

### FEATURES

#### Electrical

- ♦ Peak Efficiency up to 97.7% @54Vin
- ♦ PMBus Communication
- ♦ Fully regulated output voltage
- ♦ Fully protected: Input UVLO and OVP. Output OVP, OCP and OTP
- ♦ Remote ON/OFF
- ♦ Monotonic and pre-biased startup
- ♦ No minimum load required
- ♦ Parallel Operation with Direct Output Connection
- ♦ 707Vdc isolation

#### Mechanical

Size:

58.4 x 36.8 x 15.4mm (2.30"x1.45"x0.61")

#### Safety & Reliability

- ♦ IEC/EN/UL/CSA 62368-1, 2<sup>nd</sup> edition
- ♦ IEC/EN/UL/CSA 60950-1, 2<sup>nd</sup> edition+A2
- ♦ ISO 9001, TL 9000, ISO 14001, QS 9000,
- ♦ OHSAS18001 certified manufacturing facility

### SOLDERING METHOD

- ♦ Wave soldering
- ♦ Hand soldering
- ♦ Reflow soldering (MSL rating of 3)

### OPTIONS

- ♦ Negative/Positive Remote on/off
- ♦ Analog/Digital option

### APPLICATIONS

- ♦ Optical Transport
- ♦ Data Networking
- ♦ Communications
- ♦ Servers



Photo is for reference only

Input voltage: 40~60V  
Single output: 12.2V@0A, 11.8V@60A  
Output power: 700W

The Q54SH12060 series, Quarter brick, 40~60V input, single output 11.8V, isolated DC/DC converter is the latest offering from a world leader in power system and technology and manufacturing — Delta Electronics, Inc. This product provides up to 800 watts of power at 40~60V input in an industry standard footprint and pin out. With creative design technology and optimization of component placement, these converters possess outstanding electrical and thermal performances, as well as extremely high reliability under highly stressful operating conditions. The Q54SH12060 offers peak 97.7% high efficiency. The Q54SH12060 is fully protected from abnormal input/output voltage, current, and temperature conditions and meets 707V isolation. And it can be connected in parallel directly for higher power without external oring-fet.

(T<sub>A</sub>=25°C, airflow rate=300 LFM, V<sub>in</sub>=54Vdc, nominal V<sub>out</sub> unless otherwise noted.)

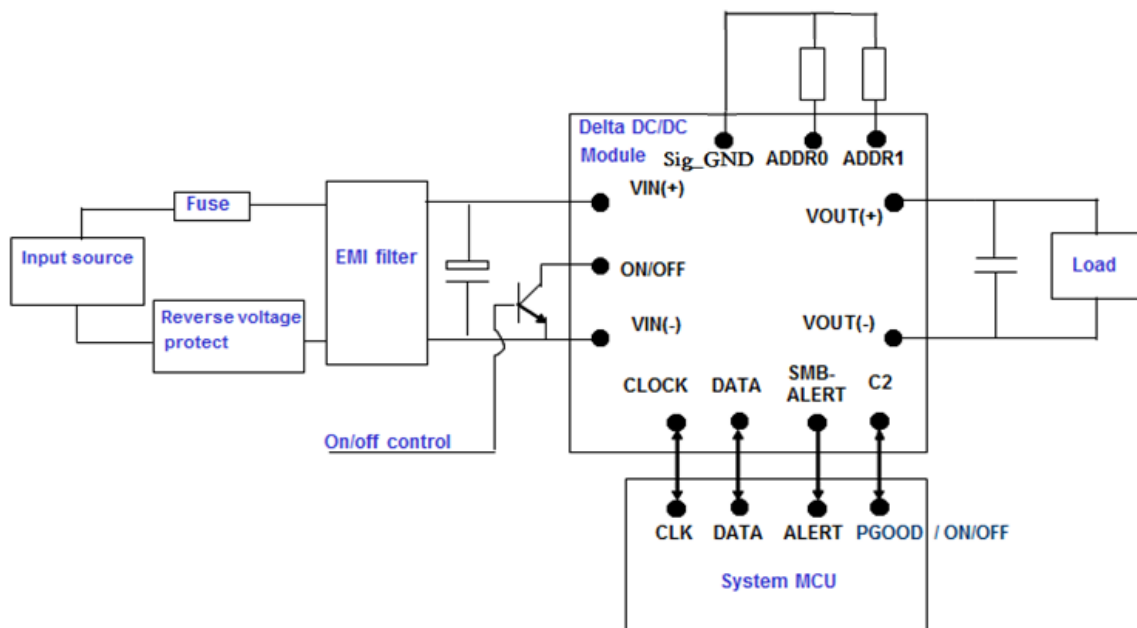
| PARAMETER   | NOTES and CONDITIONS  | Min.  | Typ.  | Max.  | Units |
|---|---|-------|-------|-------|-------|
| <b>ABSOLUTE MAXIMUM RATINGS</b>                     |   |       |       |       |       |
| Input Voltage                                       |   |       |       |       | Vdc   |
| Continuous  |   | 0     |       | 60    | Vdc   |
| Transient   | 10mS  |       |       | 63    | Vdc   |
| Operating Ambient Temperature                       |   | -10   |       | 85    | °C    |
| Storage Temperature                                 |   | -55   |       | 125   | °C    |
| Input/Output Isolation Voltage                      |   |       |       | 707   | Vdc   |
| <b>INPUT CHARACTERISTICS</b>                        |   |       |       |       |       |
| Operating Input Voltage                             |   | 40    | 54    | 60    | Vdc   |
| Input Under-Voltage Lockout                         |   |       |       |       |       |
| Turn-On Voltage Threshold                           |   | 39    |       | 40    | Vdc   |
| Turn-Off Voltage Threshold                          |   | 37    |       | 39    | Vdc   |
| Lockout Hysteresis Voltage                          |   | 1     | 2     |       | Vdc   |
| Input Over-Voltage Protection                       |   |       | 63    |       | Vdc   |
| Maximum Input Current                               | Full Load, 40V <sub>in</sub>  |       |       | 20    | A     |
| No-Load Input Current                               | V <sub>in</sub> =54V, I <sub>o</sub> =0A  |       | 170   |       | mA    |
| Off Converter Input Current                         | V <sub>in</sub> =54V  |       | 15    |       | mA    |
| Inrush Current                                      | the peak current when unit is enabled after V <sub>in</sub> is present                          |       |       | 250   | A     |
| Internal Input Ripple Current                       | P-P thru 12μH inductor, 5Hz to 20MHz  |       | 100   |       | mArms |
| <b>OUTPUT CHARACTERISTICS</b>                       |   |       |       |       |       |
| Output Voltage Set Point                            | V <sub>in</sub> =54V, I <sub>o</sub> =Open Load, T <sub>c</sub> =25°C                           | 12.16 | 12.20 | 12.24 | Vdc   |
|   | V <sub>in</sub> =54V, I <sub>o</sub> =Full Load, T <sub>c</sub> =25°C                           | 11.76 | 11.80 | 11.84 | Vdc   |
| Output Regulation                                   |   |       |       |       |       |
| Load Regulation                                     | V <sub>in</sub> =54V, I <sub>o</sub> =I <sub>o</sub> min to I <sub>o</sub> max                  |       | 400   |       | mV    |
| Line Regulation                                     | V <sub>in</sub> =40V to 60V, I <sub>o</sub> =0  | -30   |       | 30    | mV    |
| Temperature Regulation                              | T <sub>a</sub> =-20°C to 85°C   | -40   |       | 40    | mV    |
| Total Output Voltage Range                          | Over sample load, line and temperature  | 11.64 |       | 12.36 | V     |
| Current Sharing Accuracy                            | Droop current sharing mode, 50A load, V <sub>in</sub> =54V, T <sub>a</sub> =25°C                |       |       | 10    | %     |
| Output Voltage Ripple and Noise                     | 5Hz to 20MHz bandwidth  |       |       |       |       |
| Peak-to-Peak  | Full Load, Co=1100uF(100uF ceramic ,1000uF Oscon )+ 10μF tantalum                               |       |       | 150   | mV    |
| RMS   | Full Load, Co=1100uF(100uF ceramic ,1000uF Oscon )+ 10μF tantalum                               |       |       | 100   | mV    |
| Operating Output Current Range (Stable)             | V <sub>in</sub> =40V to 60V   | 0     |       | 60    | A     |
| Output Over Current Protection(hiccup mode)         | when V <sub>o</sub> <10%V <sub>o,nom</sub>  | 70    | 75    | 80    | A     |
| <b>DYNAMIC CHARACTERISTICS</b>                      |   |       |       |       |       |
| Output Voltage Current Transient                    | Co=1000uF Oscon cap, 100μF Ceramic load cap   |       |       |       |       |
| 25% load step Change in Output Current              | 50% I <sub>o,max</sub> to 75% I <sub>o,max</sub> ; 2A/μs  | 11.50 |       | 12.35 | V     |
| 70% load step Change in Output Current              | 18A to 60A; 10A/μs  | 11.40 |       | 12.45 | V     |
| Settling Time (within 1% nominal V <sub>out</sub> ) |   |       |       | 200   | μs    |
| Turn-On Delay and Rise Time                         |   |       |       |       |       |
| Start-Up Delay Time From Input Voltage              | On/Off=On, from V <sub>in</sub> =Turn-on Threshold to V <sub>o</sub> =10% V <sub>o,nom</sub>    | 30    | 40    | 50    | mS    |
| Start-Up Delay Time From On/Off Control             | V <sub>in</sub> =V <sub>in,nom</sub> , from On/Off=On to V <sub>o</sub> =10% V <sub>o,nom</sub> | 0     | 3     | 5     | mS    |
| Output Voltage Rise Time                            | V <sub>o</sub> =10% to 90% V <sub>o,nom</sub>   | 15    | 20    | 25    | mS    |
| Output Capacitance Range                            | 100uF ceramic, others are Oscon or AL   | 1100  |       | 10000 | μF    |
| <b>EFFICIENCY</b>                                   |   |       |       |       |       |
| Peak Efficiency                                     | 75% Load, 54V <sub>in</sub>   |       | 97.7  |       | %     |
| Full Load Efficiency                                | 100% Load, 54V <sub>in</sub>  |       | 97.5  |       | %     |
| <b>ISOLATION CHARACTERISTICS</b>                    |   |       |       |       |       |
| Input to Output                                     |   |       |       | 707   | Vdc   |
| Isolation Capacitance                               |   |       | 80    |       | nF    |
| <b>FEATURE CHARACTERISTICS</b>                      |   |       |       |       |       |
| Switching Frequency                                 | V <sub>in</sub> =40~60V   | 300   |       | 800   | KHz   |
| On/Off Control, Negative Remote On/Off logic        |   |       |       |       |       |
| Logic Low (Module On)                               | V <sub>on/off</sub>   |       |       | 0.8   | V     |
| Logic High (Module Off)                             | V <sub>on/off</sub>   | 2.4   |       | 20    | V     |
| ON/OFF Current                                      | I <sub>on/off</sub> at V <sub>on/off</sub> =0.0V  |       |       | 0.2   | mA    |
| Leakage Current                                     | Logic High, V <sub>on/off</sub> =15V  | 10    |       | 500   | uA    |

