
# i9C DC/DC Power Module Series

Input: 9-80V, Output:5-60V,1500W
Step-up/Step-down converter with
Programmable High Efficiency Pass-Through
(PHEPT) mode; Wide 1/4 brick footprint

i9C power modules step the voltage up or down to perform local voltage conversion between 12V, 24V, 48V and 60V buses. The i9C series utilizes a non-isolated power topology to offer a high power density with a superior level of performance. The base-plated design features both threaded and non-threaded mounting holes for extreme flexibility and to support manufacturing processes needed for various cooling approaches. The high efficiency and programmable pass-through mode enable users to achieve a high usable power even in the most demanding thermal environments.

**Features**

- Size – 57.9mm x 55.9 mm x 15.2 mm (2.28 in. x 2.2 in. x 0.60 in.)
- Maximum weight 115g (4.06 oz.)
- Through-hole pins 3.68mm (0.145”)
- Base Plate for conduction cooling
- Up to 1500W of output power in high ambient temperature, low airflow environments with minimal power de-rating
- Wide output voltage adjustment range
- Choice of User Programmable High Efficiency Pass-Through operation (PHEPT) or Fully Regulated operation
- Negative logic On/Off
- Power Good
- Remote Sense
- User Adjustable Over Current Protection
- Constant switching frequency
- Low Power SLEEP Mode
- Full Auto-recovery Protection
  - Input undervoltage
  - Short Circuit
  - Thermal Limit
- Patented Technology
- ISO Certified manufacturing facilities

**Optional Features**

- Positive logic On/Off
- External clock synchronization

## Ordering Information:

| Product Identifier | Package Size | Platform | Input Voltage | Output Current | Units | Main Output Voltage | # of Outputs | | Feature Set | | RoHS indicator |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **i** | **9** | **C** | **4W** | **030** | **A** | **480** | **V** | **-** | **0C3** | **-** | **R** |
| TDK-Lambda | 57.9mm x 55.9 mm | i9C non-isolated step up and step down | 2W:9V to 40V<br>4W: 9V to 80V | 30 | Amps | 48V | Single | | See option table | | R=RoHS Compliant |

## Option Table:

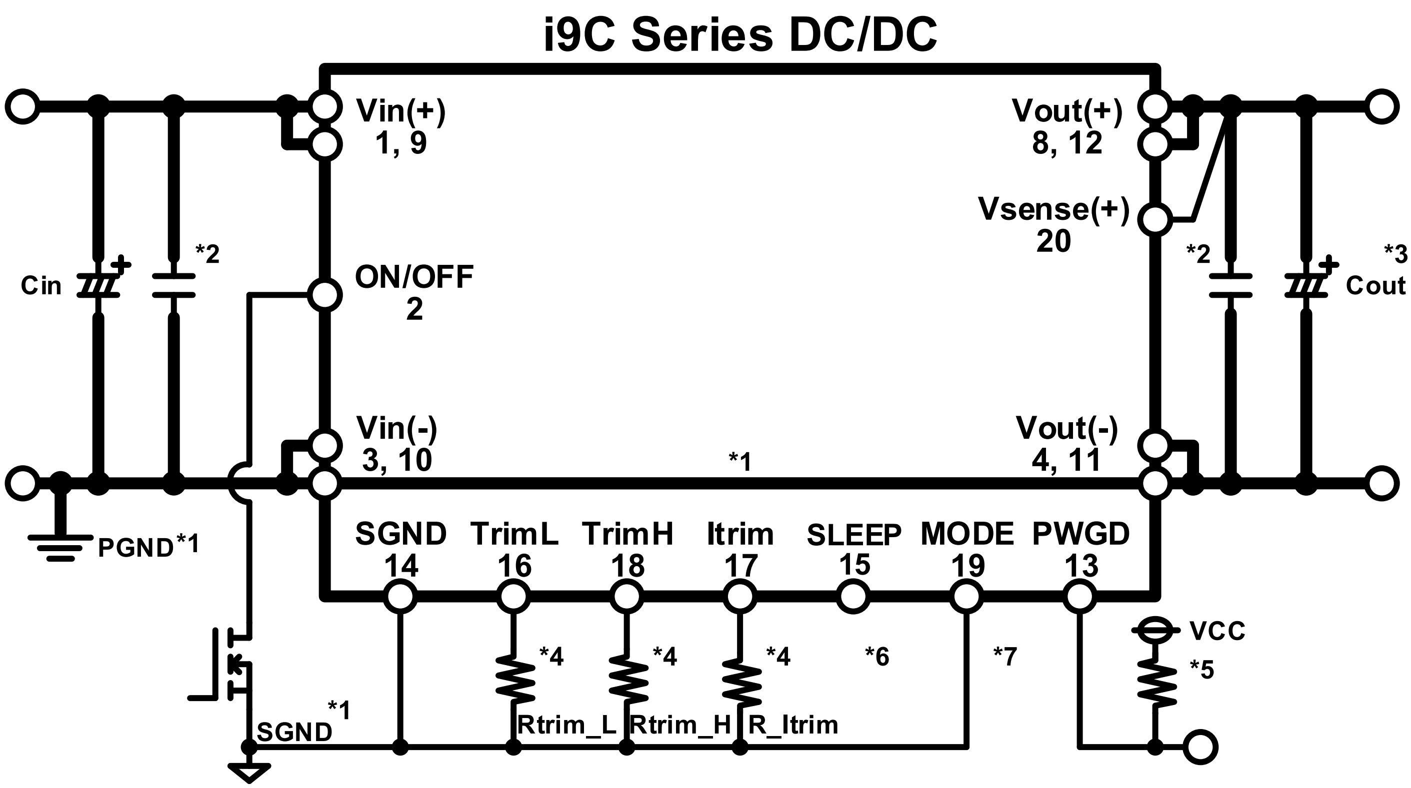
| Feature Set | Positive Logic On/Off | Negative Logic On/Off | PHEPT | SLEEP | Adjustable OCP | Base Plate |
|---|---|---|---|---|---|---|
| -0C3 * | NO | YES | YES | YES | YES | Flanged |
| -NC3 | NO | YES | YES | YES | YES | Non-Flanged |

** Preferred Option*

## Product Offering:

| Product Code | Input Voltage (V) | Output Voltage (V) | Output Current (A) | Maximum Output Power (W) | Efficiency (Switching) | Efficiency (Pass-through) |
|---|---|---|---|---|---|---|
| i9C4W030A480V | 9 - 80 | 9.6 - 60 | 30 | 1500 | 97% | 99% |
| i9C2W050A240V | 9 - 40 | 5 - 36 | 50 | 1500 | 95% | 97.5% |

## Typical Application Circuit:

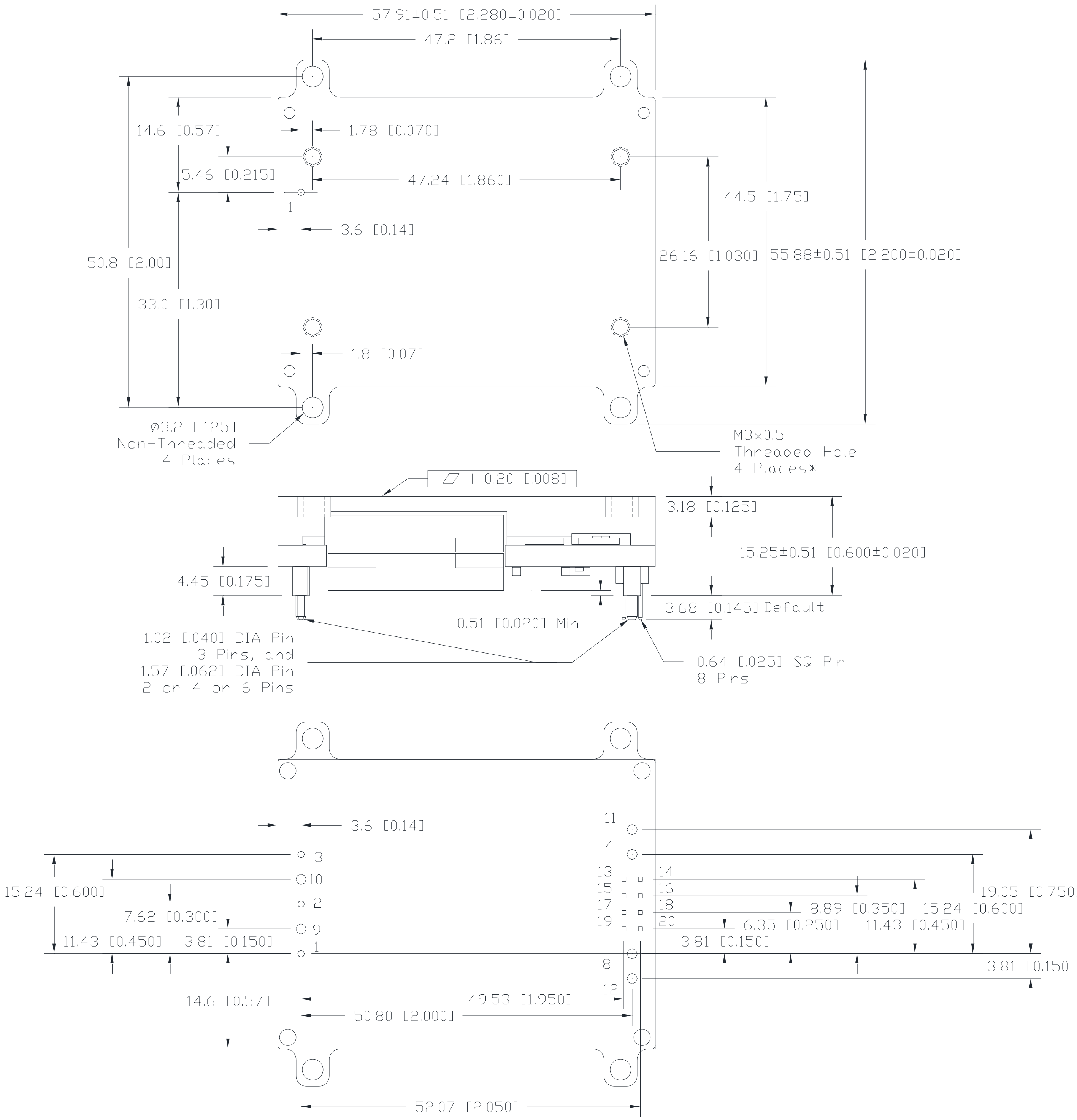



Design Guideline / Recommendation

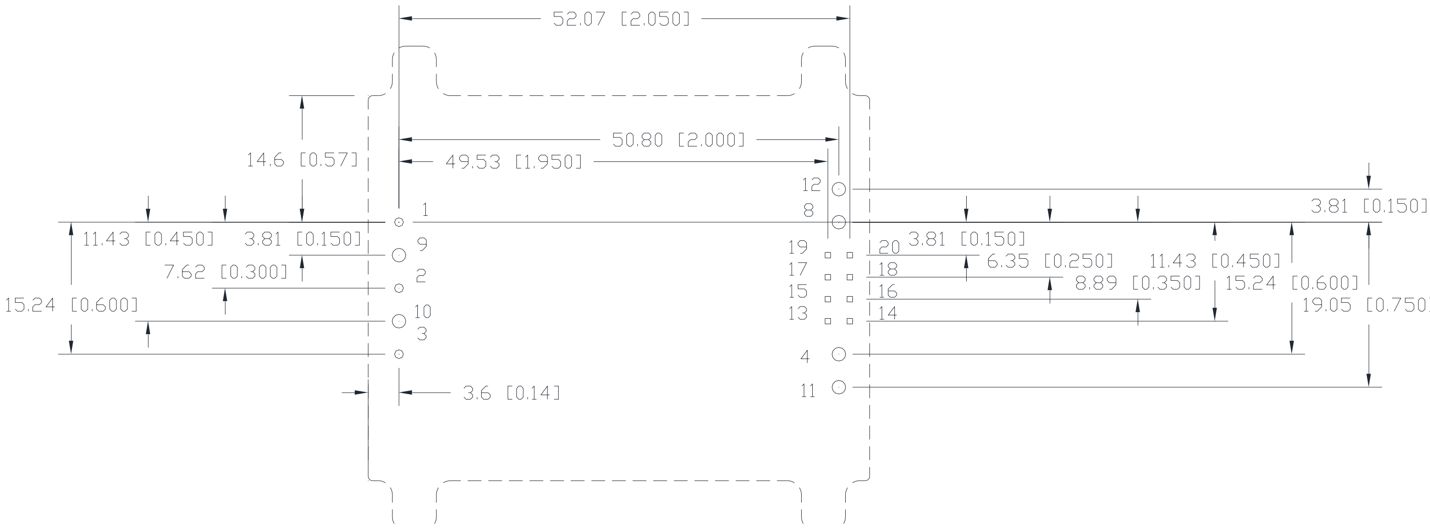
1. Power GND and Signal GND should be separated. Vin(-) and Vout(-) should be connected by a heavy copper ground plane underneath the i9C module. Pin 14 SGND, is internally grounded.
2. Input and Output MLCC should be placed close to the i9C module to reject high frequency noise. Minimum 4 x 22uF recommended at input and 2 x 22uF at output.
3. Cout bulk capacitors may carry significant ripple current especially during step-up operation. Cin bulk capacitors may carry significant ripple current especially during step-down operation. Please check ripple current capability of capacitor versus actual measured current.
4. TRIM resistors must connect to Signal GND. Itrim pin must be tied directly to SGND if this feature is not used.
5. PWGD is open-drain. Refer to Operating Information description.
6. SLEEP pin state (open or grounded) is critical for proper operation, please refer to SLEEP section of this document.
7. Refer to Operating Information description to understand use of MODE pin.

## Mechanical Specification:

Dimensions are in mm [in]. Unless otherwise specified, tolerances are: x.x ± 0.5 [0.02] / x.xx ± 0.25 [0.010]
To avoid damaging components, do not exceed 8.0 [0.32] depth with M3 screws



## Recommended Hole Pattern: (Top View)




## Pin Assignment:

| PIN | Function | PIN | Function | PIN | Function |
|---|---|---|---|---|---|
| 1, 9 | Vin (+) | 13 | PWGD | 18 | TrimH |
| 2 | On / Off | 14 | SGND | 19 | MODE |
| 3, 10 | Vin (-) / GND | 15 | SLEEP | 20 | Vsense(+) |
| 4, 11 | Vout (-) / GND | 16 | TrimL | | |
| 8, 12 | Vout (+) | 17 | Itrim | | |

Note: Pin base material is brass or copper with gold over nickel plating.
Maximum Weight: Flanged Baseplate (-0Cx-R) : 115g (4.06 oz.)

## Absolute Maximum Ratings:

Stresses in excess of Absolute Maximum Ratings may cause permanent damage to the device.

| Characteristic | | Min | Max | Unit | Notes & Conditions |
|---|---|---|---|---|---|
| Vin (Continuous Input Voltage) | i9C4W | -0.25 | 80 | Vdc | 90V t < 1 ms |
| | i9C2W | -0.25 | 40 | Vdc | 50V t < 1 ms |
| SLEEP, MODE | | -0.25 | 5 | Vdc | |
| PWGD | | -0.25 | 30 | Vdc | |
| Vtrim, Itrim | | -0.25 | 1.2 | Vdc | |
| Isolation Voltage | | --- | --- | Vdc | NOT APPLICABLE – non isolated |
| Storage Temperature | | -55 | 125 | ˚C | |
| Operating Temperature Range (Tc) | | -40 | 117* | ˚C | Measured at the location specified in the thermal measurement figure; maximum temperature varies with output current – see curve in the thermal performance section of the data sheet. |

*Per UL conditions of acceptability

## Input Characteristics:

Unless otherwise specified, specifications apply over all rated Input Voltage, Resistive Load and Temperature Conditions.

