VOUT_MODE	20h	Read byte	Bit field	-	0x17	-	-	Only Linear Mode is supported, exp=-9
VOUT_COMMAND	21h	R/W word	VOUT linear	4.0	12.0	12.8	V	
VOUT_TRIM	22h	R/W word	VOUT linear	-2.4	0.0	1.2	V	Two's complement format
VOUT_CAL_OFFSET	23h	Read word	VOUT linear	-	Factory set	-	-	
VOUT_MAX	24h	Read word	VOUT linear	4.0	12.8	12.8	V	
VOUT_MARGIN_HIGH	25h	R/W word	VOUT linear	4.0	12.6	12.8	V	
VOUT_MARGIN_LOW	26h	R/W word	VOUT linear	4.0	10.8	12.8	V	
VOUT_TRANSITION_RATE	27h	R/W word	Linear	0.001	0.094	3.0	mV/μs	
VOUT_DROOP	28h	R/W word	Linear	0.0	18.18	100.0	mV/A	
VOUT_SCALE_LOOP	29h	Read word	Linear	-	Factory set	-	-	
VOUT_SCALE_MONITOR	2Ah	Read word	Linear	-	Factory set	-	-	
MAX_DUTY	32h	Read word	Linear	-	99	-	%	
FREQUENCY_SWITCH	33h	R/W word	Linear	125	140	150	KHz	
VIN_ON	35h	R/W word	Linear	35.0	35.0	75.0	V	
VIN_OFF	36h	R/W word	Linear	33.0	33.0	73.0	V	
IOUT_CAL_GAIN	38h	Read word	Linear	-	Factory set	-	-	
IOUT_CAL_OFFSET	39h	Read word	Linear	-	Factory set	-	-	
VOUT_OV_FAULT_LIMIT	40h	R/W word	VOUT linear	0.0	15.6	16.0	V	
VOUT_OV_FAULT_RESPONSE	41h	R/W byte	Bit field	-	Option	-	-	Bits[7:6], only 0b10 is supported
VOUT_OV_WARN_LIMIT	42h	R/W word	VOUT linear	0.0	13.0	16.0	V	
VOUT_UV_WARN_LIMIT	43h	R/W word	VOUT linear	0.0	0.0	16.0	V	
VOUT_UV_FAULT_LIMIT	44h	R/W word	VOUT linear	0.0	0.0	16.0	V	
VOUT_UV_FAULT_RESPONSE	45h	R/W byte	Bit field	-	Option	-	-	Bits[7:6], only 0b00 and 0b10 are supported
IOUT_OC_FAULT_LIMIT	46h	R/W word	Linear	0.0	38.0	100.0	A	