| PARAMETER  | NOTES and CONDITIONS   | Min. | Typ. | Max. | Units              |
|--|--|------|------|------|--------------------|
| <b>GENERAL SPECIFICATIONS</b>  |  |      |      |      |                    |
| MTBF   | $I_o=80\%$ of $I_{o,max}$ ; $T_a=25^{\circ}\text{C}$   | 2    |      |      | Mhours             |
| Weight   | With Base-plate  |      | 90   |      | grams              |
| Over-Temperature Shutdown<br>(With Base-plate)   | Refer to Figure 16 for Hot spot 1 location<br>( $54V_{in}$ , $80\%$ $I_o$ , 200LFM, Airflow from $V_{in+}$ to $V_{in-}$ )  |      | 128  |      | $^{\circ}\text{C}$ |
| Over-Temperature Shutdown<br>(With 0.5" Height Transverse Heat Sink QTL050A)   | Refer to Figure 18 for Hot spot 2 location<br>( $54V_{in}$ , $80\%$ $I_o$ , 200LFM, Airflow from $V_{in+}$ to $V_{in-}$ )  |      | 128  |      | $^{\circ}\text{C}$ |
| Over-Temperature Shutdown<br>(With 0.5" Height Longitudinal Heat Sink QLL050A)   | Refer to Figure 20 for Hot spot 3 location<br>( $54V_{in}$ , $80\%$ $I_o$ , 200LFM, Airflow from $V_{out}$ to $V_{in}$ )   |      | 128  |      | $^{\circ}\text{C}$ |
| Over-Temperature Shutdown (NTC Resistor)   |  |      | 130  |      | $^{\circ}\text{C}$ |
| Note: Please attach thermocouple on NTC resistor to test OTP function, the hot spots' temperature is just for reference. |  |      |      |      |                    |
| <b>PMBUS SIGNAL INTERFACE CHARACTERISTICS</b>  |  |      |      |      |                    |
| Logic Input Low ( $V_{IL}$ )   | Data, SMBAlert, Clock pin  | 0    |      | 0.8  | V                  |
| Logic Input High ( $V_{IH}$ )  | Data, SMBAlert, Clock pin  | 2.4  |      | 3.6  | V                  |
| Logic Output Low ( $V_{OL}$ )  | Data, SMBAlert, Clock pin; $I_{OL}=4\text{mA}$   |      |      | 0.4  | V                  |
| Logic Output High ( $V_{OH}$ )   | Data, SMBAlert, Clock pin; $I_{OH}=-4\text{mA}$  | 2.5  |      |      | V                  |
| PMBus Operating Frequency Range  |  | 100  | 100  | 400  | KHz                |
| <b>PMBUS MONITORING CHARACTERISTICS</b>  |  |      |      |      |                    |
| Output Current Reading Accuracy  | $V_{in}=54\text{V}$ , $I_o=50\% \sim 100\%$ of $I_{o,max}$ ;<br>$V_{in}=54\text{V}$ , $I_o=5\% \sim 50\%$ of $I_{o,max}$ ; | -5   |      | +5   | %                  |
| Output Voltage Reading Accuracy  |  | -3   |      | +3   | A                  |
| Input Voltage Reading Accuracy   |  | -2   |      | +2   | %                  |
| Temperature Reading Accuracy   |  | -4   |      | +4   | %                  |
|  |  | -5   |      | +5   | $^{\circ}\text{C}$ |

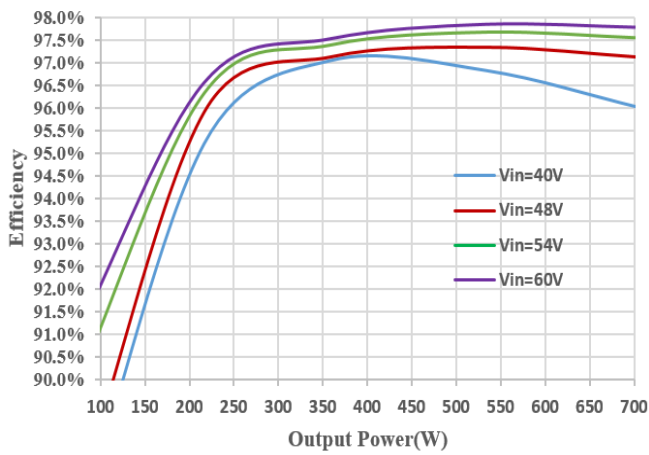
## PIN DEFINATION

| Pin# | Name    | Function   | Pin# | Name     | Function  |
|------|---------|--|------|----------|---|
| 1    | VIN(+)  |  | 7    | Sig_GND  | Signal ground                                       |
| 2    | ON/OFF  | Primary on/off control pin   | 8    | Data     | PMBus data line                                     |
| 3    | VIN(-)  |  | 9    | SMBAlert | PMBus SMBAlert line                                 |
| 4    | VOUT(-) |  | 10   | Clock    | PMBus clock line                                    |
| 5    | VOUT(+) |  | 11   | Addr1    | ADDR1 pin sets the high order digit of the address. |
| 6    | C2      | PGOOD pin, and this pin also could be configured as secondary on/off control pin | 12   | Addr0    | ADDR0 pin sets the low order digit of the address.  |

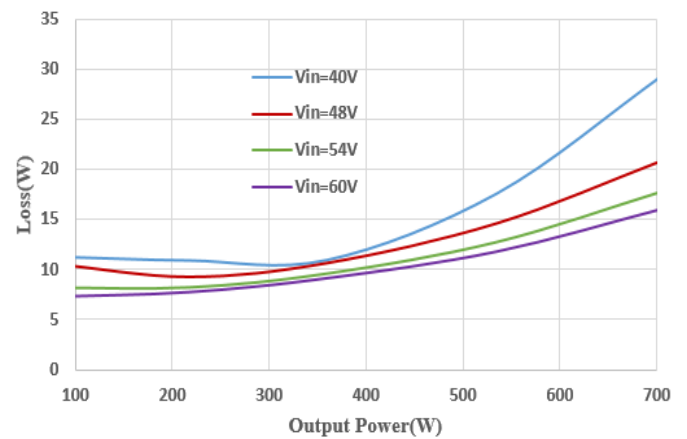
## SIMPLIFIED APPLICATION CIRCUIT



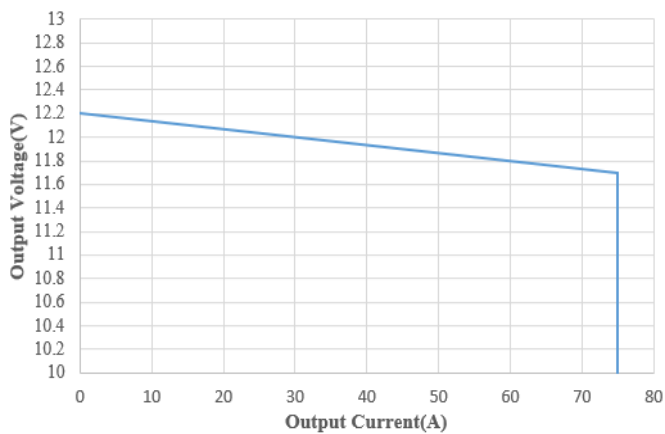
$T_A=25^{\circ}\text{C}$



**Figure 1: Efficiency vs. Output Power**

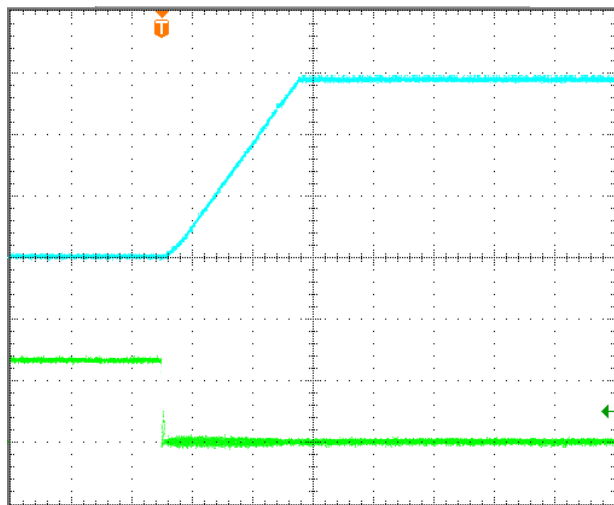


**Figure 2: Loss vs. Output Power**



**Figure 3: Output Voltage vs. Output Current** showing typical current limit curves and converter shutdown points.  $V_{in}=54\text{V}$

$T_A=25^{\circ}\text{C}$ ,



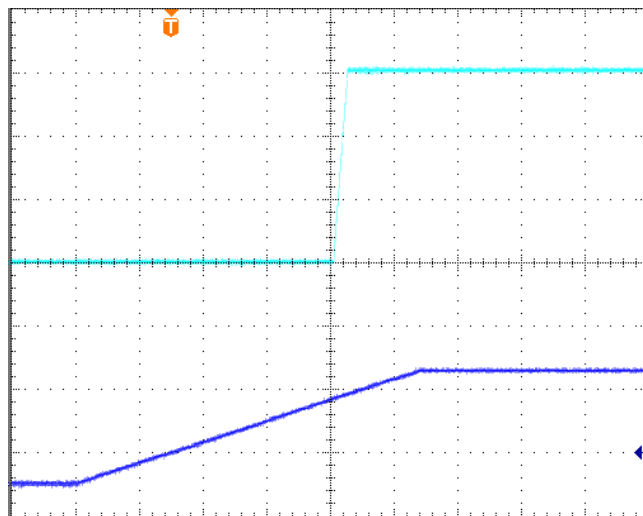
**Figure 4: Remote On/Off (negative logic) at full load**

$V_{in}=54\text{V}$ ,  $I_{out} = I_{o, \max}$

Time: 10ms/div.

$V_{out}$  (top trace): 4V/div;

$V_{\text{remote On/Off signal}}$  (bottom trace): 2V/div.



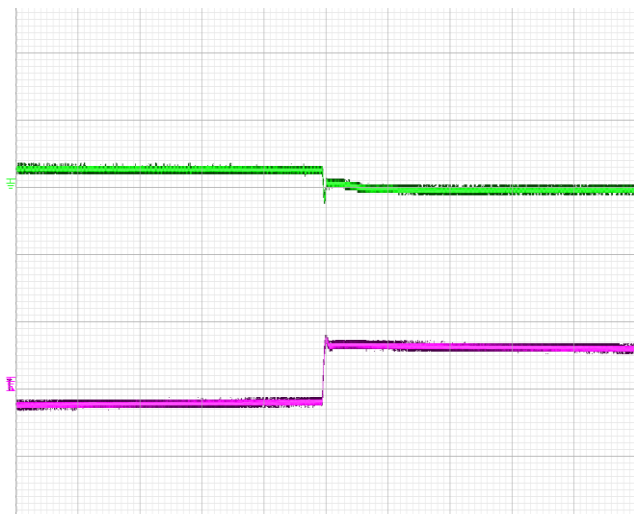
**Figure 5: Input Voltage Start-up at full load**

$V_{in}=54\text{V}$ ,  $I_{out} = I_{o, \max}$

Time: 100ms/div.

$V_{out}$  (top trace): 4V/div;

$V_{in}$  (bottom trace): 30V/div.



**Figure 6: Transient Response**

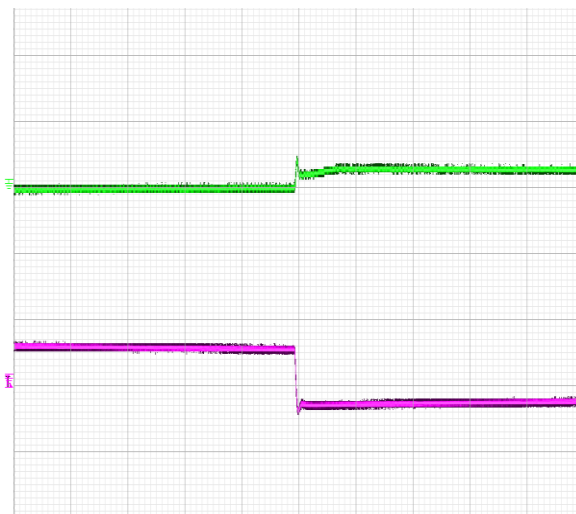
( $V_{in}=54\text{V}$ , 2A/μs step change in load from 50% to 75% of  $I_{o, \max}$ )

$V_{out}$  (top trace): 0.5 V/div, 500us/div;

$I_{out}$  (bottom trace): 20A/div.