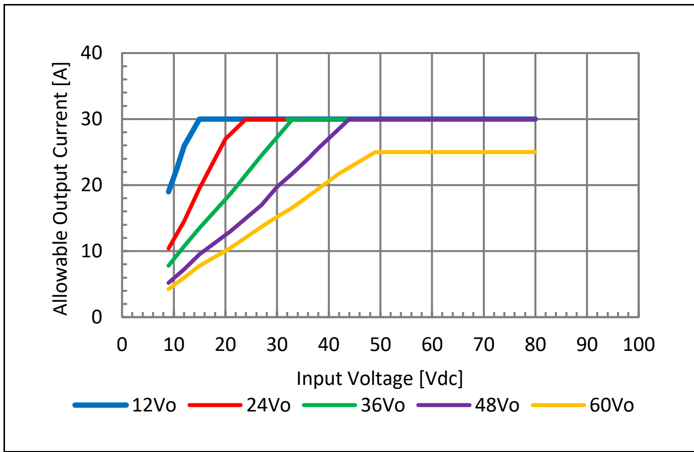
| Characteristic | | Min | Typ | Max | Unit | Notes & Conditions |
|---|---|---|---|---|---|---|
| Operating Input Voltage | i9C4W | 9 | --- | 80 | Vdc | |
| | i9C2W | 9 | --- | 40 | Vdc | |
| Maximum Input Current | i9C4W | --- | --- | 50 | A | |
| | i9C2W | --- | --- | 60 | A | |
| Stand-by Input current | i9C4W | --- | 2.5 | --- | mA | On/Off: off; Vin = 48V |
| | i9C2W | --- | 2.5 | --- | mA | On/Off: off; Vin = 24V |
| No load input current | i9C4W | --- | 140 | --- | mA | MODE= Low; SLEEP= Low; Vin=54 Vo=48 |
| | i9C2W | --- | 80 | --- | mA | MODE= Low; SLEEP= Low; Vin=32 Vo=24 |
| No load input current | i9C4W | | 10 | --- | mA | MODE= Low; SLEEP= Open; Vin=54 Vo=48 |
| | i9C2W | --- | 8 | --- | mA | MODE= Low; SLEEP= Open; Vin=32 Vo=24 |
| Startup Delay Time from On/Off | | --- | 2* | --- | ms | |
| Output Voltage Rise Time | | --- | 3* | --- | ms | With minimum output capacitor |
| Turn on input voltage | | --- | 7.5 | --- | V | |
| Turn off input voltage | | --- | 7 | --- | | |
| Turn on / off hysteresis | | --- | 0.5 | --- | V | |
| Output / Input conversion ratio “Vo / Vin” | | 0.187 | --- | 6 | --- | |

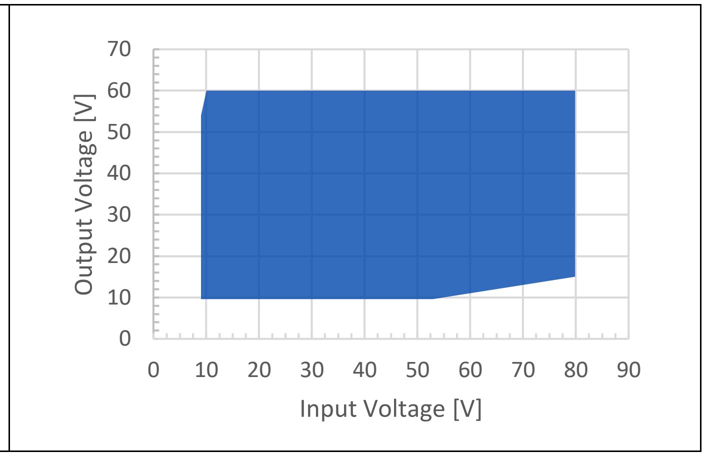
*Engineering estimate

Caution: The power modules are not internally fused. An external input line fast blow fuse with a maximum value of 60A is required; see the Safety Considerations section of the data sheet.

## Operating Range:

### i9C4W030A480V

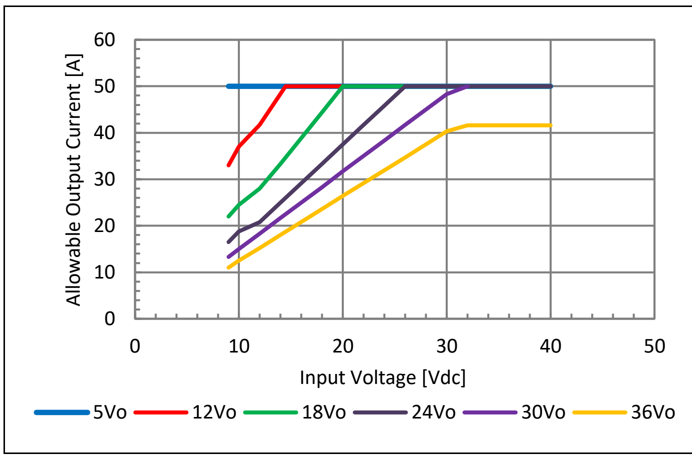


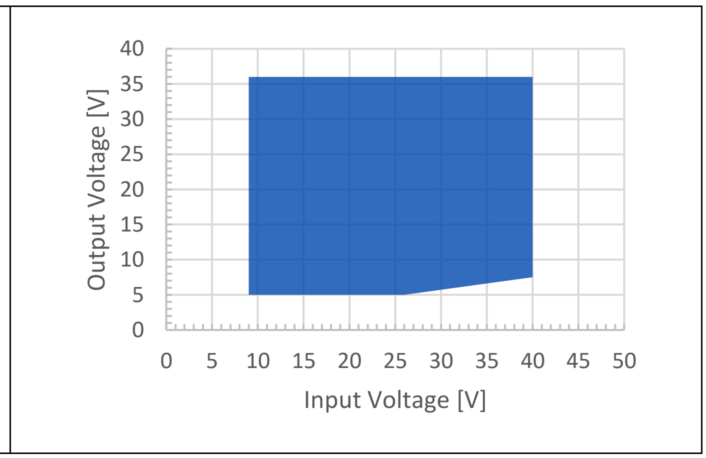




Valid Input voltage versus output current operating range*

Valid Input voltage versus output voltage operating range**

### i9C2W050A240V




Valid Input voltage versus output current operating range*

Valid Input voltage versus output voltage operating range**

* Allowable output current is limited by combination of Vin and Vout during Step-up mode. Output voltage may start to decrease if allowable output current is exceeded.

** Unit will not be damaged if operated at high lines with output voltage set below the region specified but within the specified output voltage operating range. In this region unit may have high ripple or not regulate the voltage properly at light loads.

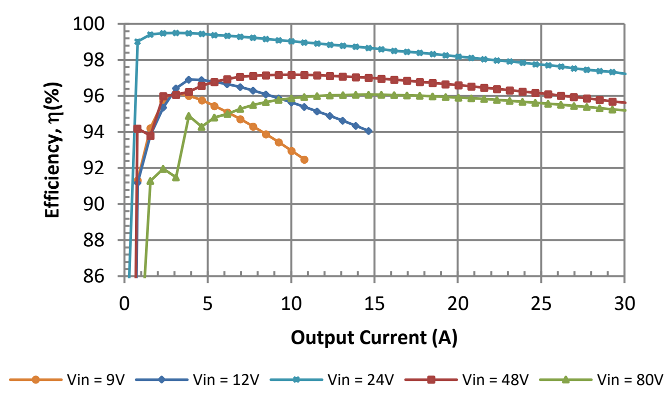
## Electrical Characteristics:

### i9C4W030A480V-xxx-R

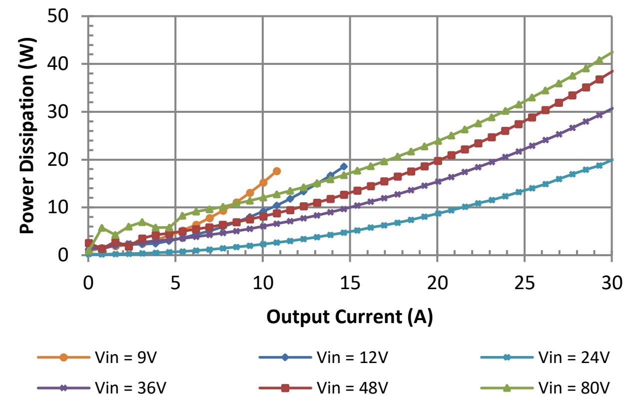
| Characteristic | | Min | Typ | Max | Unit | Notes & Conditions |
|---|---|---|---|---|---|---|
| Output Voltage Initial Set point | | -2.5 | - | +2.5 | % | Vin = Vin,nom; Io = Io,min, Tc = 25 ˚C |
| Output Voltage Tolerance | | -4.0 | - | +4.0 | % | Over all rated line, load, temperature conditions to end of life |
| Efficiency<br>(20V-28V pass-thru) | Vo = 20V<br>Vo = 24V<br>Vo = 28V | ---<br>---<br>--- | 94<br>97<br>95 | ---<br>---<br>--- | %<br>%<br>% | Vin=12V; Io=Io,max; Tc = 25˚C<br>Vin=24V; Io=Io,max; Tc = 25˚C<br>Vin=48V; Io=Io,max; Tc = 25˚C |
| Efficiency<br>(42V-54V pass-thru) | Vo = 42V<br>Vo = 48V<br>Vo = 54V | ---<br>---<br>--- | 95.5<br>98.5<br>97.5 | ---<br>---<br>--- | %<br>%<br>% | Vin=24V; Io=Io,max; Tc = 25˚C<br>Vin=48V; Io=Io,max; Tc = 25˚C<br>Vin=60V; Io=Io,max; Tc = 25˚C |
| Efficiency | Vo = 24V | ---<br>---<br>--- | 93<br>95.5<br>95 | ---<br>---<br>--- | %<br>%<br>% | Vin=12V; Io=Io,max; Tc = 25˚C<br>Vin=24V; Io=Io,max; Tc = 25˚C<br>Vin=48V; Io=Io,max; Tc = 25˚C |
| Efficiency | Vo = 48V | ---<br>---<br>--- | 95.7<br>97.5<br>97.5 | ---<br>---<br>--- | %<br>%<br>% | Vin=24V; Io=Io,max; Tc = 25˚C<br>Vin=48V; Io=Io,max; Tc = 25˚C<br>Vin=60V; Io=Io,max; Tc = 25˚C |
| Line Regulation | | --- | 0.2 | --- | % | Vin = Vin,min to Vin,max |
| Load Regulation | | --- | 0.5 | --- | % | Iout = Io,min to Io,max |
| Output Current | | 0 | --- | 30 | A | Observe maximum power limit. Allowable output current varies with input voltage, please refer to operating range chart. |
| Output Current Limiting Threshold | | --- | 40 | --- | A | Itrim: short to SGND |
| Short Circuit Current | | --- | 40 | --- | A | Itrim: short to SGND |
| Output Ripple and Noise Voltage*<br>Step down : 80Vin, 24Vo, 30A<br>Step up : 12Vin, 48Vo, 7.25A | | <br>---<br>--- | <br>120<br>380 | <br>---<br>--- | <br>mVpp<br>mVpp | |
| Dynamic Response*<br>Recovery Time<br>Transient Voltage | | <br>---<br>--- | <br>2<br>3 | <br>---<br>--- | <br>ms<br>% | di/dt =1A/us, Vin=24; Vo=48V, load step from 25% to 75% of Io,max.<br>Cout = Cout,min |
| Switching Frequency | | --- | 260 | --- | kHz | |
| External Load Capacitance | | 1000 | --- | 10000* | µF | If operating in range where input and output voltage are both near the minimum specified value, use of an output capacitance above the minimum is recommended |
| Output Voltage Adjustment Range | | 9.6 | --- | 60 | V | |
| Programmable high efficiency pass-through Voltage range | | +/-10 | --- | --- | % | Configured by TrimH/TrimL |
| Output Voltage Sense Range | | --- | --- | 5 | % | |
| Vref | | --- | 1.0 | --- | V | Required for trim calculation |
| Vo,nom | | --- | 9.485 | --- | V | Required for trim calculation |
| Vo,short | | --- | 64.387 | --- | V | Required for trim calculation |
| F | | --- | 28000 | --- | Ω | Required for trim calculation |
| G | | --- | 510 | --- | Ω | Required for trim calculation |

*Due to the extremely wide range of input and output conditions, i9C performance such as output ripple and transient voltage behavior can vary significantly from application to application. Please confirm performance in actual use case. TDK-Lambda can assist with selection of external components. Please contact technical support, especially if very low ESR capacitor banks or values beyond the listed range are required.

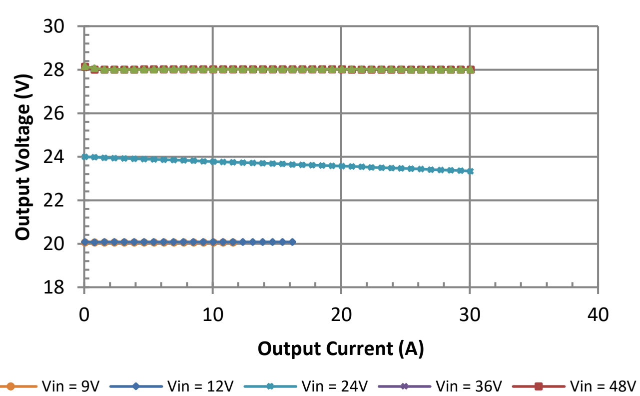
## Static Characteristic: i9C4W030A480V PHEPT Mode Vo_L= 20V Vo_H = 28V



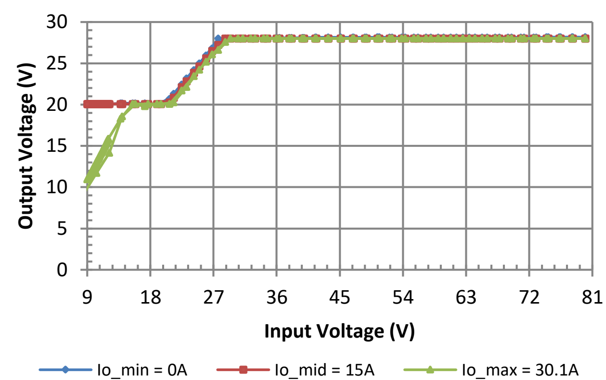

Typical efficiency versus output current at Tamb = 25 ˚C.



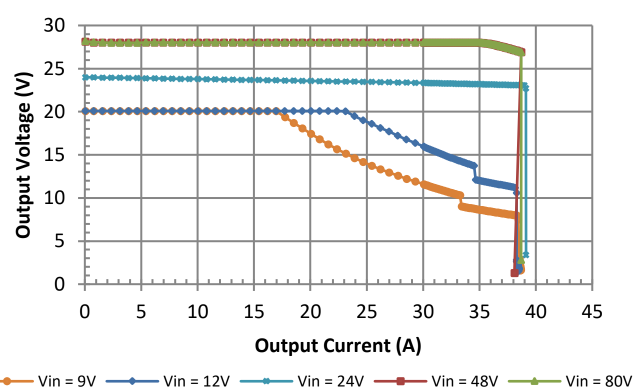

Typical power dissipation versus output current at Tamb = 25 ˚C.



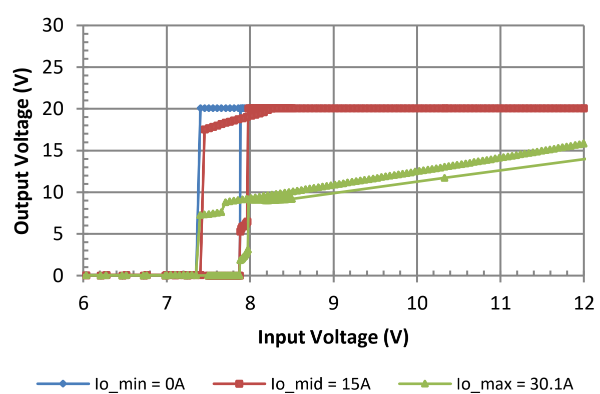

Typical load regulation at 25 ˚C.




Typical line regulation at 25 ˚C.