Cmd Name	Cmd Code	Transfer Type	Data Format	Min	Default Value	Max	Data Unit	Note
IOUT_OC_FAULT_RESPONSE	47h	R/W byte	Bit field	-	Option	-	-	Bits[7:6], only 0b11 is supported
IOUT_OC_WARN_LIMIT	4Ah	R/W word	Linear	0.0	35.0	100.0	A	
OT_FAULT_LIMIT	4Fh	R/W word	Linear	-40	120	130	˚C	
OT_FAULT_RESPONSE	50h	R/W byte	Bit field	-	0xC0	-	-	Bits[7:6], only 0b11 is supported
OT_WARN_LIMIT	51h	R/W word	Linear	-40	110	130	˚C	
UT_WARN_LIMIT	52h	R/W word	Linear	-50	-35	130	˚C	
UT_FAULT_LIMIT	53h	R/W word	Linear	-50	-45	130	˚C	
UT_FAULT_RESPONSE	54h	R/W byte	Bit field	-	0xC0	-	-	Bits[7:6], only 0b11 is supported
VIN_OV_FAULT_LIMIT	55h	R/W word	Linear	41.0	85.0	90.0	V	
VIN_OV_FAULT_RESPONSE	56h	R/W byte	Bit field	-	Option	-	-	Bits[7:6], only 0b11 and ob10 are supported
VIN_OV_WARN_LIMIT	57h	R/W word	Linear	41.0	80.0	90.0	V	
VIN_UV_WARN_LIMIT	58h	R/W word	Linear	33.0	34.0	75.0	V	
VIN_UV_FAULT_LIMIT	59h	R/W word	Linear	33.0	34.0	75.0	V	
VIN_UV_FAULT_RESPONSE	5Ah	R/W byte	Bit field	-	Option	-	-	Bits[7:6], only 0b00 and ob10 are supported
POWER_GOOD_ON	5Eh	R/W word	VOUT linear	0.0	8.0	16.0	V	
POWER_GOOD_OFF	5Fh	R/W word	VOUT linear	0.0	5.0	16.0	V	
TON_DELAY	60h	R/W word	Linear	0.0	0.0	1000.0	ms	
TON_RISE	61h	R/W word	Linear	4.0	10 .0	1000.0	ms	
TON_MAX_FAULT_LIMIT	62h	R/W word	Linear	0.0	15.0	1000.0	ms	
TON_MAX_FAULT_RESPONSE	63h	R/W byte	Bit field	-	Option	-		Bits[7:6], only 0b00 and ob10 are supported
TOFF_DELAY	64h	R/W word	Linear	0.0	5.0	1000.0	ms	
TOFF_FALL	65h	R/W word	Linear	4.0	10.0	1000.0	ms	
TOFF_MAX_WARN_LIMIT	66h	R/W word	Linear	0.0	15.0	1000.0	ms	
STATUS_BYTE	78h	Read byte	Bit field	-	-	-	-	
STATUS_WORD	79h	Read word	Bit field	-	-	-	-	
STATUS_VOUT	7Ah	Read byte	Bit field	-	-	-	-	
STATUS_IOUT	7Bh	Read byte	Bit field	-	-	-	-	
STATUS_INPUT	7Ch	Read byte	Bit field	-	-	-	-	
STATUS_TEMPERATURE	7Dh	Read byte	Bit field	-	-	-	-	
STATUS_CML	7Eh	Read byte	Bit field	-	-	-	-	
READ_VIN	88h	Read word	Linear	-	-	-	V	
READ_VOUT	8Bh	Read word	VOUT linear	-	-	-	V	
READ_IOUT	8Ch	Read word	Linear	-	-	-	A	
READ_TEMPERATURE_1	8Dh	Read word	Linear	-	-	-	˚C	The converter’s temperature

Cmd Name	Cmd Code	Transfer Type	Data Format	Min	Default Value	Max	Data Unit	Note
READ_TEMPERATURE_2	8Eh	Read word	Linear	-	-	-	˚C	The digital chip's temperature
READ_DUTY_CYCLE	94h	Read word	Linear	-	-	-	%	
READ_FREQUENCY	95h	Read word	Linear	-	-	-	KHz	
PMBUS_REVISION	98h	Read byte	Bit field	-	0x42	-	-	
MFR_ID	99h	Block read	Bytes	-	Factory set	-	ASCII	
MFR_MODEL	9Ah	Block read	Bytes	-	Factory set	-	ASCII	
MFR_REVISION	9Bh	Block read	Bytes	-	Factory set	-	ASCII	Hardware revision | firmware revision
MFR_LOCATION	9Ch	Block read	Bytes	-	Factory set	-	ASCII	
MFR_DATE	9Dh	Block read	Bytes	-	Factory set	-	ASCII	
MFR_SERIAL	9Eh	Block read	Bytes	-	Factory set	-	ASCII	
MFR_VIN_MIN	A0h	Read word	Linear	-	36.0	-	V	
MFR_VIN_MAX	A1h	Read word	Linear	-	75.0		V	
MFR_VOUT_MIN	A4h	Read word	VOUT linear	-	4.0	-	V	
MFR_VOUT_MAX	A5h	Read word	VOUT linear	-	12.8	-	V	
MFR_TAMBIENT_MAX	A8h	Read word	Linear	-	85	-	˚C	
MFR_TAMBIENT_MIN	A9h	Read word	Linear	-	-40	-	˚C	
IC_DEVICE_ID	ADh	Block read	Bytes	-	-	-	ASCII	
IC_DEVICE_REV	AEh	Block read	Bytes	-	-	-	ASCII	
USER_DATA_00	B0h	Block R/W	Bytes	-	All 0x00	-	-	Length is 20 bytes
QDS4 Specific Commands								
MFR_PGOOD_POLARITY	D0h	R/W byte	Bit field	-	Option	-	-	
MFR_TEMP_OFFSET_INT	E1h	Read word	Linear	-	Factory set	-	-	The internal temperature sensor offset
MFR_REMOTE_TEMP_CAL	E2h	Block read	Bytes	-	Factory set	-	-	The calibration slope and offset, 4 bytes
MFR_REMOTE_CTRL	E3h	R/W byte	Bit field	-	Option	-	-	
MFR_TEMP_HYSTERESIS	F4h	R/W word	Linear	5	20	50	˚C	
MFR_PMBUS_ADDRESS_CONFIG	F6h	R/W byte	Bit field	-	0x00	-	-	PMBus address configuration
MFR_MULTI_PIN_CONFIG	F9h	R/W byte	Bit field	-	Option	-	-	