Load cap: 10uF/16V/X7R/1206\*10pcs ceramic cap + 100uF/16V\*10pcs Oscon cap

Scope measurement should be made using a BNC cable (length shorter than 20 inches). Position the load between 51 mm to 76 mm (2 inches to 3 inches) from the module



**Figure 7: Transient Response**

( $V_{in}=54\text{V}$ , 2A/μs step change in load from 75% to 50% of  $I_{o, \max}$ )

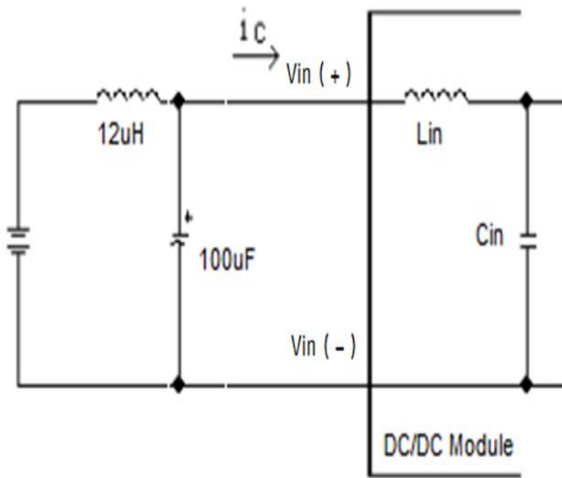
$V_{out}$  (top trace): 0.5 V/div, 500us/div;

$I_{out}$  (bottom trace): 20A/div.

Load cap: 10uF/16V/X7R/1206\*10pcs ceramic cap + 100uF/16V\*10pcs Oscon cap

Scope measurement should be made using a BNC cable (length shorter than 20 inches). Position the load between 51 mm to 76 mm (2 inches to 3 inches) from the module

$T_A=25^{\circ}\text{C}$ ,  $V_{in}=54\text{Vdc}$

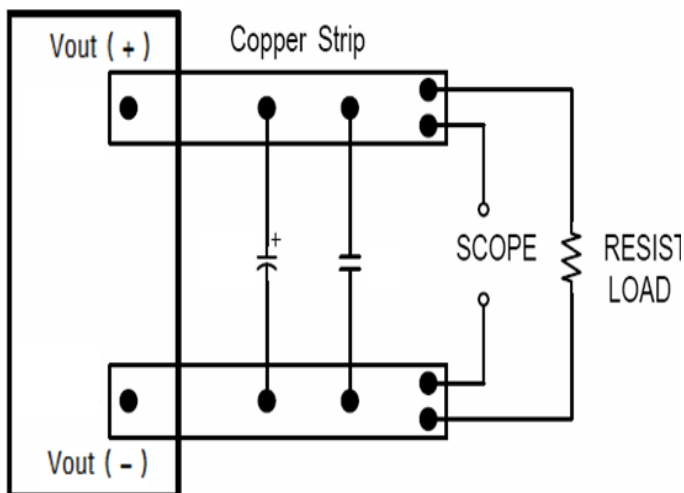


**Figure 8: Test Setup Diagram for Input Ripple Current**

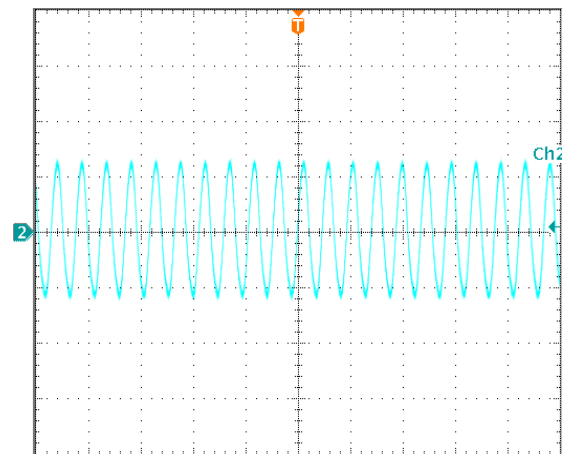
Note: Measured input reflected-ripple current with a simulated source Inductance of  $12\mu\text{H}$ . Measure current as shown above.



**Figure 9: Input Terminal Ripple Current,  $i_c$ , at max output current and nominal input voltage with  $12\mu\text{H}$  source impedance and  $100\mu\text{F}$  electrolytic capacitor (200 mA/div, 5us/div).**



**Figure 10: Test Setup for Output Voltage Noise and Ripple**



**Figure 11: Output Voltage Ripple and Noise at nominal input voltage and max load current (20 mV/div, 2us/div)  
Load cap:  $1100\mu\text{F}$ , ( $1000\mu\text{F}$  Oscon,  $100\mu\text{F}$  ceramic).  
Bandwidth: 20MHz.**

## Input Source Impedance

The impedance of the input source connecting to the DC/DC power modules will interact with the modules and affect the stability. A low ac-impedance input source is recommended. A low ESR electrolytic capacitor higher than 100 $\mu$ F (ESR < 0.7 $\Omega$  at 100kHz) is suggested.

## Layout and EMC Considerations

Delta's DC/DC power modules are designed to operate in a wide variety of systems and applications. For design assistance with EMC compliance and related PWB layout issues, please contact Delta's technical support team..

### Schematic and Components List

Cin is 100 $\mu$ F low ESR Aluminum cap $\times$ 3pcs in parallel;  
CX1 is 2.2 $\mu$ F ceramic cap $\times$ 2pcs in parallel;  
CY1 and CY2 are 33nF ceramic cap;  
CX2 is NC;  
CY is 66nF;  
L1 is 0.32mH;  
L2 is 0.32mH;

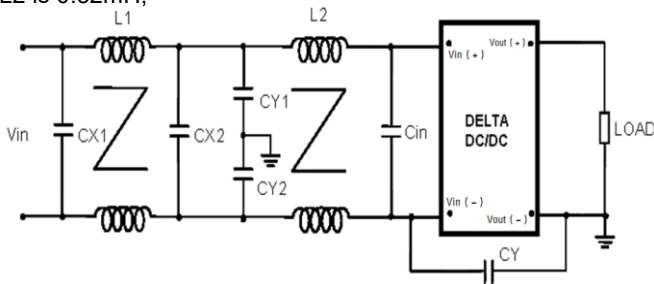


Figure 12-1: Recommended Input Filter

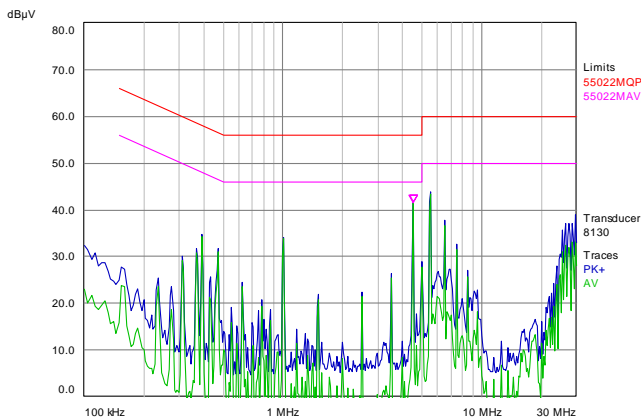


Figure 12-2: Test Result of EMC( $V_{in}=54V$ ,  $I_o=60A$ ).

## Safety Considerations

The power module must be installed in compliance with the spacing and separation requirements of the end-user's safety agency standard, i.e. IEC 62368-1: 2014 (2nd edition), EN 62368-1: 2014 (2nd edition), UL 62368-1, 2nd Edition, 2014-12-01 and CSA C22.2 No. 62368-1-14, 2nd Edition, 2014-12. UL60950-1, CSA C22.2 NO. 60950-1 2nd, IEC 60950-1 2nd: 2005, EN 60950-1 2nd: 2006+A11+A1: 2010, if the system in which the power module is to be used must meet safety agency requirements.

Both the input and output of this product meet SELV requirement. This module has function insulation with 707Vdc isolation

This power module is not internally fused. To achieve optimum safety and system protection, an input line fuse is highly recommended. The safety agencies require a normal-blow fuse with 50A maximum rating to be installed in the ungrounded lead. A lower rated fuse can be used based on the maximum inrush transient energy and maximum input current.

## Soldering and Cleaning Considerations

Post solder cleaning is usually the final board assembly process before the board or system undergoes electrical testing. Inadequate cleaning and/or drying may lower the reliability of a power module and severely affect the finished circuit board assembly test. Adequate cleaning and/or drying is especially important for un-encapsulated and/or open frame type power modules. For assistance on appropriate soldering and cleaning procedures, please contact Delta's technical support team.

## Remote On/Off

The remote on/off feature on the module is negative logic. Negative logic turns the module on during a logic low and off during a logic high.

Remote on/off can be controlled by an external switch between the on/off terminal and the Vin (-) terminal. The switch can be an open collector or open drain.

For negative logic if the remote on/off feature is not used, please short the on/off pin to Vin (-).

The DC level on/off signal is suggested.

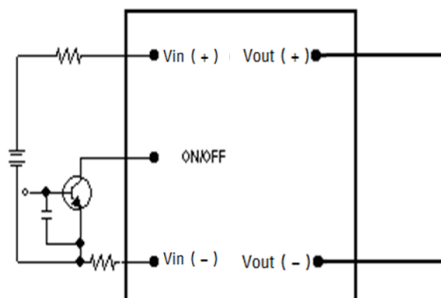


Figure 13: Remote On/Off Implementation

## Over-Current Protection

The modules include an internal output over-current protection circuit, which will endure current limiting for an unlimited duration during output overload. If the output current exceeds the OCP set point, the modules will shut down (hiccup mode).

The modules will try to restart after shutdown. If the overload condition still exists, the module will shut down again. This restart trial will continue until the overload condition is corrected.



## Over-Voltage Protection

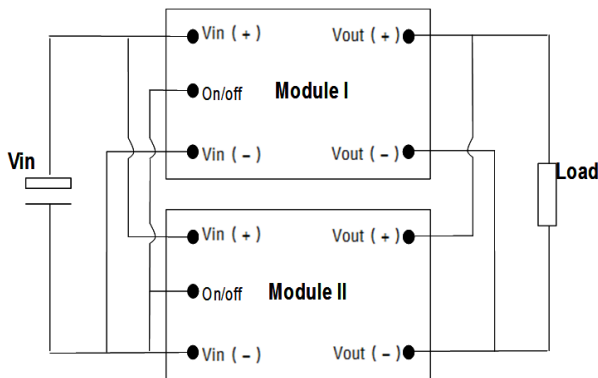
The modules include an internal input over-voltage protection circuit, which monitors the voltage on the input terminals. If this voltage exceeds the over-voltage set point, the protection circuit will shut down, and then restart with a time delay after the fault no longer exists.

## Over-Temperature Protection

The over-temperature protection consists of circuitry that provides protection from thermal damage. If the temperature exceeds the over-temperature threshold, the module will shut down. The module will restart after the temperature is within specification.

## Parallel and Droop Current Sharing

The modules are capable of operating in parallel, and realizing current sharing by droop current sharing method. There is about 400mV output voltage droop from 0A to full output Load, and there is no current sharing pin. By connecting the Vin pin and the Vo pin of the parallel module together, the current sharing can be realized automatically.



**Figure 14:** Parallel and droop current sharing configuration for no redundancy requirement system

If the system has no redundancy requirement, the module can be connected in parallel directly for higher power without adding external oring-fet; whereas, if the redundancy function is required, the external oring-fet should be added.