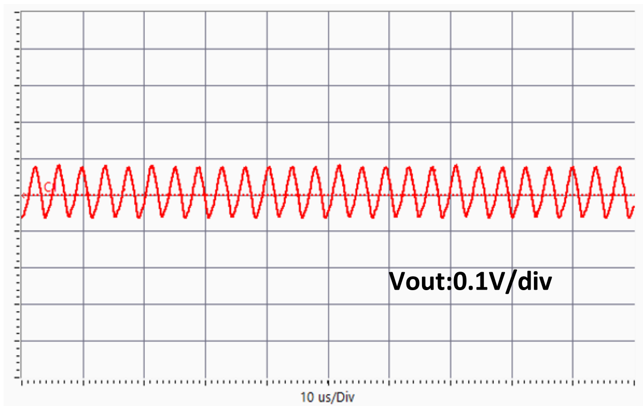



Typical Output voltage versus Output Current characteristics at 25 ˚C with Itrim tied to SGND pin.

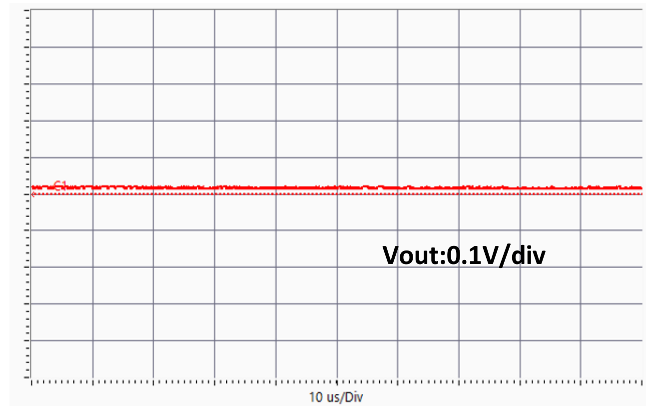



Typical UVLO characteristics, Input Voltage versus Output Voltage at 25 ˚C.

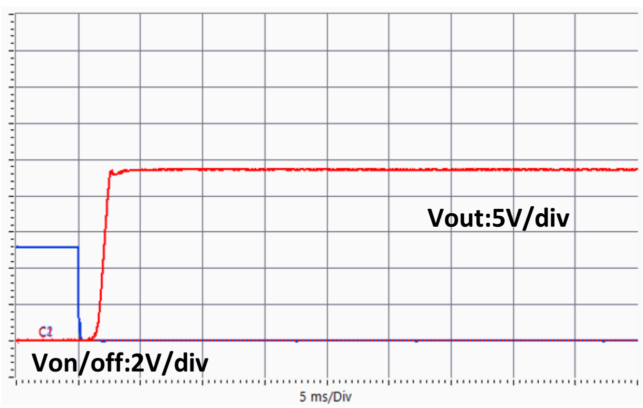
## Typical Waveforms: i9C4W030A480V PHEPT Mode Vo_L= 20V Vo_H = 28V



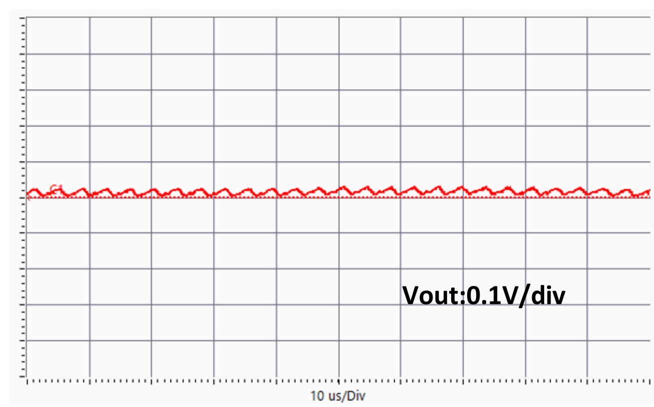

Typical Output ripple with 12V input, 20 V output, 14A load and Cout = Comin at Ta = 25 °C.



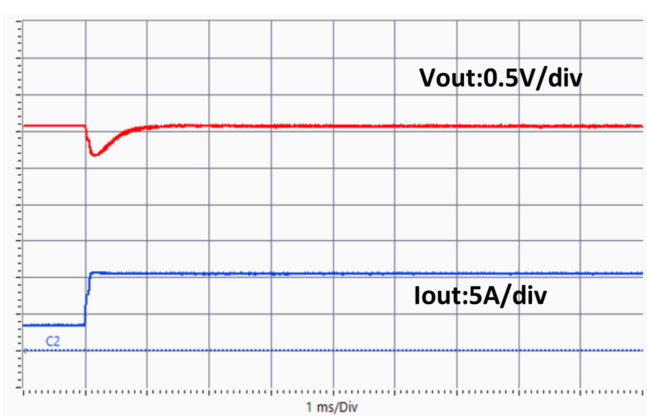

Typical Output ripple with 24V input, 24 V output, 30A load and Cout = Comin at Ta = 25 °C.




Typical startup characteristic from On/Off with 24V input, 24V output at full load; Cout = Comin at Ta = 25 °C. Ch1 red = Vout, Ch2 = On/off.



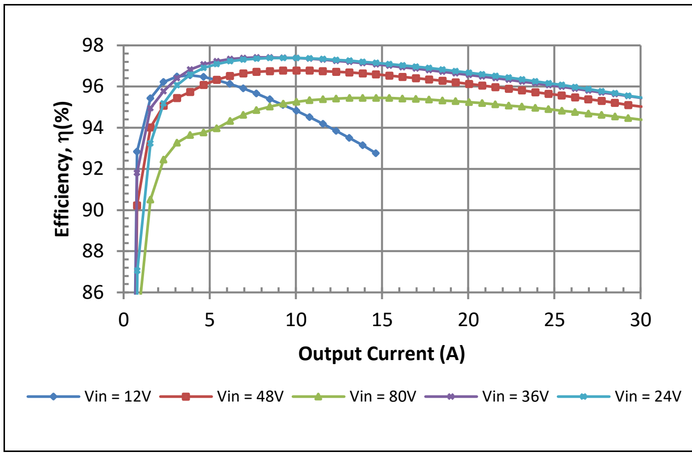

Typical Output ripple with 48V input, 28 V output, 30A load and Cout = Comin at Ta = 25 °C.



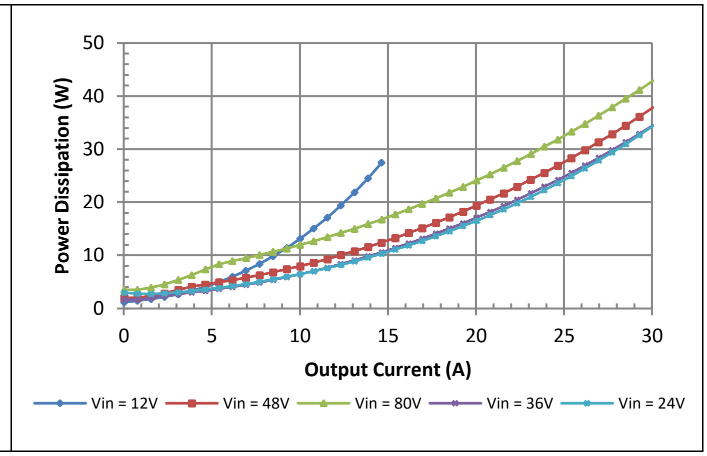

Typical Load transient response with step-up mode;
Load Step from 3.5A to 10.5A
Vin=12V, Vo=20V Cout = 3 x 330uF electrolytic cap


Mode Transition:
Step-up -> Pass-Thru -> Step-down
SW2 = boost power mosfet, SW1 = buck power mosfet

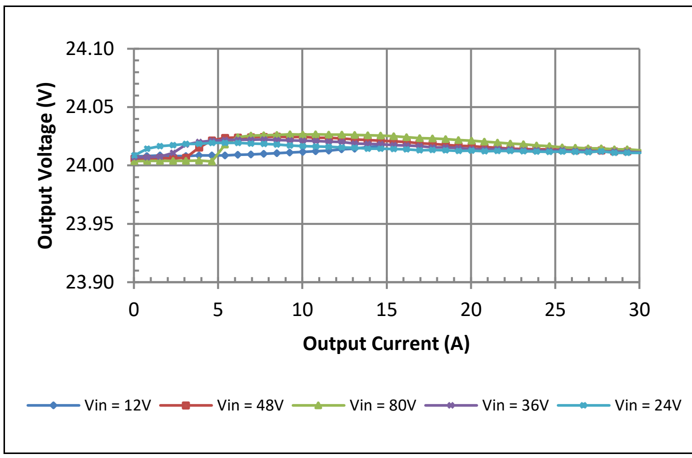
## Static Characteristic: i9C4W030A480V_Fully Regulated Mode Vo = 24V



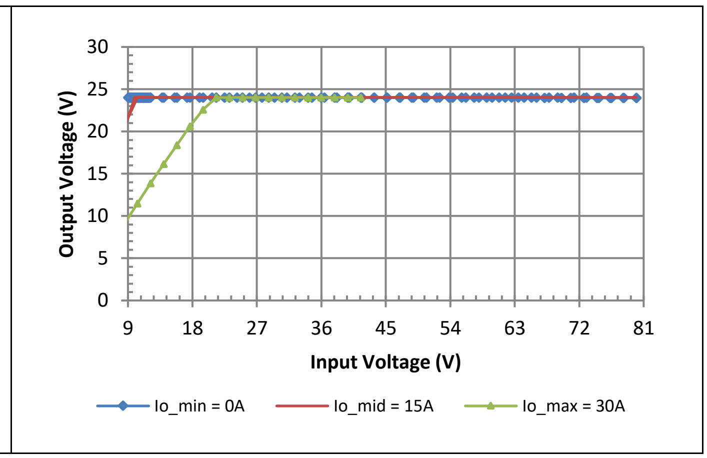

Typical efficiency versus output current at Tamb = 25 ˚C.



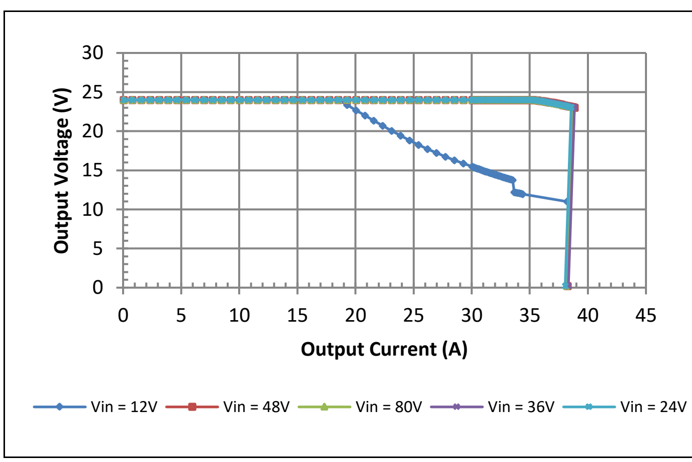

Typical power dissipation versus output current at Tamb = 25 ˚C.



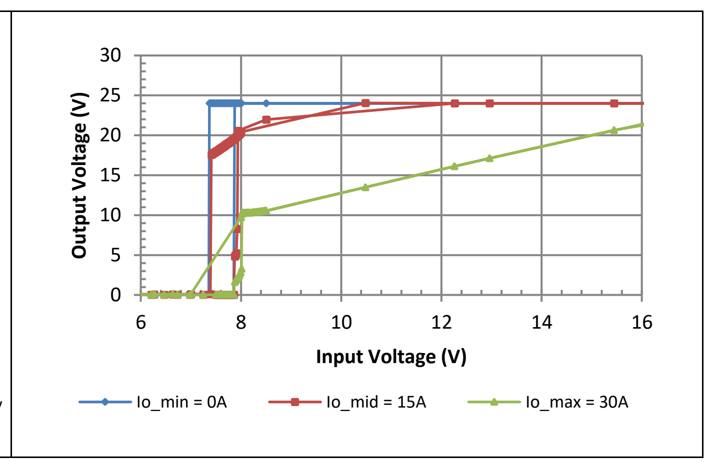

Typical load regulation at 25 ˚C.




Typical line regulation at 25 ˚C.

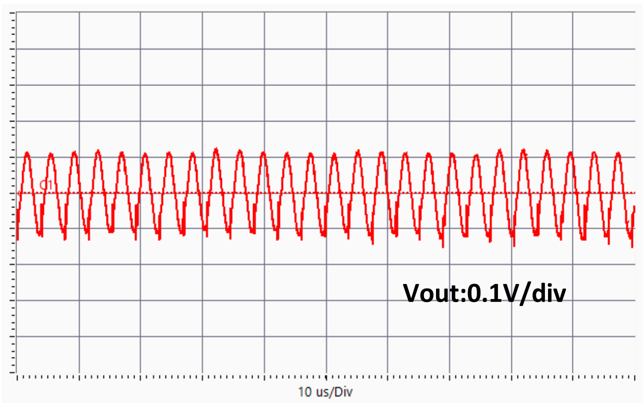



Typical Output voltage versus Output Current characteristics at 25 ˚C with Itrim tied to SGND pin.

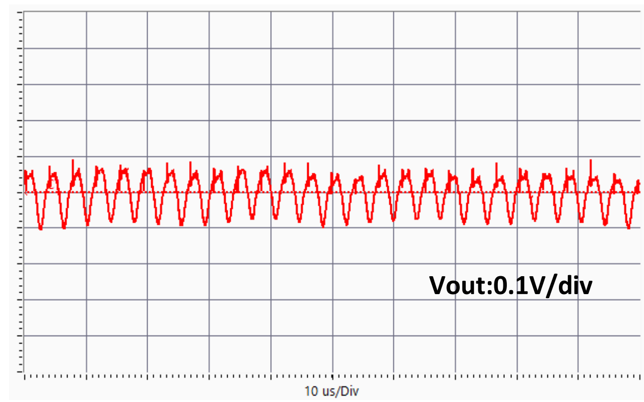



Typical UVLO characteristics, Input Voltage versus Output Voltage at 25 ˚C.

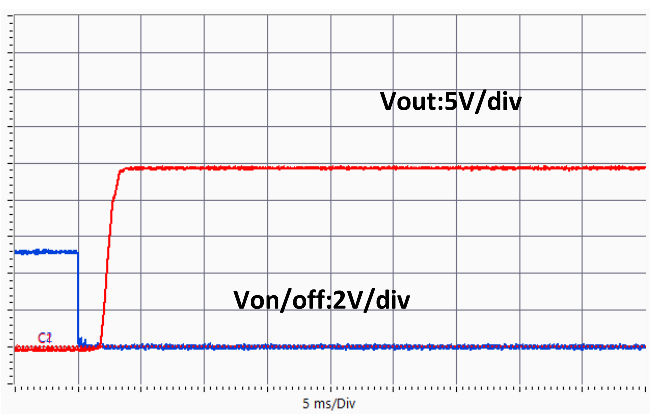
# Typical Waveforms: i9C4W030A480V_Fully Regulated Mode Vo = 24V



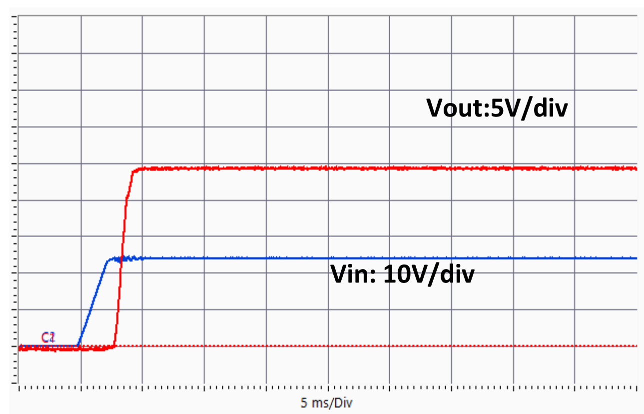

Typical Output ripple with 24V input, 24 V output, 30A load and Cout = Comin at Ta = 25 °C.



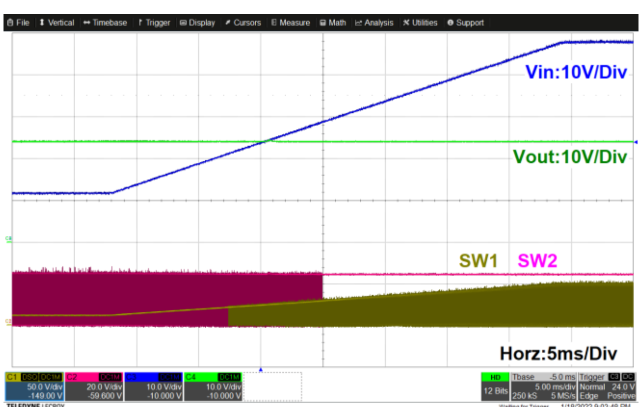

Typical Output ripple with 48V input, 24 V output, 30A load and Cout = Comin at Ta = 25 °C.