MFR_PGOOD_POLARITY [D0h]

Bit Number	Purpose	Bit Value	Meaning	Default Value
7:1	Reserved	0000000	Reserved	0b0000000
0	Power Good Polarity	0	Active low	0
		1	Active high	

MFR_REMOTE_CTRL [E3h]

Bit Number	Purpose	Bit Value	Meaning	Default Value
7:5	Reserved	000	Reserved	0b000
4	Primary RC's relationship with ON_OFF_CONFIG	0	Primary RC is OR'ed with ON_OFF_CONFIG's configuration	1
		1	Primary RC is AND'ed with ON_OFF_CONFIG's configuration	
3	Reserved	0	Reserved	0
2	Response to the primary RC pin	0	primary RC is ignored	0
		1	primary RC is required to be asserted to start the unit	
1	Polarity of primary RC pin	0	Active Low	0
		1	Active High	
0	Primary RC pin turn-off action	0	Use the programmed turn off delay and fall time	1
		1	Turn off the output immediately	

MFR_PMBUS_ADDRESS_CONFIG [F6h]

Bit Number	Purpose	Bit Value	Meaning	Default Value
7	Reserved	0	Address configured using resistors	0
		1	Address configured using command	
6:0	address	0000000	Pmbus address	0b0000000

MFR_MULTI_PIN_CONFIG [F9h]

Bit Number	Purpose	Bit Value	Meaning	Default Value
7:6	Current Share Mode	00	Stand alone	0b00
		10	Droop	
5	Power Good Mode	0	MULTI Pin outputs Power Good signal using the polarity defined with MFR_PGOOD_POLARITY	0
		1	MULTI Pin outputs an open drain Power Good signal	
4	Reserved	0	Reserved	0
3	Reserved	0	Reserved	0
2	Power Good Enable	0	Disabled	1
		1	Enabled	
1	Reserved	0	Reserved	0
0	CTRL Mode	0	PMBus Control	1
		1	Secondary Remote Control	

Note: Changes made to bits[7:6] can only be effective after operating command STORE_USER_ALL[15h] and recycling the input voltage.