For a normal parallel operation, the following precautions must be observed:

1. The current sharing accuracy equation is:  

$$X\% = \frac{|I_{o1} - I_{o2}|}{I_{rated}}$$
Where,  
 $I_{o1}$  is the output current of module1;  
 $I_{o2}$  is the output current of module2  
 $I_{rated}$  is the rated full load current of per module.
2. To ensure a better steady current sharing accuracy, below design guideline should be followed:
  - a) The inputs of the converters must be connected to the same voltage source; and the PCB trace resistance from Input voltage source to Vin+ and Vin- of each converter should be equalized as much as possible.
  - b) The PCB trace resistance from each converter's output to the load should be equalized as much as possible.

c) For accurate current sharing accuracy test, the module should be soldered in order to avoid the unbalance of the touch resistance between the modules to the test board.

3. To ensure the parallel module can start up monotonically without triggering the OCP circuit, below design guideline should be followed:

a) Before all the parallel modules finished start up, the total load current should be lower than the rated current of 1 module.

b) The ON/OFF pin of the converters should be connected together to keep the parallel modules start up at the same time.

c) The under voltage lockout point will slightly vary from unit to unit. The dv/dt of the rising edge of the input source voltage must be greater than 1V/ms to ensure that the parallel module start up at the same time.

## Configurable Control Pins

The module contains one configurable control pins C2, referenced to the module secondary SIG\_GND. See Mechanical Views for pin locations. The following table lists the default factory configurations for the functions assigned to the pin.

| Pin Designation/Function | Configuration       |
|--------------------------|---------------------|
| C2                       |                     |
| Power Good               | Factory Default     |
| On/Off                   | Optional Vias PMBUS |

Note1: Power Good is an Open-drain output.

Note2: On/Off is an Open-drain input



## DIGITAL FEATURE DESCRIPTIONS

The module has a digital PMBus interface to allow the module to be monitored, controlled and configured by the system. The module supports 4 PMBus signal lines, Data, Clock, SMBALERT (optional), Control (C2 pin, optional), and 2 Address line Addr0 and Addr1. More detail PMBus information can be found in the PMB Power Management Protocol Specification, Part I and part II, revision 1.2; which is shown in <http://pmbus.org>. 100kHz to 400kHz bus speeds are supported by the module. Connection for the PMBus interface should be following the High Power DC specifications given in section 3.1.3 in the SMBus specification V2.0 or the Low Power DC specifications in section 3.1.2. The complete SMBus specification is shown in <http://smbus.org>.

Note: If a series of commands consecutively sending to this module more than 30ms time, the bus free time between stop and start condition (TBUF) that defined in SMBUS AC specifications should not be all less than 200us in these commands.

The module supports the Packet Error Checking (PEC) protocol. It can check the PEC byte provided by the PMBus master, and include a PEC byte in all message responses to the master.

SMBALERT protocol is also supported by the module. SMBALERT line is also a wired-AND signal; by which the module can alert the PMBUS master via pulling the SMBALERT pin to an active low. There are only one way that the master and the module response to the alert of SMBALERT line.

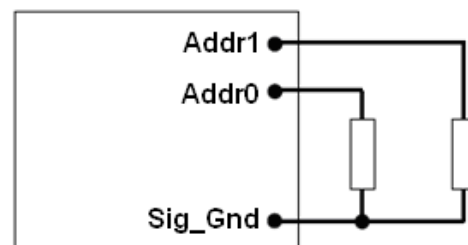
This way is for the module used in a system that does not support Alert Response Address (ARA). The module is to retain its resistor programmed address, when it is in an ALERT active condition. The master will communicate with the slave module using the programmed address, and using the various READ\_STATUS commands to find who cause for the SMBALERT. The CLEAR\_FAULTS command will clear the SMBALERT.

The module contains a data flash used to store configuration settings, which will not be programmed into the device data flash automatically. The STORE\_DEFAULT\_ALL command must be used to commit the current settings are transfer from RAM to data flash as device defaults.

### PMBUS Addressing

The Module has flexible PMBUS addressing capability. When connect different resistor from Addr0 and Addr1 pin to Sig\_GND pin, 64 possible 7bits addresses can be acquired. The address is in the form of octal digits; Each pin offers one octal digit, and then combine together as decimal format to form the decimal address as shown in below.

$$\text{Address} = 8 * \text{ADDR1} + \text{ADDR0}$$



Corresponded to each octal digit, the requested resistor values are shown in below, and +/-1% resistors accuracy can be accepted. If there are any resistances exceeding the requested range, address 126 will be return. 0-12 and 40, 44, 45, and 55 in decimal address can't be used, since they are reserved according to the SMBus specifications, and which will also return address 126.

Address 127 (or 0x7F) is reserved address by PMBUS. The built-in digital PWM controller uses this address for Factory test purposes, and will ack this address. Application should not use this address either.

| Octal digit | Resistor(Kohm) |
|-------------|----------------|
| 0           | 10             |
| 1           | 15.4           |
| 2           | 23.7           |
| 3           | 36.5           |
| 4           | 54.9           |
| 5           | 84.5           |
| 6           | 130            |
| 7           | 200            |

## Black Box Function

There is a black box function realized by the page 44~63 of D-flash, which has 20K erase cycles up to 120C hotspot temp. Page 44~63, total 20 pages and 32 bytes per page, are assigned to record 20 history events. These 20 history events are recorded circularly, so the oldest event will be overwritten by new event if more than 20 events are recorded. Any shutdown events including the ENABLE ONOFF will trigger the black box to record data. The black box will stop recording data if the past 4 shutdown reason is the same. The black box will re-enable record function until it finds the past 4 shutdown reason is different. Every page has the same record content, which is shown as below:

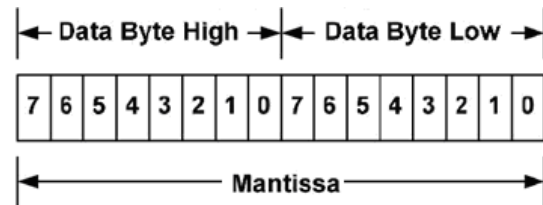
| Byte    | Content  |
|---------|--|
| 1 ~ 8   | <b>For Delta internal checking</b>                         |
| 9 ~ 11  | Run_Time from turn on to off                               |
| 12      | <b>For Delta internal checking</b>                         |
| 13 ~ 14 | Module's temperature when off.                             |
| 15 ~ 16 | STATUS_WORD  |
| 17 ~ 18 | Input voltage in PMBUS linear format, when module is off.  |
| 19 ~ 20 | <b>For Delta internal checking</b>                         |
| 21 ~ 22 | Output current in PMBUS linear format, when module is off. |
| 23 ~ 32 | <b>For Delta internal checking</b>                         |

For the Run\_Time from Byte 8 to Byte 10, it records the total module run time from starting output power to module is off. After extracting Run\_Time data, user should translate the Run\_Time data to the actual run time, as below:  
 If the Run\_Time data < 65535, then the actual run time = (Run\_Time) / 10000;  
 If the Run\_Time data >= 65535, then the actual run time = (Run\_Time - 65535) + 6.5535;  
 The unit of the calculation result is second.  
 The upper limit is (0x0FFFFFFE - 65535) + 6.5535 seconds.  
 It's about 193 days. After reaching the upper limit, it will stay at the upper limit, not reset to 0.

## PMBus Data Format

The module receives and report date in LINEAR format. The Exponent of the data words is fixed at a reasonable value for the command; altering the exponent is not supported. DIRECT format is not supported by the module.

For commands that set or report any voltage thresholds related to the output voltage, the module supports the linear data format consisting of a two byte value with a 16-bit, unsigned mantissa, and a fixed exponent of -12. The format of the two data bytes is shown below:



The equation can be written as:

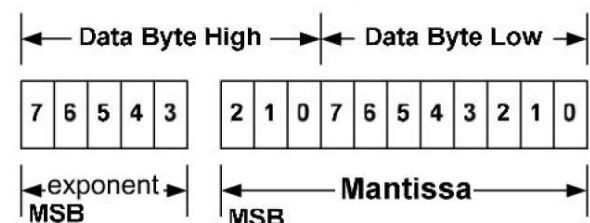
$$V_{out} = \text{Mantissa} \times 2^{(-12)}$$

For example, considering set  $V_{out}$  to 12V by VOUT\_COMMAND, the read/write data can be calculated refer to below process:

$$\text{Mantissa} = V_{out} / 2^{(-12)} = 12 / 2^{(-12)} = 49152;$$

Converter the calculated Mantissa to hexadecimal 0xC000.

For commands that set or report all other thresholds, including input voltages, output current, temperature, time and frequency, the supported linear data format is a two byte value with: an 11 bit, two's complement mantissa, and a 5 bit, two's complement exponent (scaling factor). The format of the two data bytes is shown as in below.



The equation can be written as:

$$\text{Value} = \text{Mantissa} \times 2^{(\text{exponent})}$$

For example, considering set the turn on threshold of input under voltage lockout to 34V by VIN\_ON command; the read/write data can be calculated refer to below process:

Get the exponent of Vin, -3; whose binary is 11101

$$\text{Mantissa} = V_{in} / 2^{(-3)} = 34 / 2^{(-3)} = 272;$$

Converter the calculated Mantissa to hexadecimal 110, then converter to binary 00100010000; Combine the exponent and the mantissa, 11101 and 00100010000; Converter binary 1110100100010000 to hexadecimal E910.

## SUPPORTED PMBUS COMMANDS

The main PMBus commands described in the PMBus 1.2 specification are supported by the module. Partial PMBus commands are fully supported; Partial PMBus commands have difference with the definition in PMBus 1.2 specification. All the supported PMBus commands are detail summarized in below table

| Command             | Command Code | Command description  | Transfer type | Compatible with standard PMBUS or not? | Data Format      | Default value | Range limit | Data units | Exponent | Note   |
|---------------------|--------------|--|---------------|--|------------------|---------------|-------------|------------|----------|--|
| OPERATION           | 0x01         | Turn the module on or off by PMBUS command                         | R/W byte      | Refer to below description;            | Bit field        | 0x80          | /           | /          | /        | /  |
| ON_OFF_CONFIG       | 0x02         | Configures the combination of primary on/off pin and PMBUS command | R/W byte      | Yes                                    | Bit field        | 0x1D          | /           | /          | /        | 0x1D (Neg Logic);<br>0x1F (Pos Logic);   |
| CLEAR_FAULTS        | 0x03         | Clear any fault bits that have been set                            | Send byte     | Yes                                    | /                | /             | /           | /          | /        | /  |
| WRITE_PROTECT       | 0x10         | Control writing to the PMBUS device.                               | R/W byte      | Yes                                    | /                | 0x80          | /           | /          | /        | The intent of this command is to provide protection against accidental changes.  |
| STORE_DEFAULT_ALL   | 0x11         | Stores operating parameters from RAM to data flash                 | Send byte     | Yes                                    | /                | /             | /           | /          | /        | The FLASH must be unlocked (referring to Command 0xEC) before sending this command. This command is effective to the parameter of all command in the table except 0xEC |
| RESTORE_DEFAULT_ALL | 0x12         | Restores operating parameters from data flash to RAM               | Send byte     | Yes                                    | /                | /             | /           | /          | /        | This command can't be issued when the power unit is running.   |
| CAPABILITY          | 0x19         | provides some key information of a PMBus device                    | Read Byte     | Yes                                    | /                | 0xB0          | /           | /          | /        |  |
| VOUT_MODE           | 0x20         | Read Vo data format  | Read byte     | Yes                                    | mode+exp         | 0x14          | /           | /          | /        | /  |
| VOUT_COMMAND        | 0x21         | Read the output voltage  | Read word     | Yes                                    | Vout Linear      | 12.2          | /           | Volts      | -12      | /  |
| FREQUENCY_SWITCH    | 0x95         | Read the switching frequency                                       | Read word     | Yes                                    | Frequency linear | NA            |             | KHz        | 1        | /  |
| VIN_ON              | 0x35         | Read the turn on voltage threshold of Vin under voltage lockout    | R/W word      | Yes                                    | Vin Linear       | 39.4          | 39~40       | V          | -3       | VIN_ON should be higher than VIN_OFF, and keep 2V hysteresis.  |
| VIN_OFF             | 0x36         | Read the turn off voltage threshold of Vin under voltage lockout   | R/W word      | Yes                                    | Vin Linear       | 37.8          | 37~39       | V          | -3       | VIN_ON should be higher than VIN_OFF, and keep 2V hysteresis.  |
| VOUT_OV_FAULT_LIMIT | 0x40         | Set the output overvoltage fault threshold.                        | R/W word      | Yes                                    | Vout Linear      | 13.5          | /           | V          | -12      | Must be higher than the value of VOUT_COMMAND and VOUT_OV_WARN_LIMIT;  |
| VOUT_OV_WARN_LIMIT  | 0x42         | Set a threshold causing an output voltage high warning.            | R/W word      | Yes                                    | Vout Linear      | 12.5          | 12~13       | V          | -12      | Must be the same or less than VOUT_OV_FAULT_LIMIT value  |
| IOUT_OC_FAULT_LIMIT | 0x46         | Set the output overcurrent fault threshold.                        | R/W word      | Yes                                    | Iout Linear      | 75            | 70~80       | A          | -3       | Must be greater than IOUT_OC_WARN_LIMIT value  |
| IOUT_OC_WARN_LIMIT  | 0x4A         | Set a threshold causing an output current high warning.            | R/W word      | Yes                                    | Iout Linear      | 70            | 65~75       | A          | -3       | Must be less than IOUT_OC_FAULT_LIMIT value  |
| OT_FAULT_LIMIT      | 0x4F         | Set the over temperature fault threshold.                          | R/W word      | Yes                                    | TEMP Linear      | 130           | 125~135     | Deg.C      | -2       | Must be greater than OT_WARN_LIMIT value   |