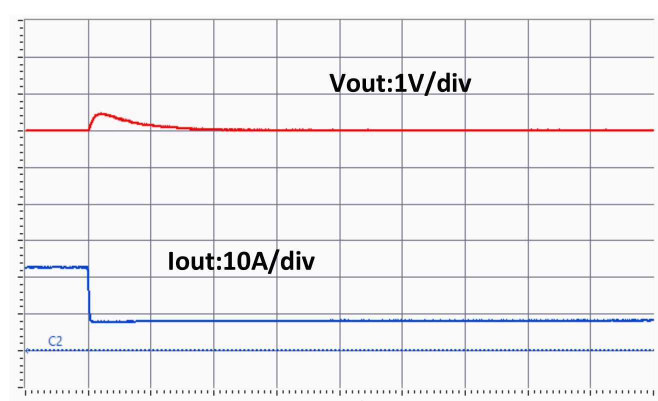

Typical startup characteristic from On/Off with 24V input, 24V output at full load; Cout = Comin at Ta = 25 °C. Ch1 = Vout, Ch2 = On/Off.




Typical startup characteristic from Input Voltage application with 24V input, 24V output at full load; Cout = Comin at Ta = 25°C. Ch1 = Vout, Ch2 = Vin.

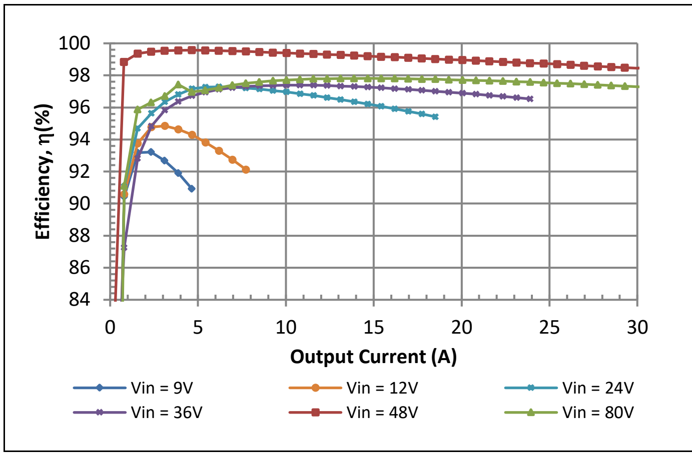



Mode Transition: Non-Pass-thru
Works as standard Step-up/Step-down Converter
SW2 = boost power mosfet, SW1 = buck power mosfet

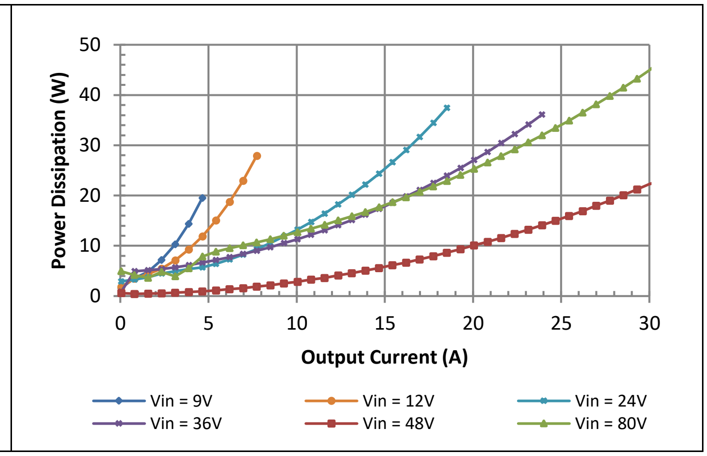



Typical Load transient response with step-up mode;
Load Step from 22.5A to 7.5A
Vin=48V, Vo=24V Cout = 3 x 330uF electrolytic cap

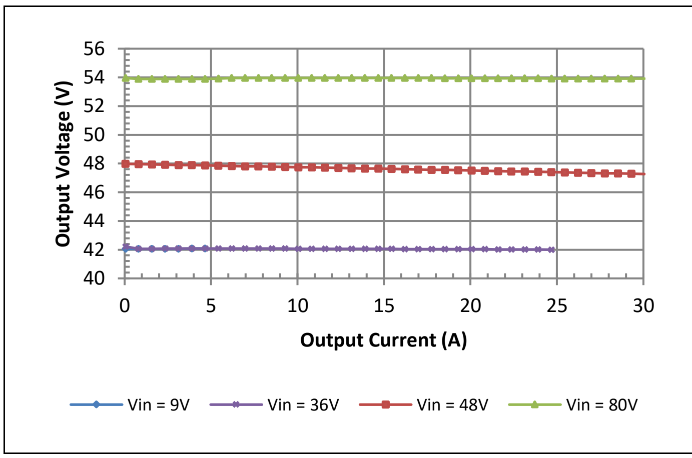
## <u>Static Characteristic</u>: i9C4W030A480V PHEPT Mode Vo_L= 42V Vo_H = 54V



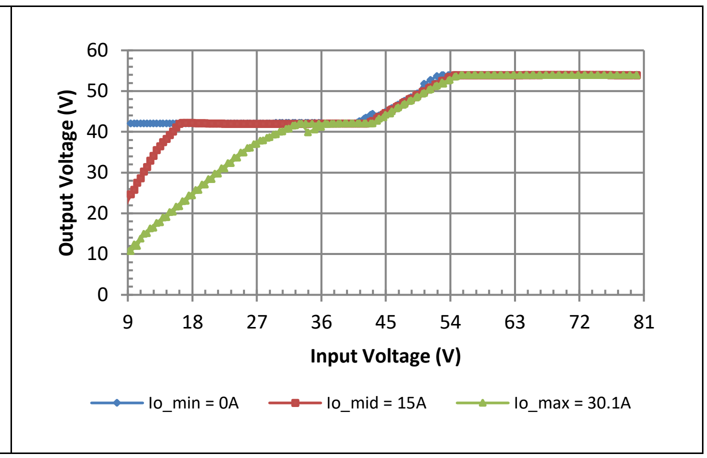

Typical efficiency versus output current at Tamb = 25 ˚C.



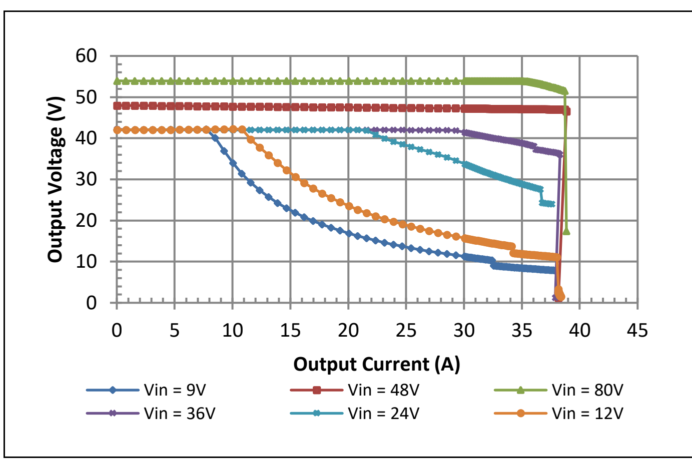

Typical power dissipation versus output current at Tamb = 25 ˚C.



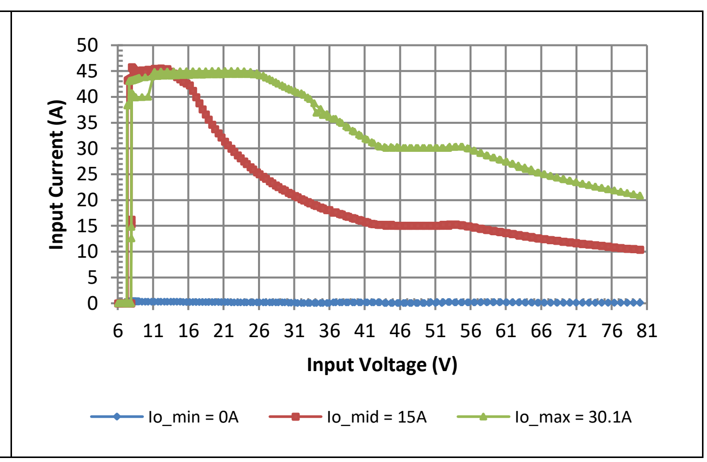

Typical load regulation at 25 ˚C.




Typical line regulation at 25 ˚C.

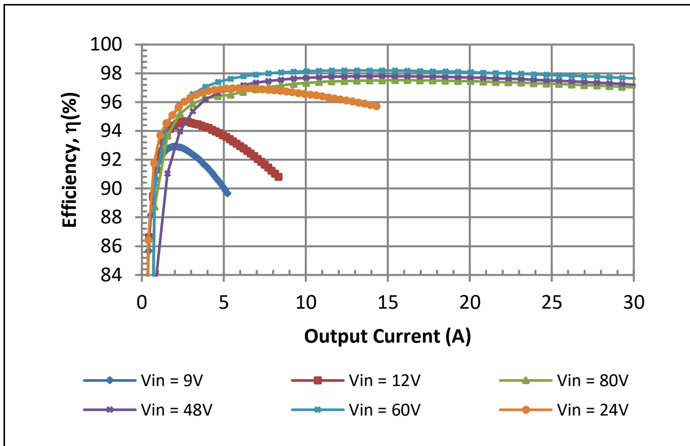



Typical Output voltage versus Output Current characteristics at 25 ˚C with Itrim tied to SGND pin.

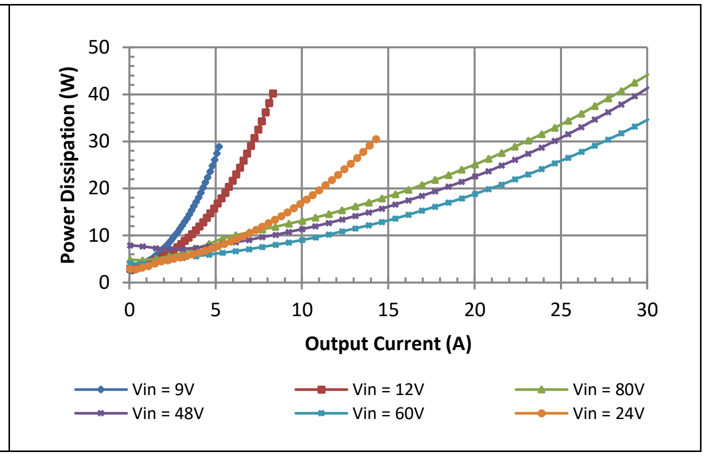



Typical Input current versus input voltage at 25 ˚C

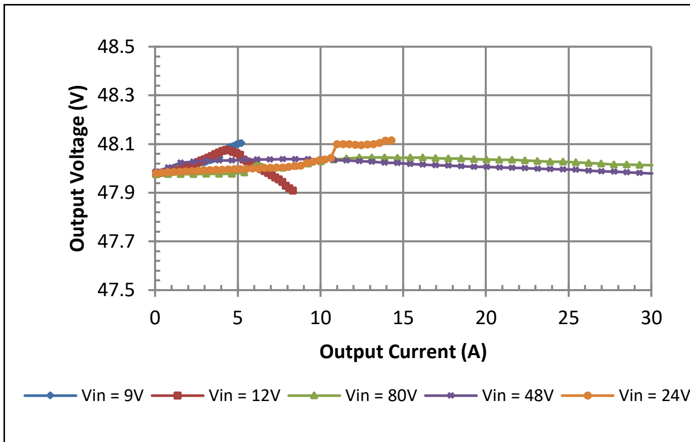
## Static Characteristic: i9C4W030A480V_Fully Regulated Mode Vo = 48V



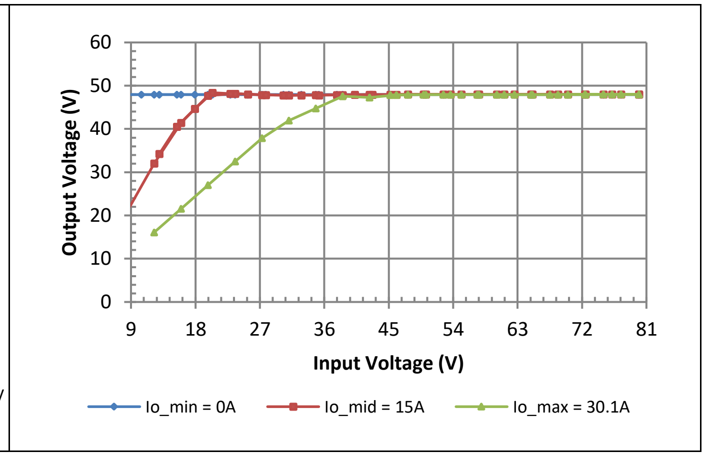
Typical efficiency versus output current at Tamb = 25 ˚C.



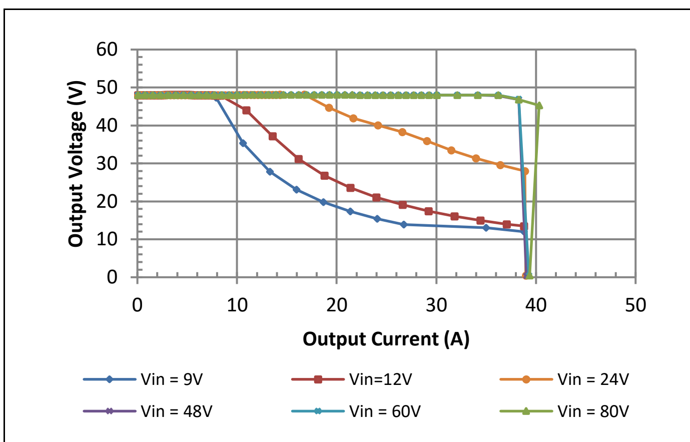
Typical power dissipation versus output current at Tamb = 25 ˚C.



Typical load regulation at 25 ˚C.



Typical line regulation at 25 ˚C.



Typical Output voltage versus Output Current characteristics at 25 ˚C with Itrim tied to SGND pin.