Mechanical Information

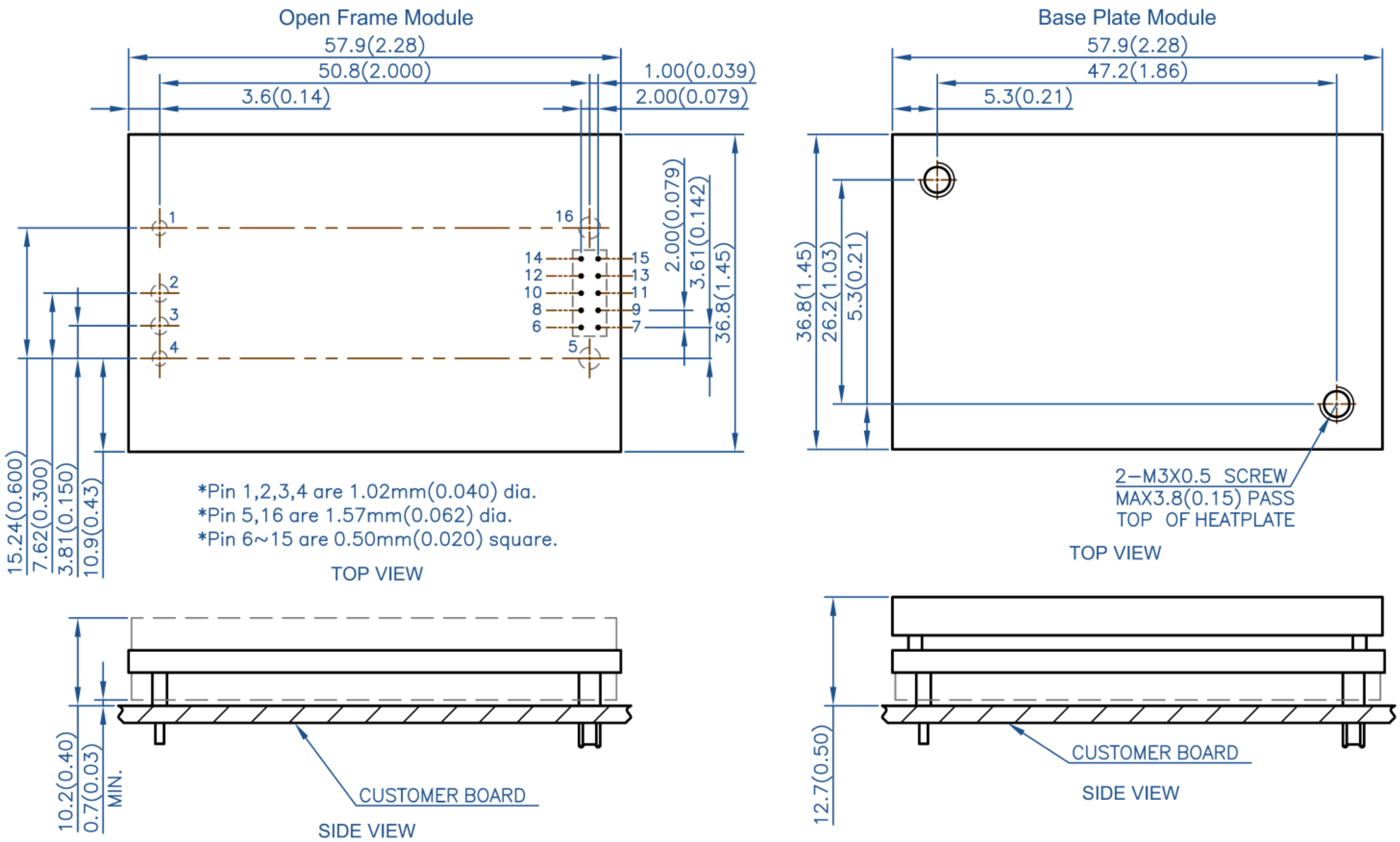

Table 6: Pin assignation

Pin	Name	Function
1	Vin(+)	Positive Input
2	RC	Remote Control
3	GND	Connected to Vin(-)
4	Vin(-)	Negative Input
5	Vout(-)	Negative Output
6	SENSE(+)	Positive Remote Sense
7	SENSE(-)	Negative Remote Sense
8	ADDR0	Address Pin0
9	ADDR1	Address Pin1
10	SCL	PMBus Clock
11	SDA	PMBus Data
12	MULTI	Configurable I/O Pin: Power Good output
13	DGND	PMBus Ground
14	SALERT	PMBus Alert signal
15	CTRL	PMBus Remote Control
16	Vout(+)	Positive Output

Notes

1) All dimensions in mm (inches)
   Tolerances: .x ± .5 (.xx ± 0.02)
   .xx ± .25 (.xxx ± 0.010)
2) Regular input and function pins are 1.02mm (0.040”) dia. with +/- 0.10mm (0.004”) tolerance; the standoff shoulders are 2.00mm (0.078”) dia. with +/- 0.15mm (0.006”) tolerance.
3) Output pins are 1.57 mm (0.062”) dia. with +/- 0.10mm (0.004”) tolerance; the standoff shoulders are 2.46mm (0.097”) dia. with +/- 0.15mm (0.006”) tolerance.
4) All pins are coated with 90%/10% solder, Gold, or Matte Tin finish with Nickel under plating.
5) Weight: 49.5 g open frame converter
6) Workmanship meets or exceeds IPC-A-610 Class II
7) Torque applied on screw should not exceed 6in-lb. (0.7 Nm)
8) Baseplate flatness tolerance is 0.10mm (0.004”) TIR for surface
9) If M3 screws are used to attach a heatsink to the baseplate, the screw length from the top surface of baseplate going down should not exceed 3.8 mm (0.15 in) max .