| Command                   | Com<br>mand<br>Code | Command description   | Transfer<br>type | Compatible<br>with standard<br>PMBUS or<br>not? | Data<br>Format      | Default<br>value  | Range<br>limit | Data<br>units | Exponent | Note   |
|---------------------------|---------------------|---|------------------|---|---------------------|-------------------|----------------|---------------|----------|--|
| OT_WARN_LIMIT             | 0x51                | Set a threshold causing a temperature high warning.   | R/W word         | Yes   | TEMP<br>Linear      | 100               | 80~120         | Deg.C         | -2       | Must be less than OT_FAULT_LIMIT value           |
| VIN_OV_FAULT_LIMIT        | 0x55                | Set the input overvoltage fault threshold.  | Read word        | Yes   | Vin<br>Linear       | 62                |                | V             | -3       | /  |
| POWER_GOOD_ON             | 0x5E                | Sets the output voltage at which the bit 3 of STATUS_WORD high byte should be asserted.         | Read word        | Yes   | Vout<br>Linear      | 11.4              |                | V             | -12      | Must be greater than POWER_GOOD_OFF value        |
| POWER_GOOD_OFF            | 0x5F                | Sets the output voltage at which the bit 3 of STATUS_WORD high byte should be negated.          | Read word        | Yes   | Vout<br>Linear      | 11.2              |                | V             | -12      | Must be less than POWER_GOOD_ON value            |
| TON_DELAY                 | 0x60                | Sets the time from input voltage condition is received until the output voltage starts to rise  | R/W word         | Yes   | Time<br>Linear      | 39                | 35~500         | ms            | -1       |  |
| TON_RISE                  | 0x61                | Sets the time from the output starts to rise until the voltage has entered the regulation band. | R/W word         | Yes   | Time<br>Linear      | 22                | 15~25          | ms            | -1       | /  |
| STATUS_WORD               | 0x79                | Returns the information with a summary of the module's fault/warning                            | Read word        | Refer to below description;                     | Bit field           | /                 | /              | /             | /        | /  |
| STATUS_VOUT               | 0x7A                | Returns the information of the module's output voltage related fault/warning                    | Read byte        | Refer to below description;                     | Bit field           | /                 | /              | /             | /        | /  |
| STATUS_IOUT               | 0x7B                | Returns the information of the module's output current related fault/warning                    | Read byte        | Refer to below description;                     | Bit field           | /                 | /              | /             | /        | /  |
| STATUS_INPUT              | 0x7C                | Returns the information of the module's input over voltage and under voltage fault              | Read byte        | Refer to below description;                     | Bit field           | /                 | /              | /             | /        | /  |
| STATUS_TEMPERATURE        | 0x7D                | Returns the information of the module's temperature related fault/warning                       | Read byte        | Refer to below description;                     | Bit field           | /                 | /              | /             | /        | /  |
| STATUS_CML                | 0x7E                | Returns the information of the module's communication related faults.                           | Read byte        | Refer to below description;                     | Bit field           | /                 | /              | /             | /        | /  |
| READ_VIN                  | 0x88                | Returns the input voltage of the module   | Read word        | Yes   | Vin<br>Linear       | /                 | /              | V             | -3       | /  |
| READ_VOUT                 | 0x8B                | Returns the output voltage of the module  | Read word        | Yes   | Vout<br>Linear      | /                 | /              | V             | -12      | /  |
| READ_IOUT                 | 0x8C                | Returns the output current of the module  | Read word        | Yes   | Iout<br>Linear      | /                 | /              | A             | -3       | /  |
| READ_TEMPERATURE_1        | 0x8D                | Returns the module's hot spot temperature of the module   | Read word        | Yes   | TEMP<br>Linear      | /                 | /              | Deg.C         | -2       | /  |
| READ_FREQUENCY            | 0x95                | Read the switching frequency  | Read word        | Yes   | Frequency<br>Linear | NA                |                | KHz           | 1        | /  |
| PMBUS_REVISION            | 0x98                | Reads the revision of the PMBus   | Read byte        | Yes   | Bit field           | 0x22              | /              | /             | /        | /  |
| MFR_ID                    | 0x99                | Read the manufacturer's ID  | Read Block       | Yes   | /                   | "DELTA "          | /              | /             | /        | Data that read should be converted to ASCII code |
| MFR_MODEL                 | 0x9A                | Read the manufacturer's model number  | Read Block       | Yes   | /                   | "Q54SH12060NRAH " | /              | /             | /        | Data that read should be converted to ASCII code |
| MFR_REVISION              | 0x9B                | Read the revision number of the module.   | Read Block       | Yes   | ASCII               | /                 | /              | /             | /        | The format is "SX.X"                             |
| MFR_LOCATION              | 0x9C                | Read the manufacturing location of the device   | Read Block       | Yes   | /                   | "Thailand "       | /              | /             | /        | Data that read should be converted to ASCII code |
| ERASE_BLACK_BOX_DATA      | 0xD1                | Erase all black box data.   | Send byte        | Refer to below description;                     | /                   | /                 | /              | /             | /        | /  |
| READ_HISTORY_EVENT_NUMBER | 0xD2                | Read the total number of history event in black box space.                                      | Read byte        | Refer to below description;                     | /                   | /                 | /              | /             | /        | /  |
| READ_HISTORY_EVENTS       | 0xD6                | Read history event from black box   | Read block       | Refer to below description;                     | /                   | /                 | /              | /             | /        | /  |
| SET_HISTORY_EVENT_OFFSET  | 0xD7                | Set history event offset  | R/W byte         | Refer to below description;                     | /                   | /                 | /              | /             | /        | /  |
| MFR_C1_C2_ARA_CONFIG      | 0xE0                | Config C2 pin function  | R/W byte         | Refer to below description;                     | Bit field           | 0x00              | /              | /             | /        | /  |

| Command                           | Com<br>mand<br>Code | Command description   | Transfer<br>type | Compatible<br>with standard<br>PMBUS or<br>not? | Data<br>Format | Default<br>value | Range<br>limit | Data<br>units | Exponent | Note  |
|-----------------------------------|---------------------|---|------------------|---|----------------|------------------|----------------|---------------|----------|---|
| MFR_C2_<br>Configure              | 0xE1                | Config C2 pin logic   | R/W<br>byte      | Refer to below<br>description;                  | Bit field      | 0x00             | /              | /             | /        | /   |
| MFR_PGOOD_<br>POLARITY            | 0xE2                | Config Power Good logic   | R/W<br>byte      | Refer to below<br>description;                  | Bit field      | 0x01             | /              | /             | /        | Default Positive<br>PGOOD logic   |
| PMBUS_CMD_F<br>LASH_KEY_WRI<br>TE | 0xEC                | Write the key to unlock the Flash<br>before Storing operating<br>parameters from RAM to data<br>flash | R/W<br>block     | No  | /              | 0xA5A5A5<br>A5   |                | /             | /        | A data<br>block: 7E, 15, DC, 42<br>should be send to<br>unlock the FLASH. |

## OPERATION [0x01]

| Bit number | Purpose                   | Bit Value | Meaning            | Default Settings, 0x80 |
|------------|---------------------------|-----------|--------------------|------------------------|
| 7:         | Enable/Disable the module | 1         | Output is enabled  | 1                      |
|            |                           | 0         | Output is disabled |                        |
| 6:0        | Reserved                  |           |                    | 0000000                |

## ON\_OFF\_CONFIG [0x02]

| Bit number | Purpose   | Bit Value | Meaning   | Default Settings, 0x1D (negative) /0x1F (positive) |
|------------|---|-----------|---|--|
| 7:5        | Reserved  |           |   | 000  |
| 4          | Controls how the unit responds to the primary on/off pin and the OPERATION command; | 1         | Module does not power up until commanded by the primary ON/OFF pin and the OPERATION            | 1  |
|            |   | 0         | Module power up at any time regardless of the state of the primary ON/OFF pin and the OPERATION |  |
| 3          | Controls how the unit responds to the OPERATION command                             | 1         | Module responds to the 7 bit in the OPERATION   | 1  |
|            |   | 0         | Module ignores the 7 bit in the OPERATION   |  |
| 2          | Controls how the unit responds to the primary on/off pin                            | 1         | Module requires the primary ON/OFF pin to be asserted to start the unit                         | 1  |
|            |   | 0         | Module ignores the state of the primary ON/OFF pin  |  |
| 1          | Control logic of primary on/off pin   | 1         | Positive Logic  | 0, negative; 1, positive.                          |
|            |   | 0         | Negative Logic  |  |
| 0          | Unit turn off delay time control  | 1         | Shut down the module with 0 delay cycle   | 1  |

## STATUS\_WORD [0x79]

### High byte

| Bit number | Purpose   | Bit Value | Meaning     |
|------------|---|-----------|-------------|
| 7          | An output voltage fault or warning                              | 1         | Occurred    |
|            |   | 0         | No Occurred |
| 6          | An output over current fault or warning                         | 1         | Occurred    |
|            |   | 0         | No Occurred |
| 5          | An input voltage fault, including over voltage and undervoltage | 1         | Occurred    |
|            |   | 0         | No Occurred |
| 4          | Reserved  |           |             |
| 3          | Power_Good  | 1         | is negated  |
|            |   | 0         | ok          |
| 2:0        | Reserved  |           |             |

## Low byte

| Bit number | Purpose   | Bit Value | Meaning     |
|------------|---|-----------|-------------|
| 7          | Reserved  |           |             |
| 6          | OFF (The unit is not providing power to the output, regardless of the reason) | 1         | Occurred    |
|            |   | 0         | No Occurred |
| 5          | An output over voltage fault  | 1         | Occurred    |
|            |   | 0         | No Occurred |
| 4          | An output over current fault  | 1         | Occurred    |
|            |   | 0         | No Occurred |
| 3          | An input under voltage fault  | 1         | Occurred    |
|            |   | 0         | No Occurred |
| 2          | A temperature fault or warning  | 1         | Occurred    |
|            |   | 0         | No Occurred |
| 1          | CML (A communications, memory or logic fault)                                 | 1         | Occurred;   |
|            |   | 0         | No Occurred |
| 0          | Reserved  |           |             |