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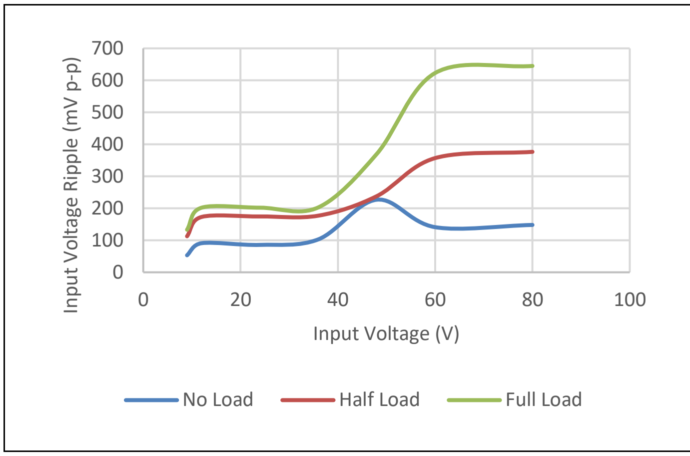
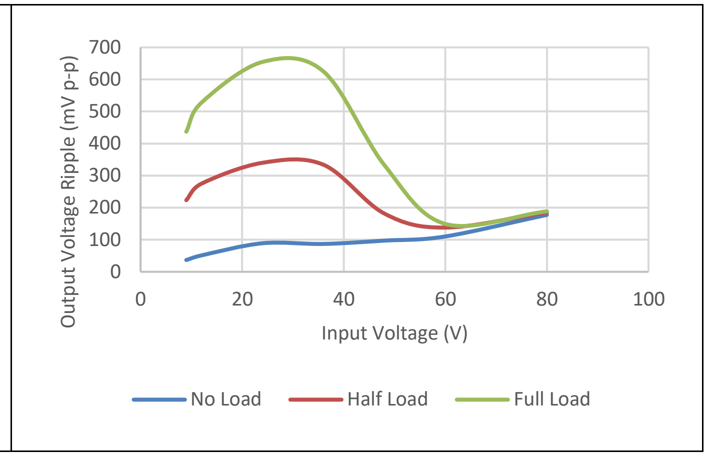
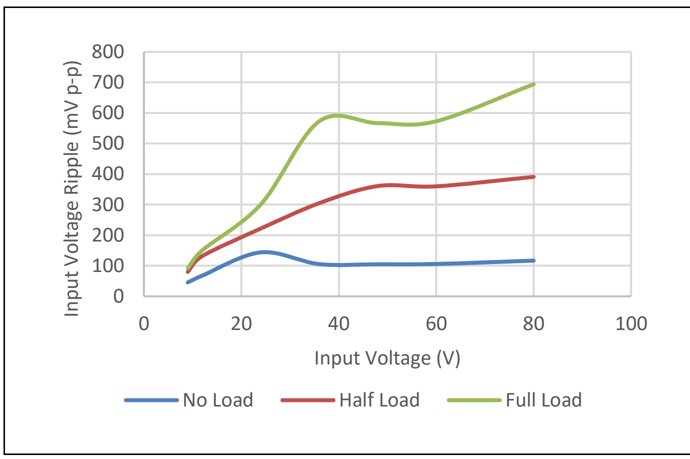
## Typical Noise Characteristics:



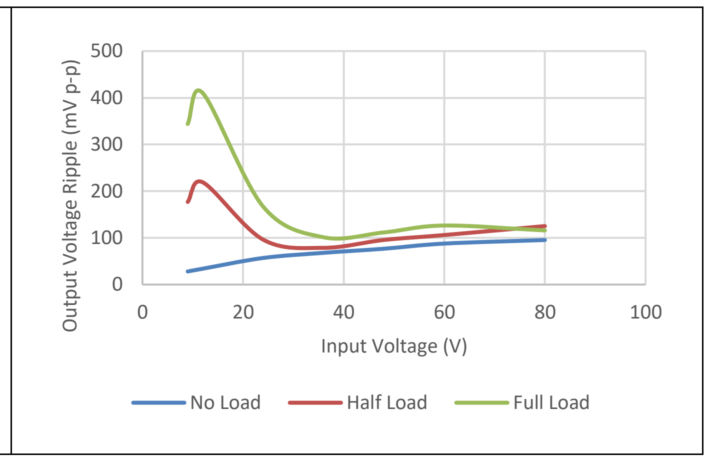

Typical Input ripple fully regulated mode Vo = 48V.



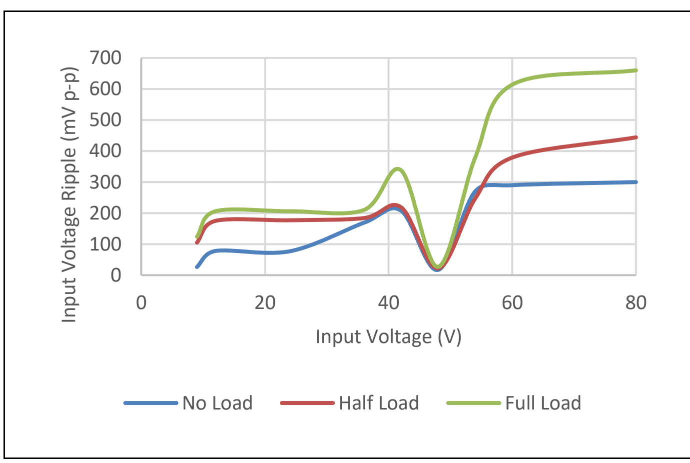

Typical Output ripple fully regulated mode Vo = 48V.



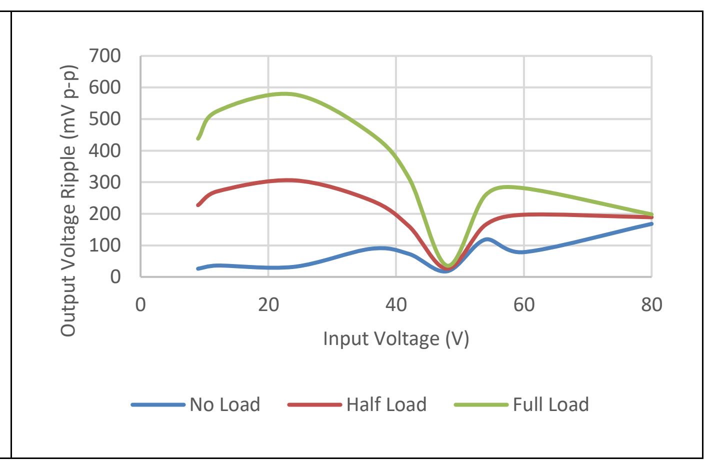

Typical Input ripple fully regulated mode Vo = 24V.




Typical Output ripple fully regulated mode Vo = 24V.




Typical Input ripple PHEPT mode Vo_L= 42V  Vo_H = 54V.

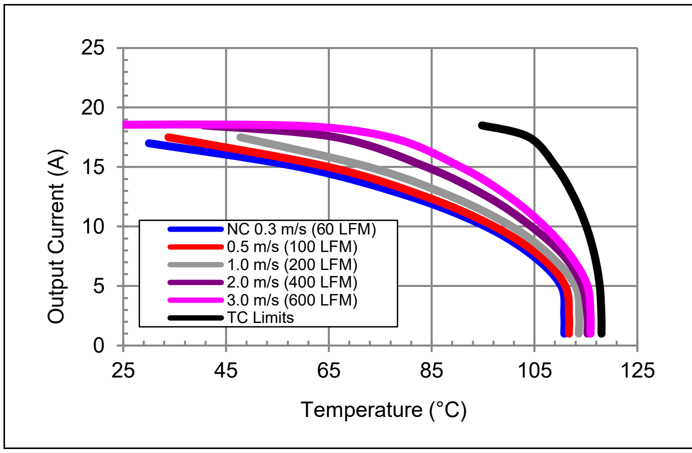



Typical Output ripple PHEPT mode Vo_L= 42V  Vo_H = 54V.

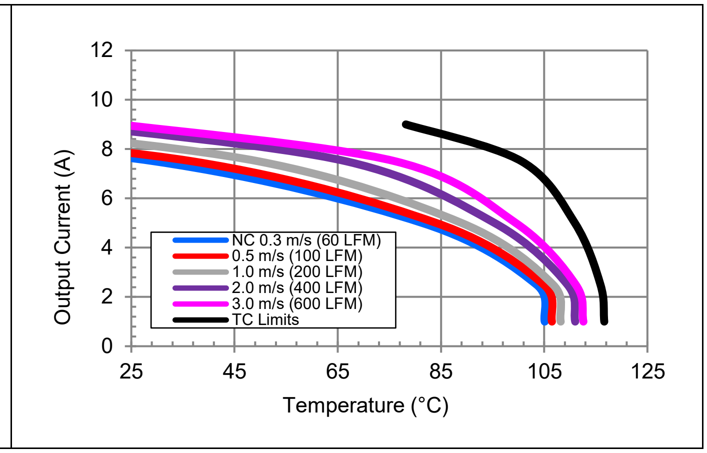
Charts based on typical data collected at room temperature on TDK-Lambda evaluation board with:
Cinput = 6 x 22uF ceramic, 2 x 10uF ceramic, 2 x 470uF electrolytic and Coutput = 4 x 22uF ceramic, 2 x 470uF electrolytic

## Thermal Performance: i9C4W030A480V PHEPT Mode

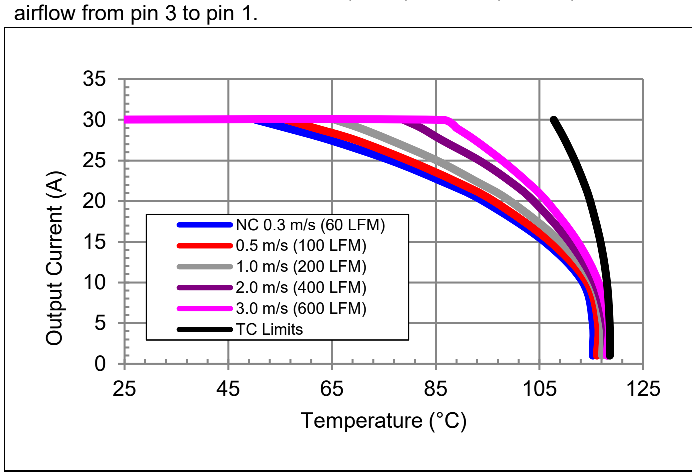
**Vo_L= 20V Vo_H = 28V** | **Vo_L= 42V Vo_H = 54V**



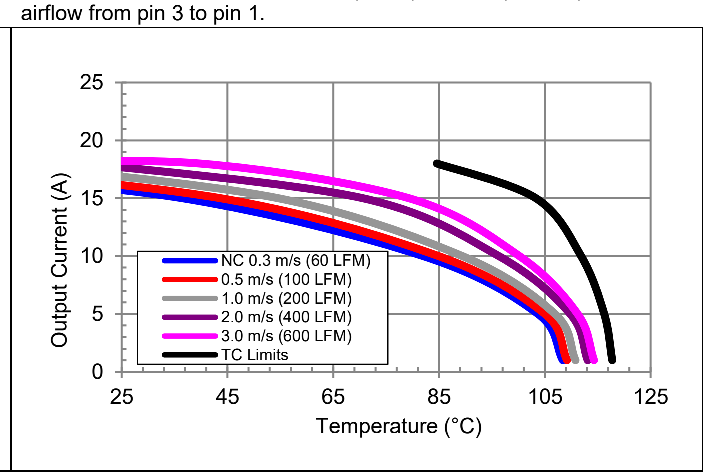

Vin=12V, Vo=20V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



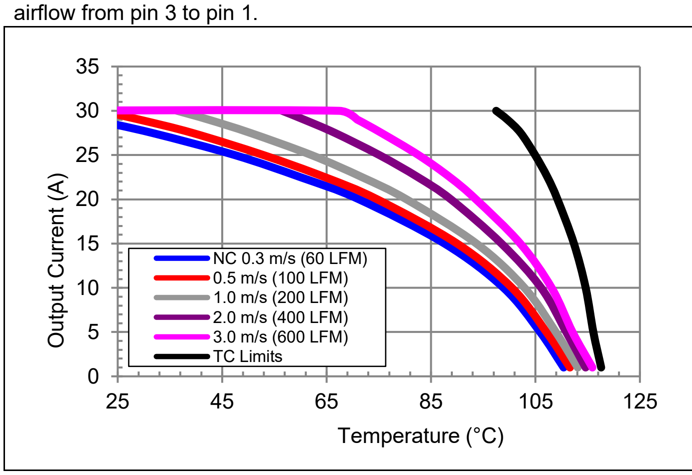

Vin=12V, Vo=42V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



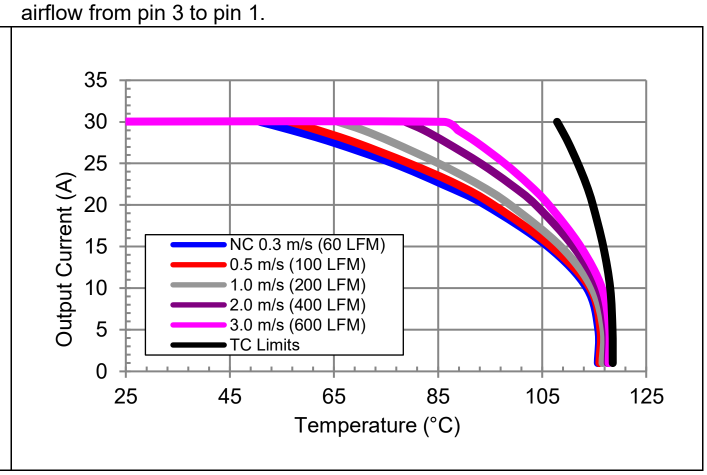

Vin=24V, Vo=24V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.




Vin=24V, Vo=42V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



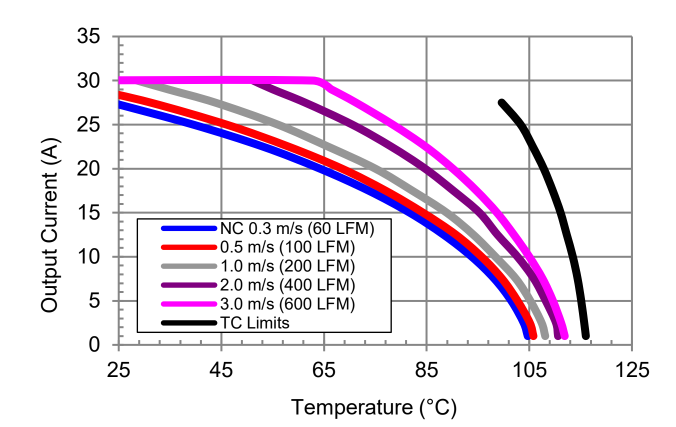

Vin=48V, Vo=28V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



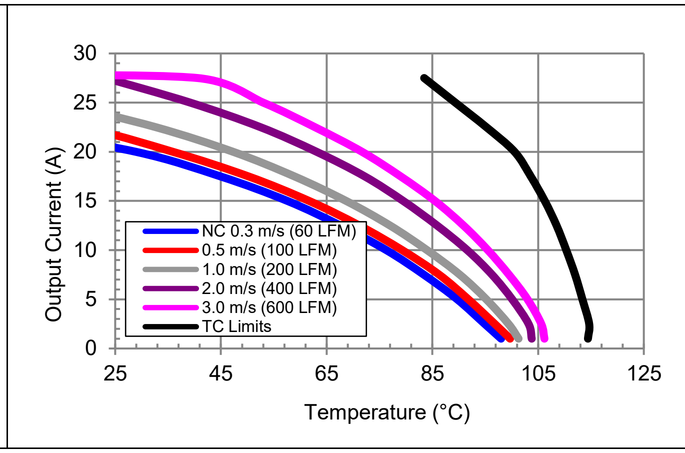

Vin=48V, Vo=48V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.

## Thermal Performance: i9C4W030A480V PHEPT Mode

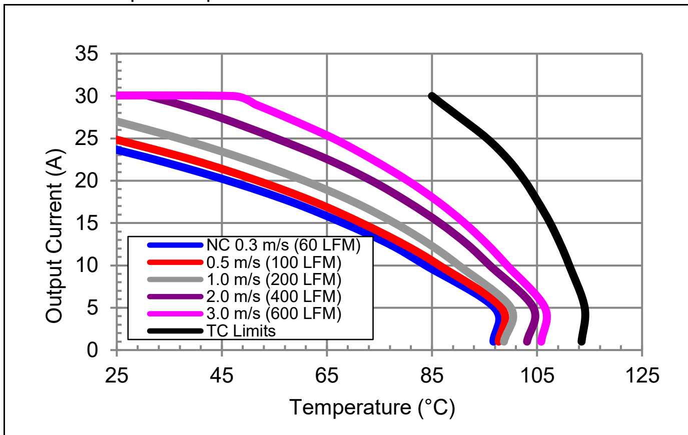
**Vo_L= 20V Vo_H = 28V** **Vo_L= 42V Vo_H = 54V**



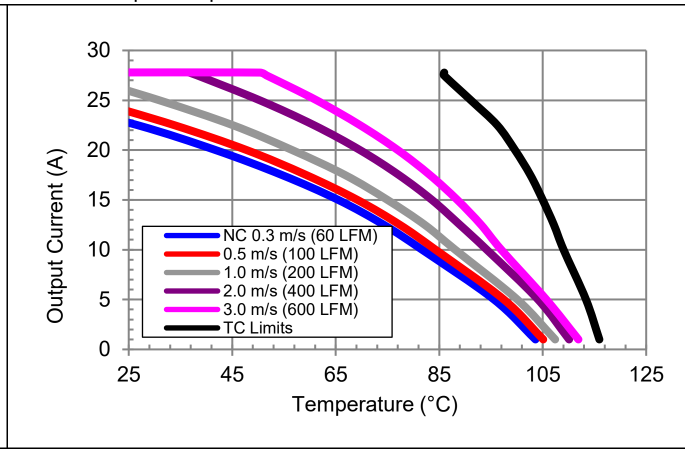

Vin=60V, Vo=28V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



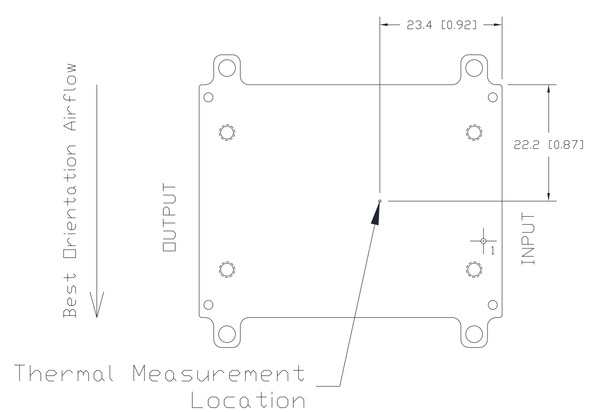

Vin=60V, Vo=54V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.