## STATUS\_VOUT [0x7A]

| Bit number | Purpose                      | Bit Value | Meaning     |
|------------|------------------------------|-----------|-------------|
| 7          | Output over voltage fault    | 1         | Occurred    |
|            |                              | 0         | No Occurred |
| 6          | Output over voltage warning  | 1         | Occurred    |
|            |                              | 0         | No Occurred |
| 5          | Output under voltage warning | 1         | Occurred    |
|            |                              | 0         | No Occurred |
| 4          | Output under voltage fault   | 1         | Occurred    |
|            |                              | 0         | No Occurred |
| 3:0        | Reserved                     |           |             |

## STATUS\_IOUT [0x7B]

| Bit number | Purpose                     | Bit Value | Meaning     |
|------------|-----------------------------|-----------|-------------|
| 7          | Output over current fault   | 1         | Occurred;   |
|            |                             | 0         | No Occurred |
| 6          | Reserved                    |           |             |
| 5          | Output over current warning | 1         | Occurred;   |
|            |                             | 0         | No Occurred |
| 4:0        | Reserved                    |           |             |

## STATUS\_INPUT [0x7C]

| Bit number | Purpose                   | Bit Value | Meaning     |
|------------|---------------------------|-----------|-------------|
| 7          | Input over voltage fault  | 1         | Occurred;   |
|            |                           | 0         | No Occurred |
| 6: 5       | Reserved                  |           |             |
| 4          | Input under voltage fault | 1         | Occurred;   |
|            |                           | 0         | No Occurred |
| 3:0        | Reserved                  |           |             |



## STATUS\_TEMPERATURE [0x7D]

| Bit number | Purpose                  | Bit Value | Meaning     |
|------------|--------------------------|-----------|-------------|
| 7          | Over temperature fault   | 1         | Occurred;   |
|            |                          | 0         | No Occurred |
| 6          | Over temperature warning | 1         | Occurred;   |
|            |                          | 0         | No Occurred |
| 5:0        | Reserved                 |           |             |

## STATUS\_CML [0x7E]

| Bit number | Purpose                              | Bit Value | Meaning     |
|------------|--------------------------------------|-----------|-------------|
| 7          | Invalid/Unsupported Command Received | 1         | Occurred;   |
|            |                                      | 0         | No Occurred |
| 6          | Invalid/Unsupported Data Received    | 1         | Occurred;   |
|            |                                      | 0         | No Occurred |
| 5          | Packet Error Check Failed            | 1         | Occurred;   |
|            |                                      | 0         | No Occurred |
| 4:0        | Reserved                             |           |             |

## MFR\_C1\_C2\_ARA\_CONFIG [0xE0]

| Bit number | Purpose           | Bit Value | Meaning   |
|------------|-------------------|-----------|---|
| 7:5        | Reserved          | 000       | Reserved  |
| 4          | ARA               | 0         | ARA not functional, module remains at resistor programmed address when SMBLAERT is asserted |
| 3:0        | PIN Configuration | 0000      | C2 pin: POWER_GOOD  |
|            |                   | 0010      | C2 pin: ON/OFF (Secondary)  |

## MFR\_C2\_Configure [0xE1]

| Bit number | Purpose                     | Bit Value | Meaning  |
|------------|-----------------------------|-----------|--|
| 7:2        | Reserved                    | 000000    | Reserved   |
| 1          | ON/OFF Configuration        | 0         | Secondary side on/off pin state when mapped to C2 is ignored |
|            |                             | 1         | AND – Primary and Secondary side on/off                      |
| 0          | Secondary Side ON/OFF Logic | 0         | Negative Logic (Low Enable: Input < 0.8V wrt Vout(-))        |
|            |                             | 1         | Positive Logic (High Enable: Input > 2.0V wrt Vout(-))       |

## MFR\_PGOOD\_POLARITY [0xE2]

| Bit number | Purpose          | Bit Value | Meaning              |
|------------|------------------|-----------|----------------------|
| 7:1        | Reserved         | 0000000   | Reserved             |
| 0          | Power Good Logic | 0         | Negative PGOOD logic |
|            |                  | 1         | Positive PGOOD logic |

## ERASE\_BLACKBOX\_DATA [0xD1]

This is a Delta MFR command which used to erase all black box data. After writing the command 0xD1, the module will be powered off automatically for erasing safely. After finishing the erasing task, the module will repower on itself again. The total time for erasing is about 400ms. So the module will be powered off at least 400ms if user send a 0xD1 command to erase black box data. User should pay attention to this feature before writing 0xD1 command.

## READ\_HISTORY\_EVENT\_NUMBER [0xD2]

This is a read-only Delta MFR command which used to get the total events number in black box.

## READ\_HISTORY\_EVENTS [0xD6]

This is a read-only Delta MFR command which used to get the history events at an appointed offset. The appointed offset can be set by command 0xD7 SET\_HISTORY\_EVENT\_OFFSET.

This command is a read block PMBUS communication protocol. So the return data from PMBUS will be as below table shows.

| Byte    | Content  |
|---------|--|
| 0       | Byte Count = 32  |
| 1 ~ 8   | <b>For Delta internal checking</b>                         |
| 9 ~ 11  | Run_Time from turn on to off                               |
| 12      | <b>For Delta internal checking</b>                         |
| 13 ~ 14 | Module's temperature when off.                             |
| 15 ~ 16 | STATUS_WORD  |
| 17 ~ 18 | Input voltage in PMBUS linear format, when module is off.  |
| 19 ~ 20 | <b>For Delta internal checking</b>                         |
| 21 ~ 22 | Output current in PMBUS linear format, when module is off. |
| 23 ~ 32 | <b>For Delta internal checking</b>                         |

Note: The Byte Count at Byte0 is the content of PMBUS block read protocol, not the black box data.

## SET\_HISTORY\_EVENT\_OFFSET [0xD7]

This is a Delta MFR command which used to set offset value to decide which history data for read. The offset and the history data has the fix relationship, as below table shows. Total 19 entries(0x30-0x42) are effective. 0x43 entry is special that prepared for current time shutdown storage, which will have no effective data if module not shutdown after repower on.

| Offset | History data                | Offset | History data                 |
|--------|-----------------------------|--------|------------------------------|
| 0x30   | The latest data(The newest) | 0x3A   | The last 10 data             |
| 0x31   | The last 1 data             | 0x3B   | The last 11 data             |
| 0x32   | The last 2 data             | 0x3C   | The last 12 data             |
| 0x33   | The last 3 data             | 0x3D   | The last 13 data             |
| 0x34   | The last 4 data             | 0x3E   | The last 14 data             |
| 0x35   | The last 5 data             | 0x3F   | The last 15 data             |
| 0x36   | The last 6 data             | 0x40   | The last 16 data             |
| 0x37   | The last 7 data             | 0x41   | The last 17 data             |
| 0x38   | The last 8 data             | 0x42   | The last 18 data(the oldest) |
| 0x39   | The last 9 data             | 0x43   | The now black box data       |

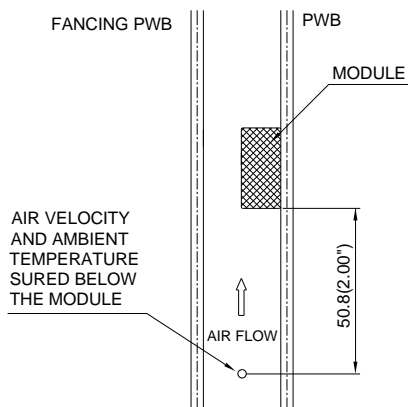
## Thermal Testing Setup

Thermal management is an important part of the system design. To ensure proper, reliable operation, sufficient cooling of the power module is needed over the entire temperature range of the module. Convection cooling is usually the dominant mode of heat transfer.

Hence, the choice of equipment to characterize the thermal performance of the power module is a wind tunnel.

Delta's DC/DC power modules are characterized in heated vertical wind tunnels that simulate the thermal environments encountered in most electronics equipment. This type of equipment commonly uses vertically mounted circuit cards in cabinet racks in which the power modules are mounted.

The following figure shows the wind tunnel characterization setup. The power module is mounted on a 185mmX185mm, 105µm (3Oz), 6 layers' test PWB and is vertically positioned within the wind tunnel. The space between the neighboring PWB and the top of the power module is constantly kept at 6.35mm (0.25").



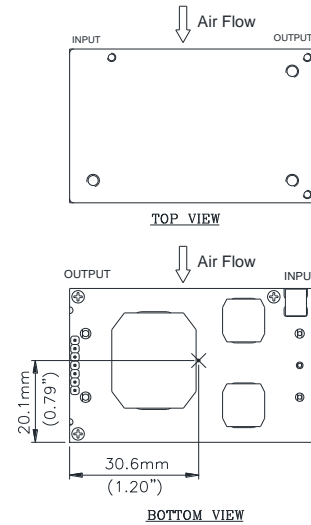
Note: Wind Tunnel Test Setup Figure Dimensions are in millimeters and (Inches)

**Figure 15: Wind Tunnel Test Setup**

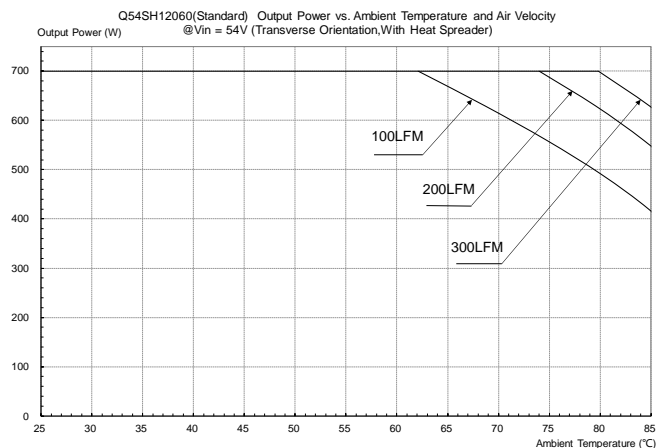
## Thermal Derating

Heat can be removed by increasing airflow over the module. To enhance system reliability, the power module should always be operated below the maximum operating temperature. If the temperature exceeds the maximum module temperature, reliability of the unit may be affected.

## Thermal Curves (With Base-plate)

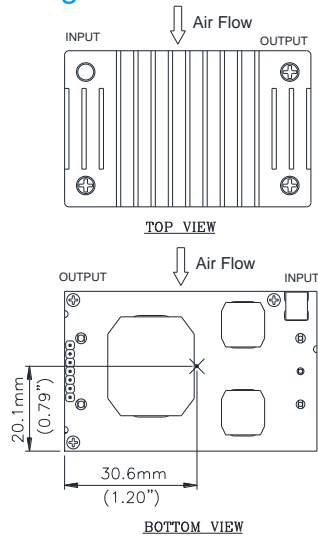


**Figure 16: Hot spot 1 temperature measurement location**  
The allowed maximum hot spot 1 temperature is defined at 120 °C.