Vin=80V, Vo=28V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.




Vin=80V, Vo=54V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.




Thermal Measurement Location

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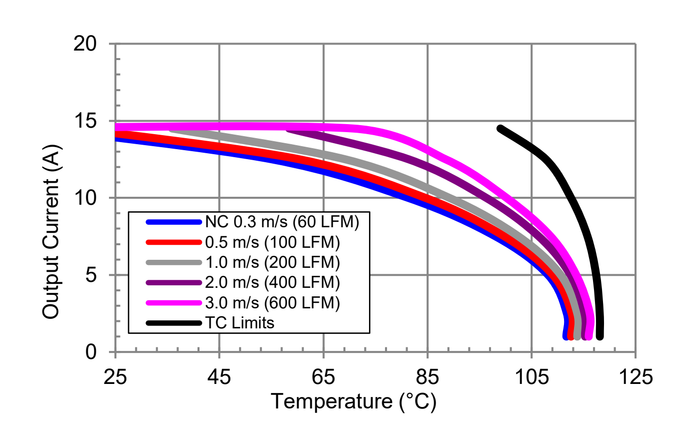
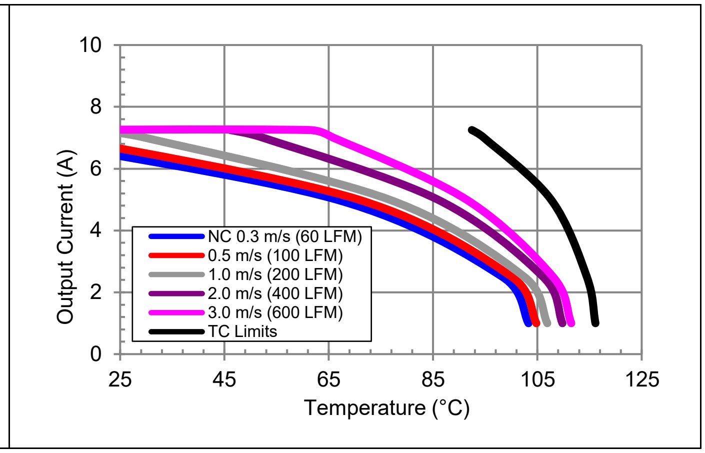
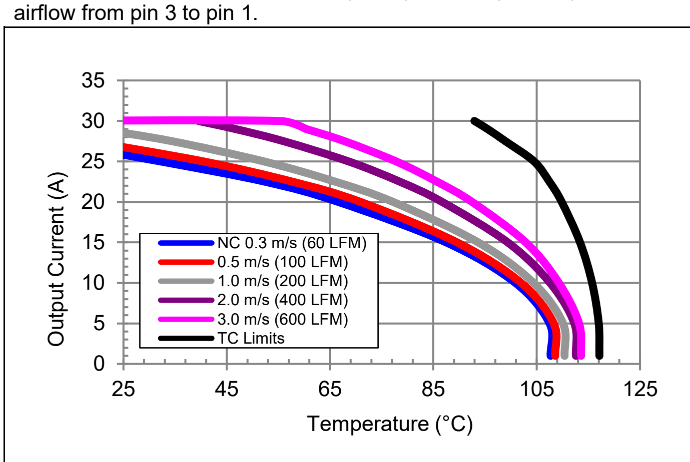
## Thermal Performance: i9C4W030A480V_Fully Regulated Mode



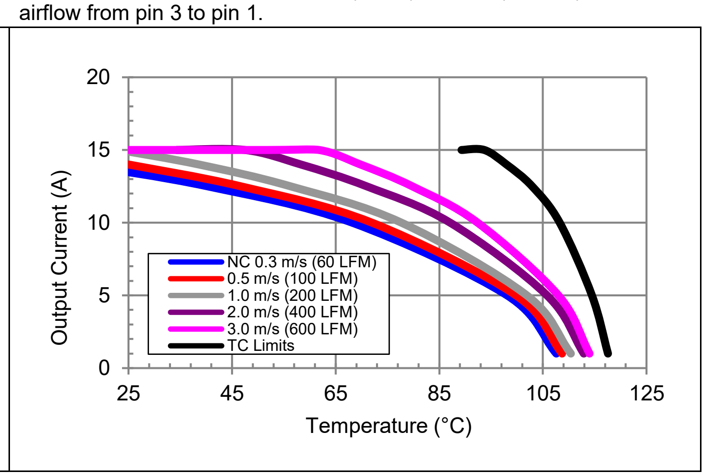

Vin=12V, Vo=24V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



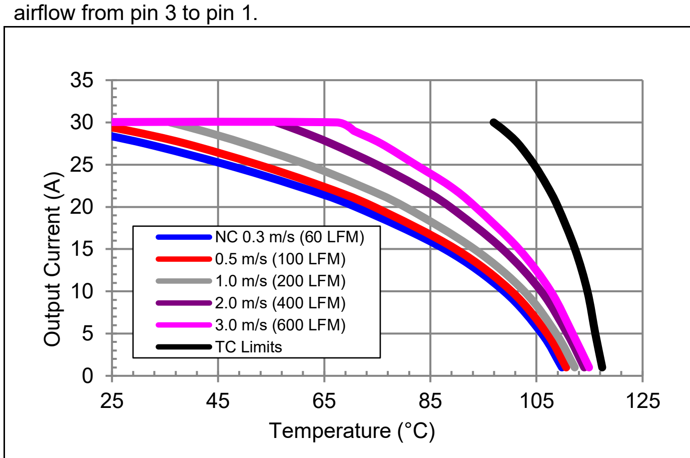

Vin=12V, Vo=48V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



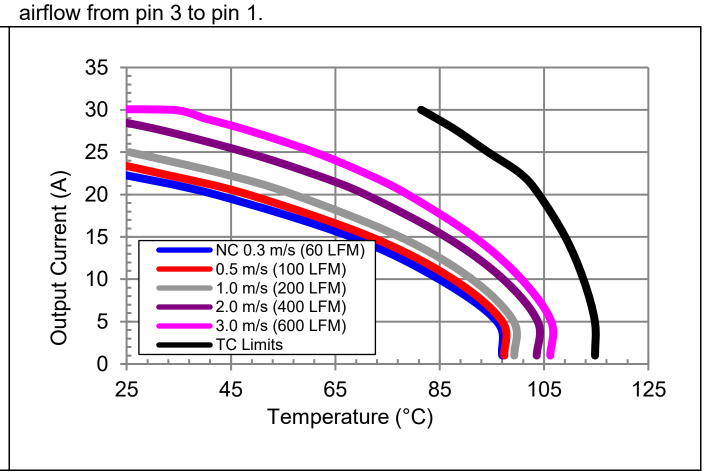

Vin=24V, Vo=24V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.




Vin=24V, Vo=48V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



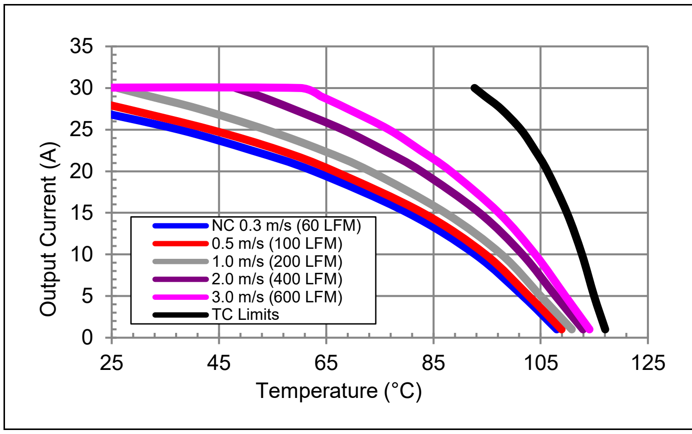

Vin=48V, Vo=24V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



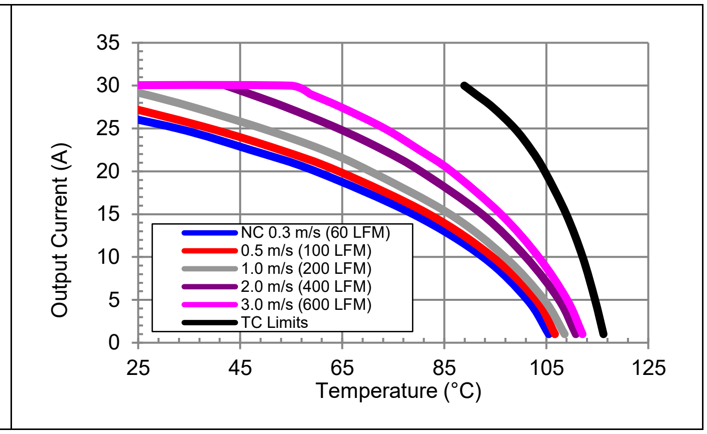

Vin=48V, Vo=48V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.

TDK·Lambda

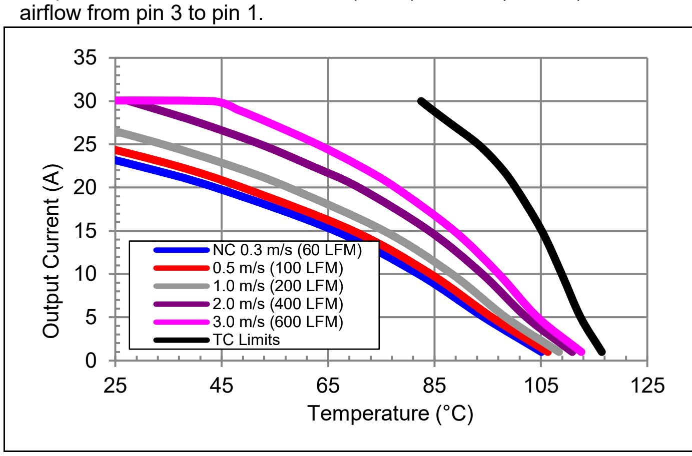
## Thermal Performance: i9C4W030A480V Fully Regulated Mode



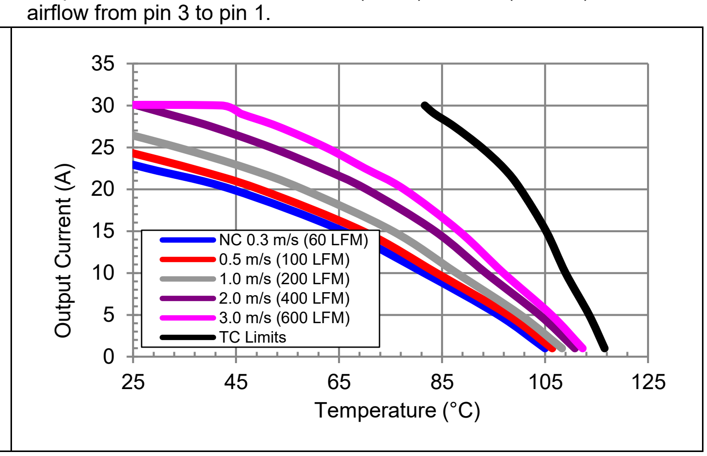

Vin=60V, Vo=24V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



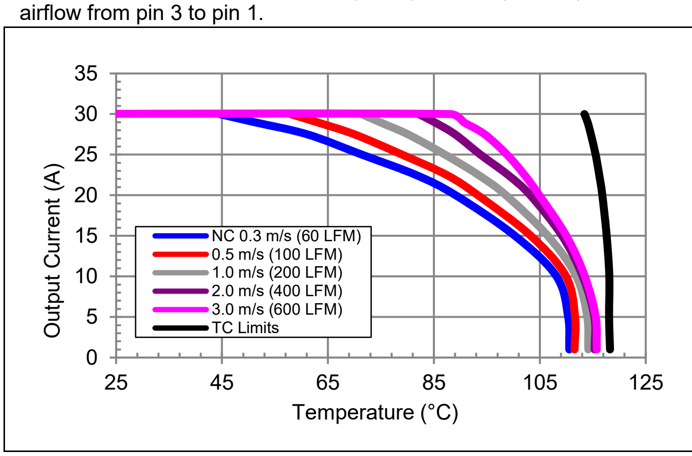

Vin=60V, Vo=48V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



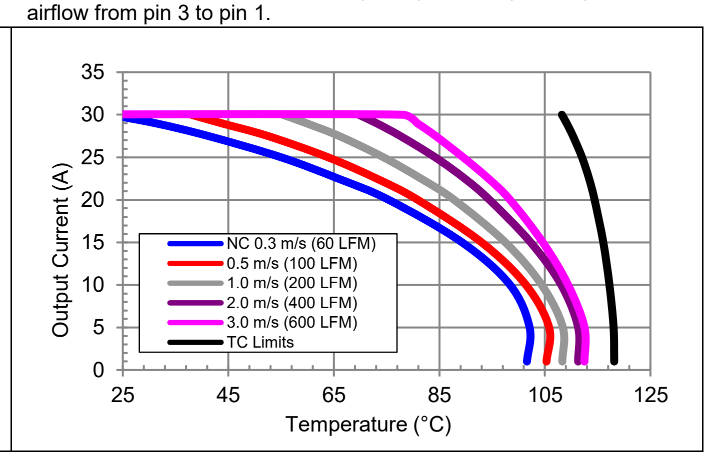

Vin=80V, Vo=24V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.




Vin=80V, Vo=48V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



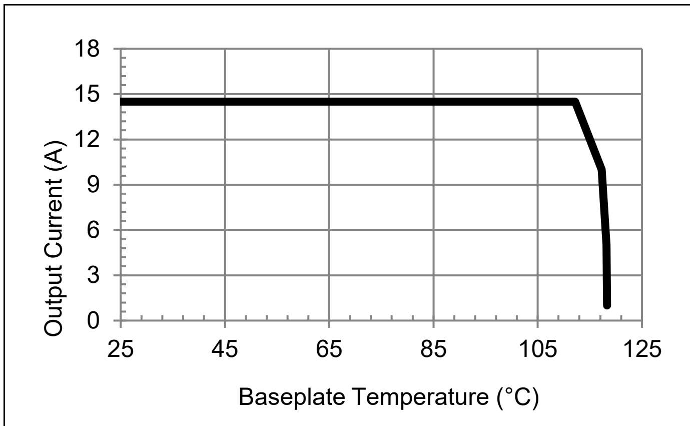

Vin=48V, Vo=24V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1 **with 1" transverse heatsink**.



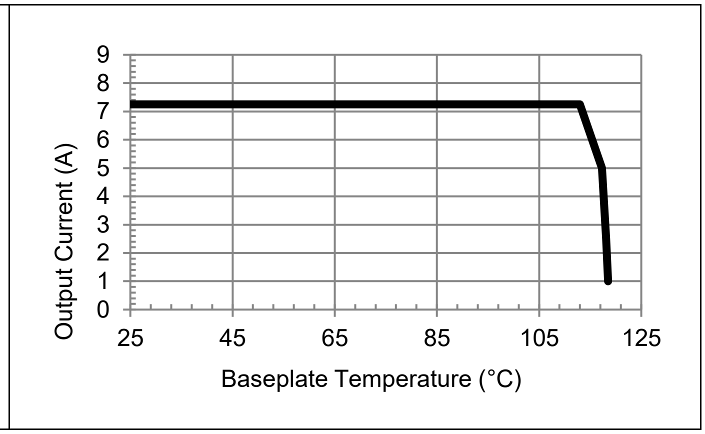

Vin=48V, Vo=48V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1 **with 1" transverse heatsink**.