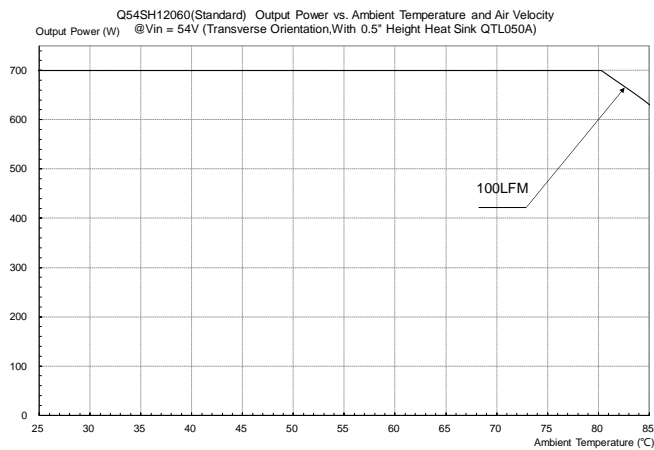


**Figure 17: Output Power vs. Ambient Temperature and Air Velocity @Vin = 54V (Transverse Orientation, Airflow from Vin+ to Vin-, With Base-plate)**

## Thermal Curves (with 0.5" height heat sink QTL050A)

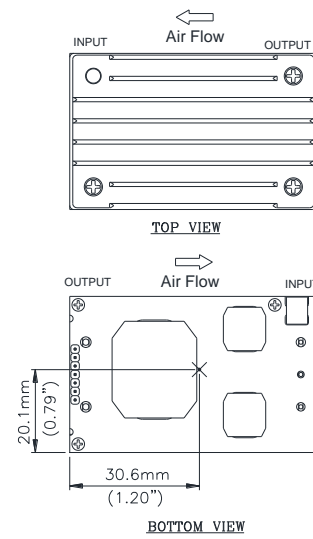


**Figure 18:** Hot spot 2 temperature measurement location  
The allowed maximum hot spot 2 temperature is defined at 120 °C.

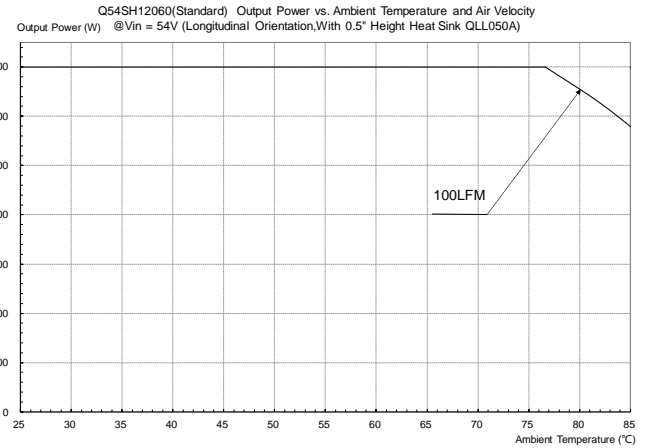


**Figure 19:** Output Power vs. Ambient Temperature and Air Velocity @Vin = 54V (Transverse Orientation, Airflow from Vin+ to Vin-, With 0.5" Height Heat Sink QTL050A)

## Thermal Curves (with 0.5" height heat sink QLL050A)

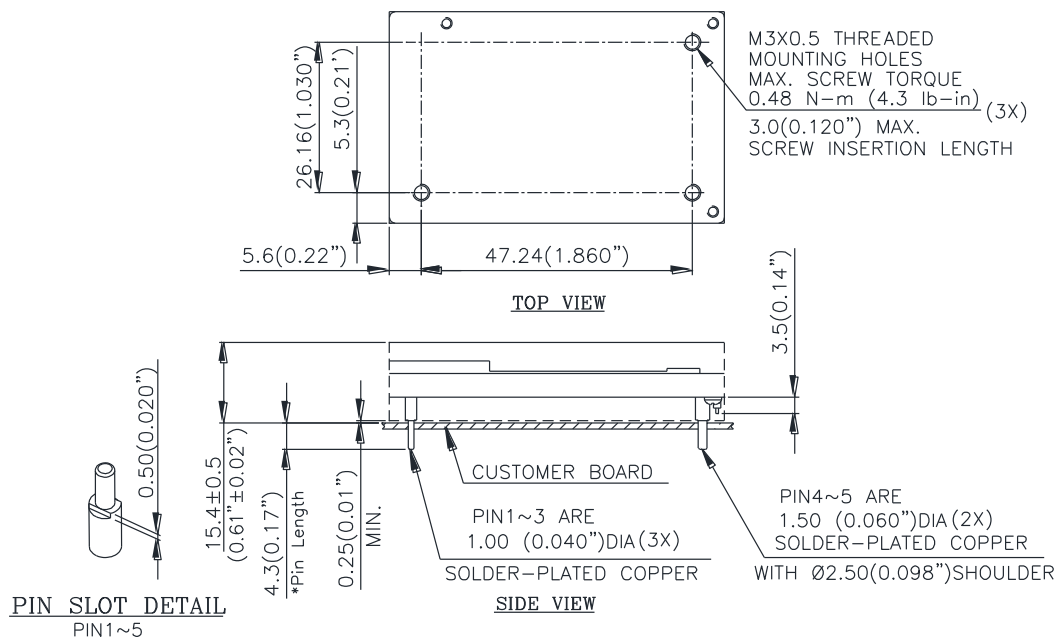


**Figure 20:** Hot spot 3 temperature measurement location  
The allowed maximum hot spot 3 temperature is defined at 120 °C.

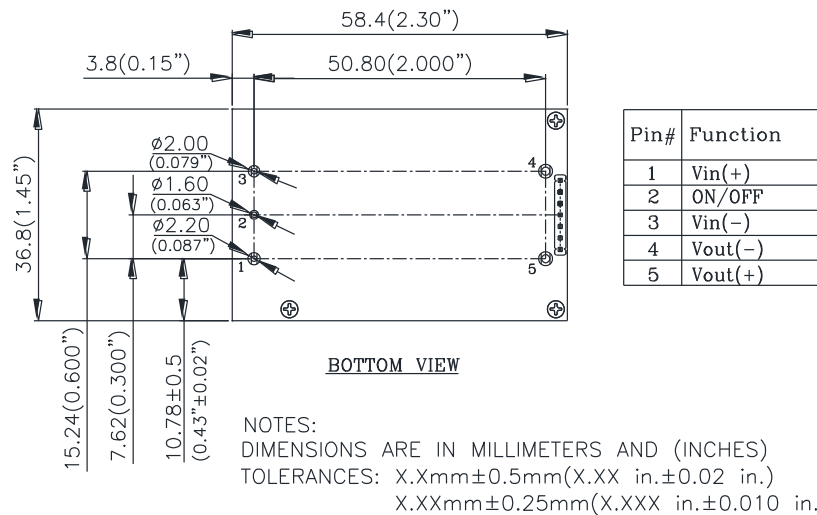


**Figure 21:** Output Power vs. Ambient Temperature and Air Velocity @Vin = 54V (Longitudinal Orientation, Airflow from Vout to Vin, With 0.5" Height Heat Sink QLL050A)

## Mechanical Drawing (with Baseplate, without digital pin)



\*Standard pin tail length. Optional pin tail lengths shown in PART NUMBERING SYSTEM



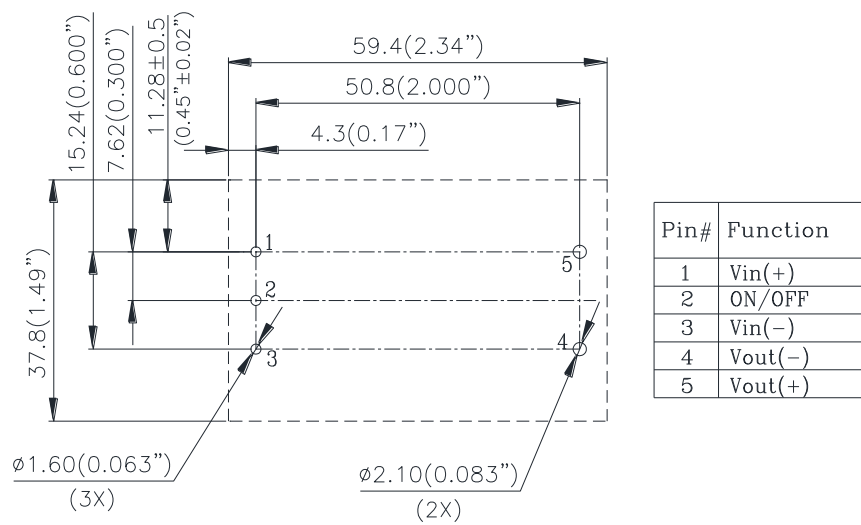
| Pin No. | Name   | Function                |
|---------|--------|-------------------------|
| 1       | +Vin   | Positive input voltage  |
| 2       | ON/OFF | Remote ON/OFF           |
| 3       | -Vin   | Negative input voltage  |
| 4       | -Vout  | Negative output voltage |
| 5       | +Vout  | Positive output voltage |

### Pin Specification:

Pins 1,2,3  
Pins 4,5

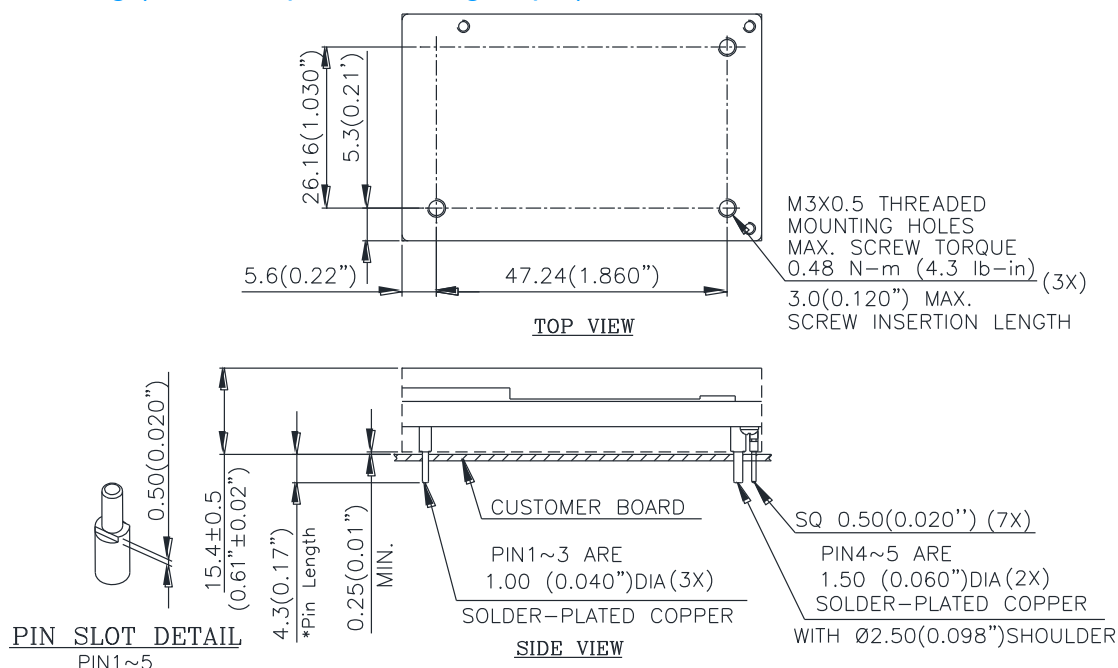
1.00mm (0.040") diameter; copper with matte Tin plating and Nickel under plating  
1.50mm (0.060") diameter; copper with matte Tin plating and Nickel under plating

### Suggested Pad Layout (without digital pin)

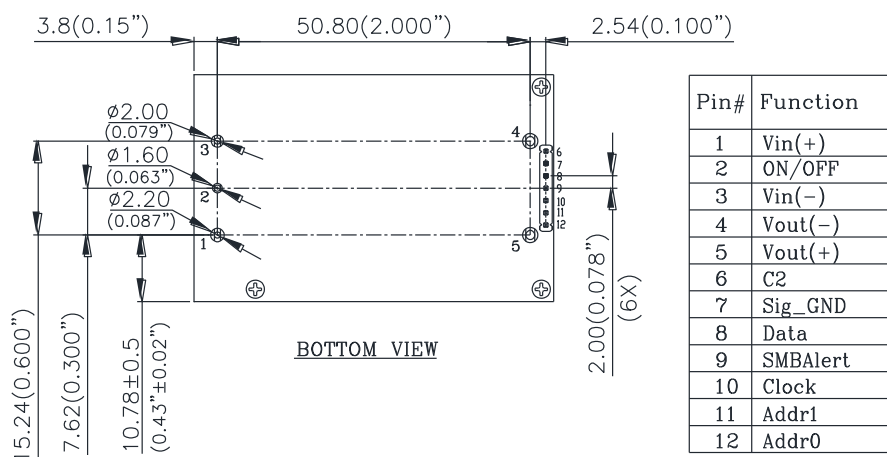


NOTES:  
DIMENSIONS ARE IN MILLIMETERS AND (INCHES)  
TOLERANCES: X.Xmm±0.5mm(X.XX in.±0.02 in.)  
                  X.XXmm±0.25mm(X.XXX in.±0.010 in.)