The thermal curves provided are based on measurements made in TDK-Lambda's test setup that is described in the Thermal Management section. Due to the large number of variables in system design and the extremely wide operating range of the module. TDK-Lambda recommends that the user verify the module's thermal performance in the end application. The critical component should be thermocoupled, monitored and should not exceed the temperature limit specified in the derating curve above. It is critical that the thermocouple be mounted in a manner that gives direct thermal contact or significant measurement errors may result. TDK-Lambda can provide modules with a thermocouple pre-mounted to the critical component for system verification tests.

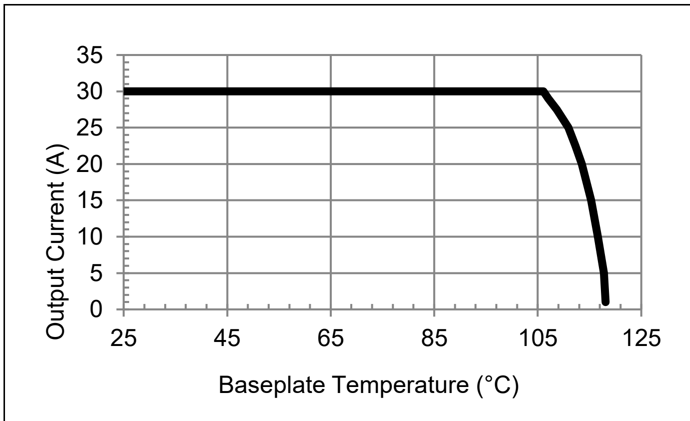
## Thermal Performance: i9C4W030A480V_Fully Regulated Mode_Conduction Cooling



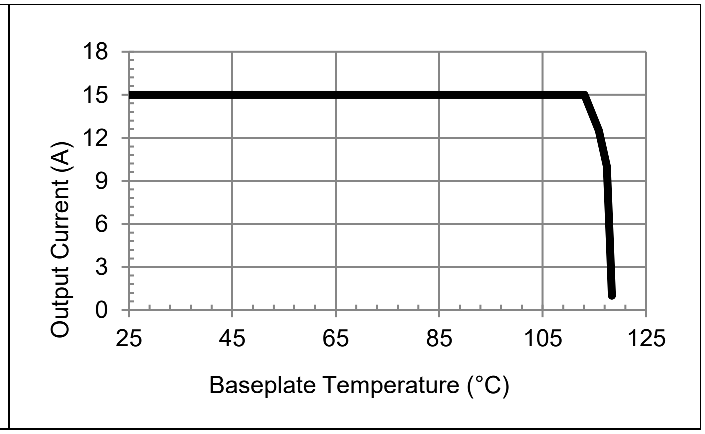

Vin=12V, Vo=24V preliminary maximum output current vs. baseplate temperature with enclosed environment and Ta = 85 ˚C.



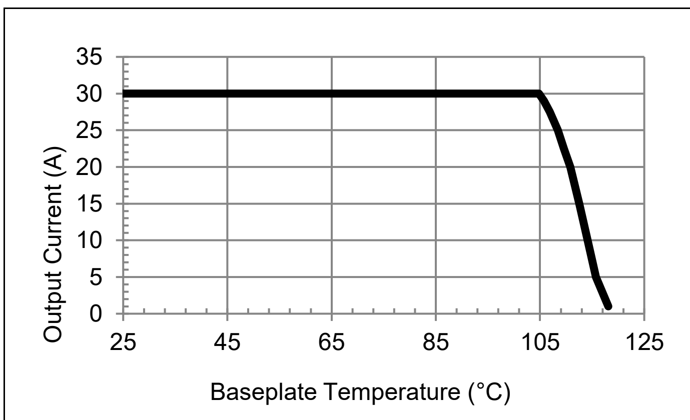

Vin=12V, Vo=48V preliminary maximum output current vs. baseplate temperature with enclosed environment and Ta = 85 ˚C.



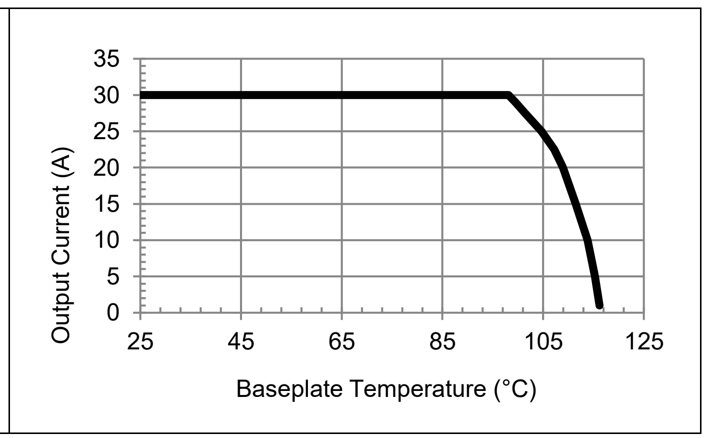

Vin=24V, Vo=24V preliminary maximum output current vs. baseplate temperature with enclosed environment and Ta = 85 ˚C.




Vin=24V, Vo=48V preliminary maximum output current vs. baseplate temperature with enclosed environment and Ta = 85 ˚C.




Vin=48V, Vo=24V preliminary maximum output current vs. baseplate temperature with enclosed environment and Ta = 85 ˚C.




Vin=48V, Vo=48V preliminary maximum output current vs. baseplate temperature with enclosed environment and Ta = 85 ˚C.

The thermal curves provided are based on measurements made in TDK-Lambda's test setup that is described in the Thermal Management section. Due to the large number of variables in system design and the extremely wide operating range of the module. TDK-Lambda recommends that the user verify the module's thermal performance in the end application. The critical component should be thermocoupled, monitored and should not exceed the temperature limit specified in the derating curve above. It is critical that the thermocouple be mounted in a manner that gives direct thermal contact or significant measurement errors may result. TDK-Lambda can provide modules with a thermocouple pre-mounted to the critical component for system verification tests.

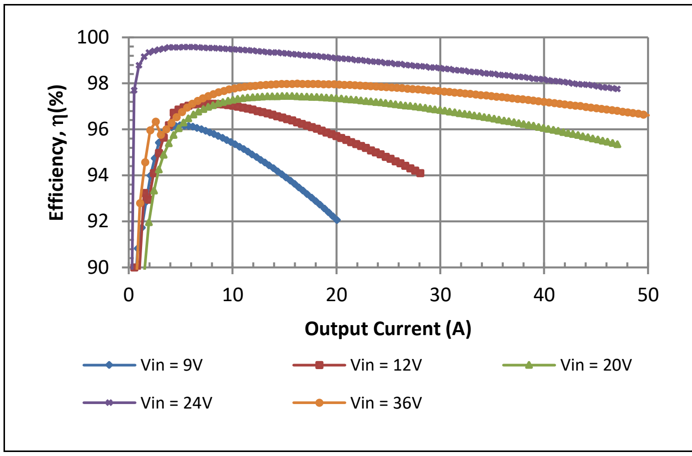
# Electrical Characteristics:

### i9C2W050A240V-xxx-R

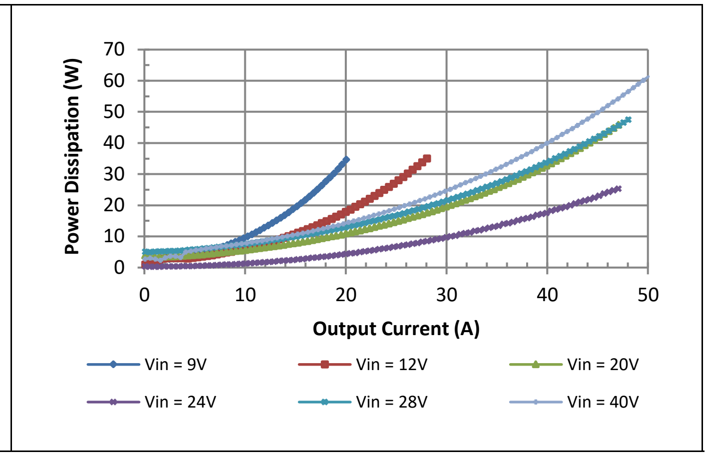
| Characteristic | Min | Typ | Max | Unit | Notes & Conditions |
|---|---|---|---|---|---|
| Output Voltage Initial Set point | -2.5 | - | +2.5 | % | Vin = Vin,nom; Io = Io,min, Tc = 25 ˚C |
| Output Voltage Tolerance | -4.0 | - | +4.0 | % | Over all rated line, load, temperature conditions to end of life |
| Efficiency Vo = 20V<br>(20V-28V pass-thru) Vo = 24V<br>Vo = 28V | ---<br>---<br>--- | 94<br>97.5<br>96.5 | ---<br>---<br>--- | %<br>%<br>% | Vin=12V; Io=Io,max; Tc = 25˚C<br>Vin=24V; Io=Io,max; Tc = 25˚C<br>Vin=36V; Io=Io,max; Tc = 25˚C |
| Efficiency Vo = 12V<br>(10V-14V pass-thru) Vo = 14V<br>Vo = 14V | ---<br>---<br>--- | 94<br>93.5<br>92 | ---<br>---<br>--- | %<br>%<br>% | Vin=12V; Io=Io,max; Tc = 25˚C<br>Vin=24V; Io=Io,max; Tc = 25˚C<br>Vin=36V; Io=Io,max; Tc = 25˚C |
| Efficiency Vo = 12V | ---<br>---<br>--- | 92.5<br>92<br>90 | ---<br>---<br>--- | %<br>%<br>% | Vin=12V; Io=Io,max; Tc = 25˚C<br>Vin=24V; Io=Io,max; Tc = 25˚C<br>Vin=36V; Io=Io,max; Tc = 25˚C |
| Efficiency Vo = 24V | ---<br>---<br>--- | 94<br>96<br>95 | ---<br>---<br>--- | %<br>%<br>% | Vin=12V; Io=Io,max; Tc = 25˚C<br>Vin=24V; Io=Io,max; Tc = 25˚C<br>Vin=36V; Io=Io,max; Tc = 25˚C |
| Line Regulation | --- | 0.2 | --- | % | Vin = Vin,min to Vin,max |
| Load Regulation | --- | 0.5 | --- | % | Iout = Io,min to Io,max |
| Output Current | 0 | --- | 50 | A | Observe maximum power limit. Allowable output current varies with input voltage, please refer to operating range chart. |
| Output Current Limiting Threshold | --- | 65 | --- | A | Itrim: short to SGND |
| Short Circuit Current | --- | 60 | --- | A | Itrim: short to SGND |
| Output Ripple and Noise Voltage*<br>Step down : 40Vin, 24Vo, 50A<br>Step up : 12Vin, 24Vo, 20A | <br>---<br>--- | <br>70<br>250 | <br>---<br>--- | <br>mVpp<br>mVpp | Across 2 x 22uF ceramic and Co,min |
| Dynamic Response*<br>Recovery Time<br>Transient Voltage | <br>---<br>--- | <br>1<br>4 | <br>---<br>--- | <br>ms<br>% | di/dt =1A/us, Vin=36; Vo=24V, load step from 25% to 75% of Io,max.<br>Cout = Cout,min |
| Switching Frequency | --- | 260 | --- | kHz | |
| External Load Capacitance | 1000 | --- | 10000* | µF | If operating in range where input and output voltage are both near the minimum specified value, use of an output capacitance above the minimum is recommended |
| Output Voltage Adjustment Range | 5 | --- | 36 | V | |
| Programmable high efficiency pass-through Voltage range | +/-10 | --- | --- | % | Configured by TrimH/TrimL |
| Output Voltage Sense Range | --- | --- | 5 | % | |
| Vref | --- | 1.0 | --- | V | Required for trim calculation |
| Vo,nom | --- | 4.03 | --- | V | Required for trim calculation |
| Vo,short | --- | 54 | --- | V | Required for trim calculation |
| F | --- | 10000 | --- | Ω | Required for trim calculation |
| G | --- | 200 | --- | Ω | Required for trim calculation |

*Due to the extremely wide range of input and output conditions, i9C performance such as output ripple and transient voltage behavior can vary significantly from application to application. Please confirm performance in actual use case. TDK-Lambda can assist with selection of external components. Please contact technical support, especially if very low ESR capacitor banks or values beyond the listed range are required.

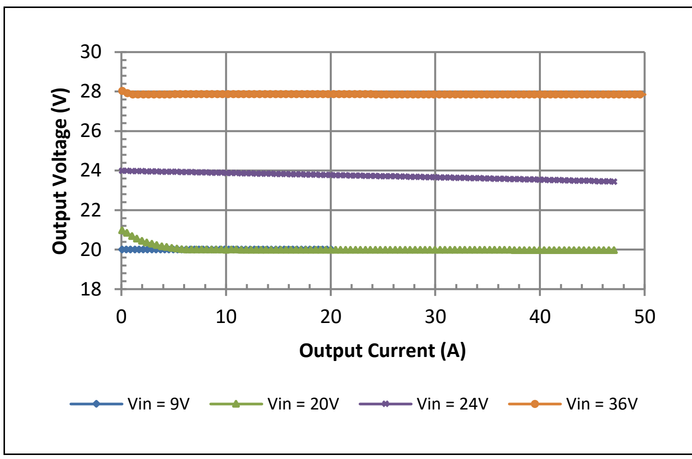
## Static Characteristic: i9C2W050A240V PHEPT Mode Vo_L= 20V Vo_H = 28V



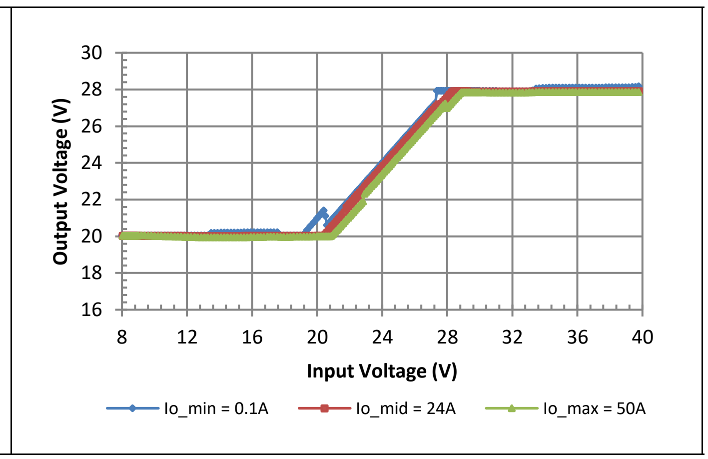

Typical efficiency versus output current at Tamb = 25 ˚C.



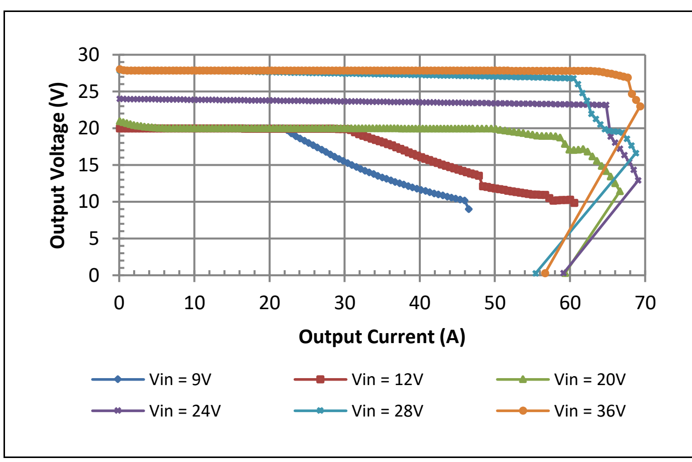

Typical power dissipation versus output current at Tamb = 25 ˚C.