## Mechanical Drawing (with Baseplate, with digital pin)



\*Standard pin tail length. Optional pin tail lengths shown in PART NUMBERING SYSTEM



### NOTES:

DIMENSIONS ARE IN MILLIMETERS AND (INCHES)

TOLERANCES: X.Xmm±0.5mm(X.XX in.±0.02 in.)

X.XXmm±0.25mm(X.XXX in.±0.010 in.)

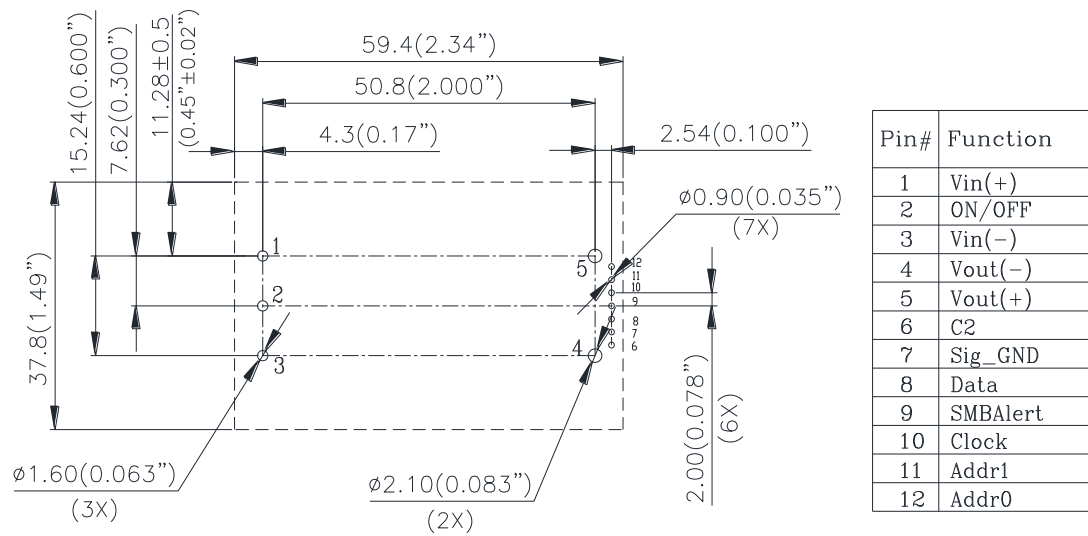
| Pin No. | Name     | Function   |
|---------|----------|--|
| 1       | +Vin     | Positive input voltage   |
| 2       | ON/OFF   | Remote ON/OFF  |
| 3       | -Vin     | Negative input voltage   |
| 4       | -Vout    | Negative output voltage  |
| 5       | +Vout    | Positive output voltage  |
| 6       | C2       | PGOOD pin, and this pin also could be configured as secondary on/off control pin |
| 7       | Sig_Gnd  | Signal ground  |
| 8       | Data     | PMBus data line  |
| 9       | SMBAlert | PMBus SMBAlert line  |
| 10      | Clock    | PMBus clock line   |
| 11      | Addr1    | ADDR1 pin sets the high order digit of the address.                              |
| 12      | Addr0    | ADDR0 pin sets the low order digit of the address.                               |

### Pin Specification:

|            |   |
|------------|---|
| Pins 1,2,3 | 1.00mm (0.040) diameter; copper with matte Tin plating and Nickel under plating |
| Pins 4,5   | 1.50mm (0.060) diameter; copper with matte Tin plating and Nickel under plating |
| Pins 6~12  | Digital pins; Square 0.50mm (0.020); copper with golden flash plating           |



## Suggested Pad Layout (with digital pin)



NOTES:  
 DIMENSIONS ARE IN MILLIMETERS AND (INCHES)  
 TOLERANCES: X.Xmm±0.5mm(X.XX in.±0.02 in.)  
 X.XXmm±0.25mm(X.XXX in.±0.010 in.)

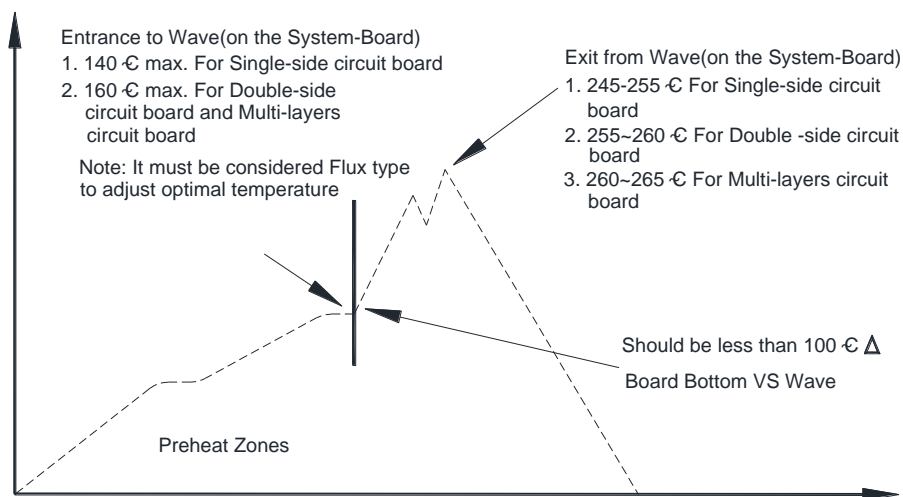
## Soldering method

Generally, as the most common mass soldering method for the solder attachment, wave soldering is used for through-hole power modules and reflow soldering is used for surface-mount ones. Delta recommended soldering methods and process parameters are provided in this document for solder attachment of power modules onto system board. SAC305 is the suggested lead-free solder alloy for all soldering methods.

Reflow soldering is not a suggested method for through-hole power modules due to many process and reliability concerns. If you have this kind of application requirement, please refer to the last page "part numbering system", the P/N marked "PIH" means support reflow process. Or contact Delta sales/FAE for further confirmation.

## Wave Soldering (Lead-free)

Delta's power modules are designed to be compatible with single-wave or dual wave soldering. The suggested soldering process must keep the power module's internal temperature below the critical temperature of 217 °C continuously. The recommended wave-soldering profile is shown in following figure.



**Recommended Temperature Profile for Lead-free Wave Soldering**  
**Note:** The temperature is measured on solder joint of pins of power module.

The typical recommended (for double-side circuit board) preheat temperature is 115+/-10°C on the top side (component side) of the circuit board. The circuit-board bottom-side preheat temperature is typically recommended to be greater than 135°C and preferably within 100 °C of the solder-wave temperature. A maximum recommended preheat up rate is 3°C /s. A maximum recommended solder pot temperature is 255+/-5°C with solder-wave dwell time of 3~6 seconds. The cooling down rate is typically recommended to be 6 °C/s maximum.

## Hand Soldering (Lead Free)

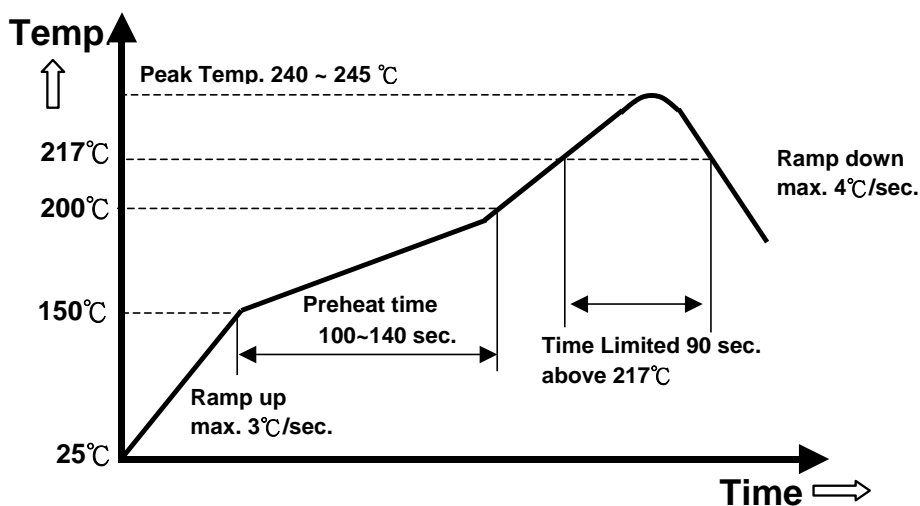
Hand soldering is the least preferred method because the amount of solder applied, the time the soldering iron is held on the joint, the temperature of the iron, and the temperature of the solder joint are variable. The recommended hand soldering guideline is listed in Table 1. The suggested soldering process must keep the power module's internal temperature below the critical temperature of 217°C continuously.

**Table 1 Hand-Soldering Guideline**

| Parameter              | Single-side<br>Circuit Board | Double-side<br>Circuit Board | Multi-layers<br>Circuit Board |
|------------------------|------------------------------|------------------------------|-------------------------------|
| Soldering Iron Wattage | 90                           | 90                           | 90                            |
| Tip Temperature        | 385+/-10°C                   | 420+/-10°C                   | 420+/-10°C                    |
| Soldering Time         | 2 ~ 6 seconds                | 4 ~ 10 seconds               | 4 ~ 10 seconds                |

## Reflow Soldering (Lead-free)

High temperature and long soldering time will result in IMC layer increasing in thickness and thereby shorten the solder joint lifetime. Therefore the peak temperature over 245°C is not suggested due to the potential reliability risk of components under continuous high-temperature. In the meanwhile, the soldering time of temperature above 217 °C should be less than 90 seconds. Please refer to following figure for recommended temperature profile parameters.



*Recommended Temperature Profile for Lead-free Reflow Soldering*  
*Note: The temperature is measured on solder joint of pins of power module.*

## PART NUMBERING SYSTEM

| Q                 | 54            | S                 | H                 | 120            | 60             | N   | R                                      | A                                   | H             | x                                   |
|-------------------|---------------|-------------------|-------------------|----------------|----------------|---|--|-------------------------------------|---------------|-------------------------------------|
| Type of Product   | Input Voltage | Number of Outputs | Product Series    | Output Voltage | Output Current | ON/OFF Logic  | Pin Length /Type                       | Pin Assignment                      | Option Code   | Customer specific                   |
| Q - Quarter Brick | 54 - 40~60V   | S - Single        | H - Series number | 120 - 12V      | 60 - 60A       | N - Negative<br>R - Negative and compliant Reflow process | R - 0.170"<br>N - 0.145"<br>K - 0.110" | D - Digital pins<br>A - Analog pins | H - Baseplate | F - Halogen free<br>Omit - Standard |

## RECOMMENDED PART NUMBER

| Model Name     | Input   | Output     | Peak Eff. |
|----------------|---------|------------|-----------|
| Q54SH12060NRAH | 40V~60V | 11.80V 60A | 97.7%     |
| Q54SH12060NKDH | 40V~60V | 11.80V 60A | 97.7%     |
| Q54SH12060RKDH | 40V~60V | 11.80V 60A | 97.7%     |

\*The Q54SH12060RKDH can be processed with paste-in-hole Pb or Pb-free reflow process

Default remote On/Off logic is negative.

Please contact with Delta sales/FAE for different optional functions.

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