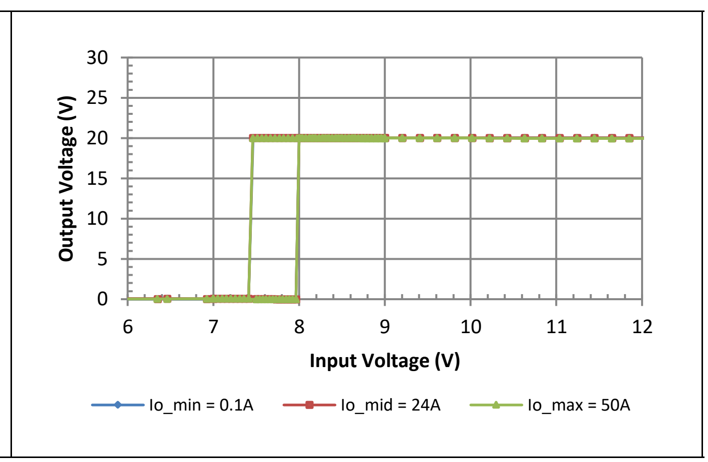

Typical load regulation at 25 ˚C.




Typical line regulation at 25 ˚C.

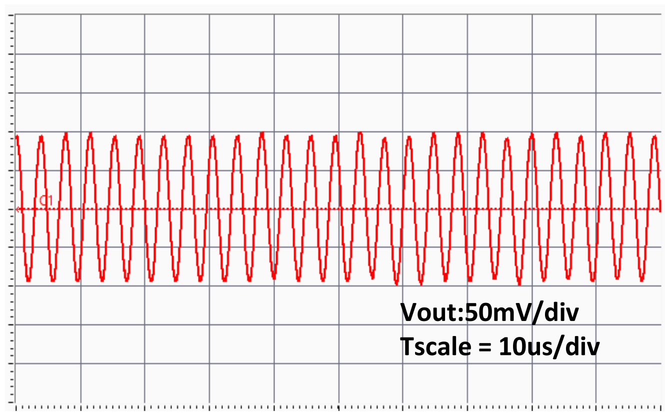



Typical Output voltage versus Output Current characteristics at 25 ˚C with Itrim tied to SGND pin.

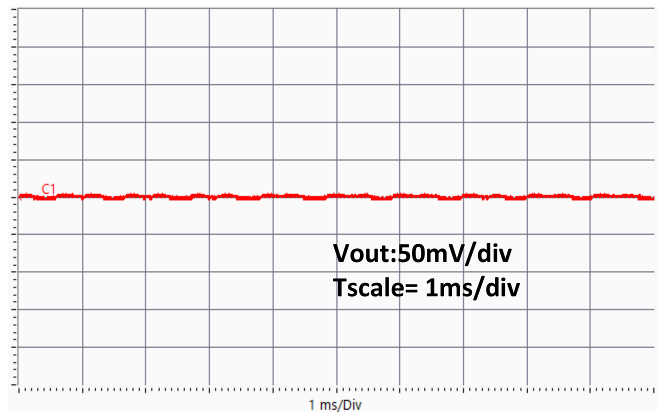



Typical UVLO characteristics, Input Voltage versus Output Voltage at 25 ˚C.

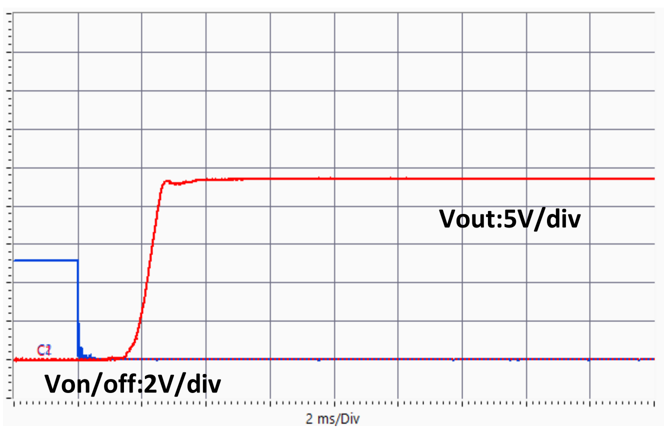
## Typical Waveforms: i9C2W050A240V  PHEPT Mode Vo_L= 20V  Vo_H = 28V



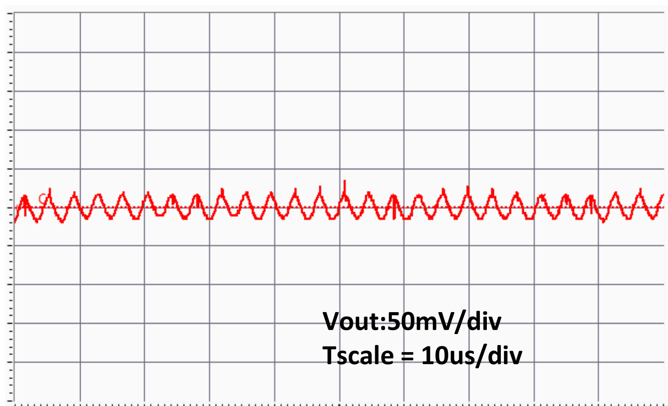

Typical Output ripple with 12V input, 20 V output, 25A load and Cout = Comin at Ta = 25°C.



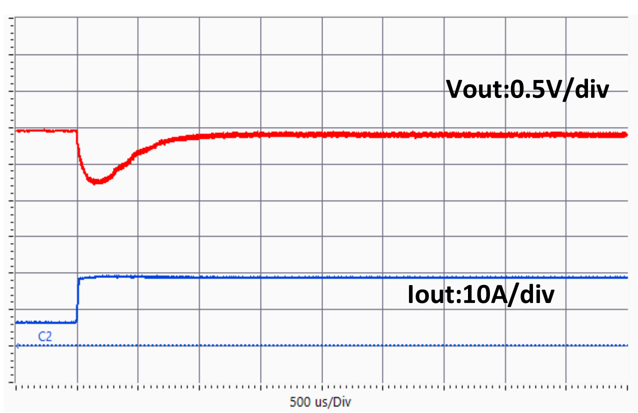

Typical Output ripple with 24V input, 24 V output, 45A load and Cout = Comin at Ta = 25°C.



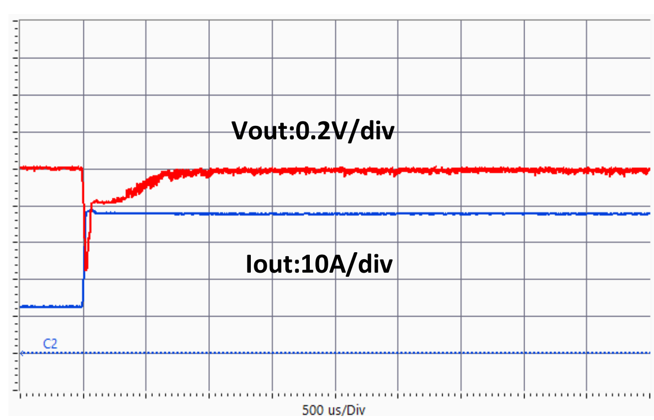

Typical startup characteristic from On/Off with 24V input, 24V output at full load; Cout = Comin at Ta = 25°C. Ch1 red = Vout, Ch2 = On/off.




Typical Output ripple with 40V input, 28 V output, 25A load and Cout = Comin at Ta = 25°C.

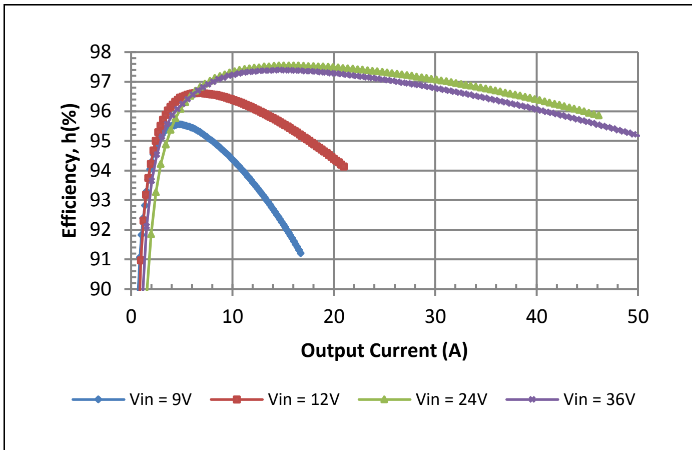



Typical Load transient response with step-up mode;
Load Step from 6.25A to 18.75A
Vin=12V, Vo=20V Cout = 3 x 330uF electrolytic cap

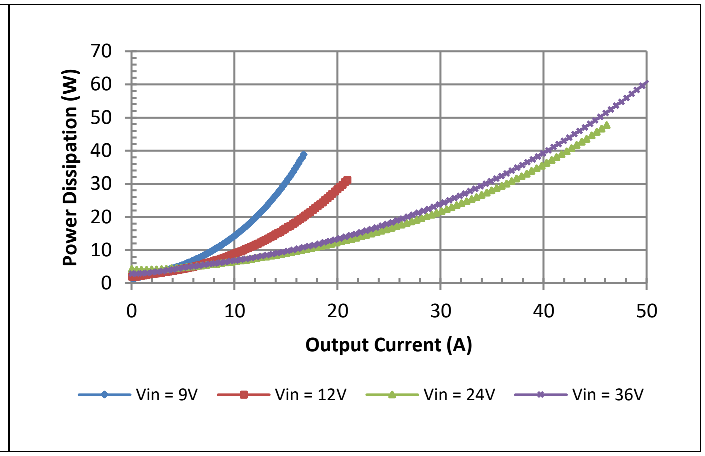



Typical Load transient response with step-down mode;
Load Step from 12.5A to 37.5A
Vin=36V, Vo=28V Cout = 3 x 330uF electrolytic cap

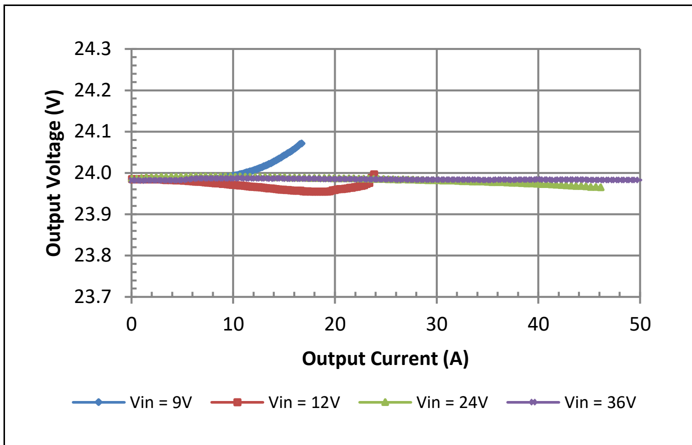
## Static Characteristic: i9C2W050A240V Fully Regulated Mode Vo = 24V



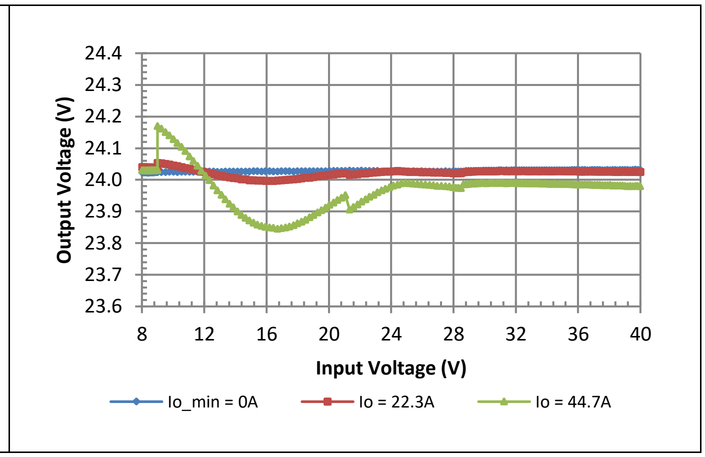

Typical efficiency versus output current at Tamb = 25 ˚C.



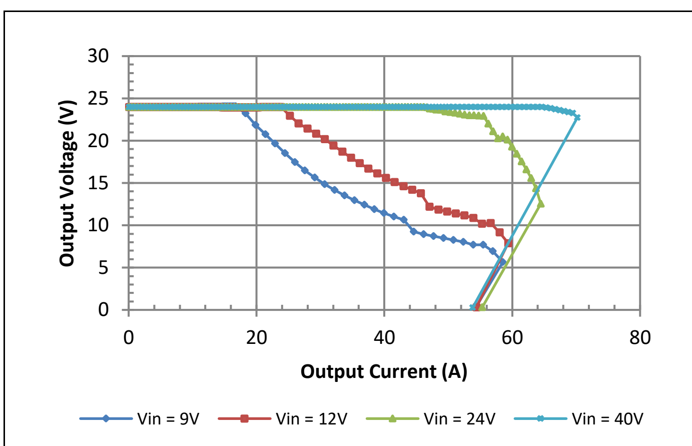

Typical power dissipation versus output current at Tamb = 25 ˚C.



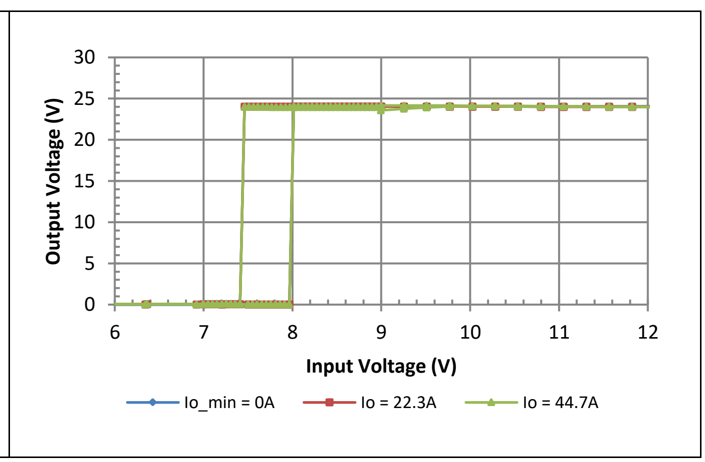

Typical load regulation at 25 ˚C.




Typical line regulation at 25 ˚C.

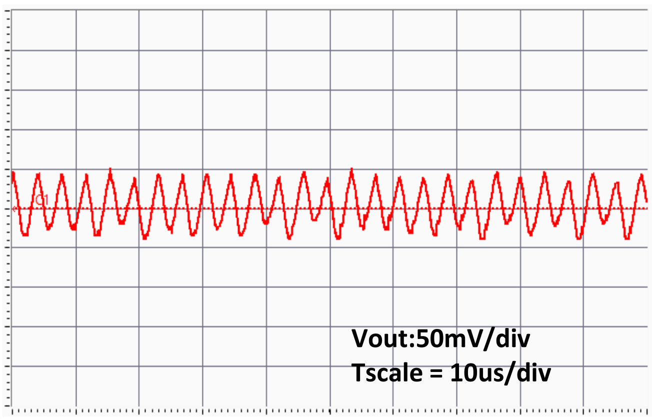



Typical Output voltage versus Output Current characteristics at 25 ˚C with Itrim tied to SGND pin.

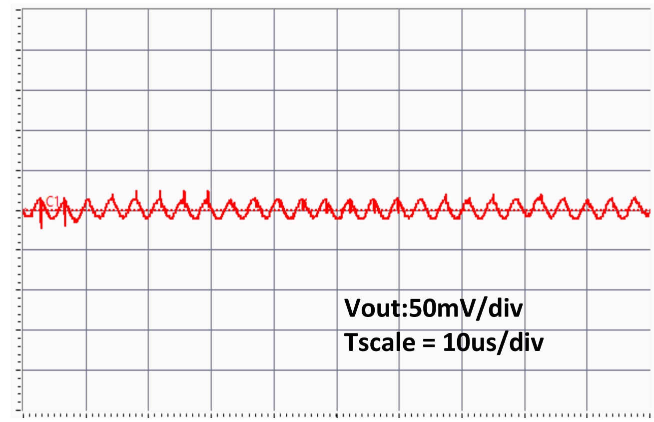



Typical UVLO characteristics, Input Voltage versus Output Voltage at 25 ˚C

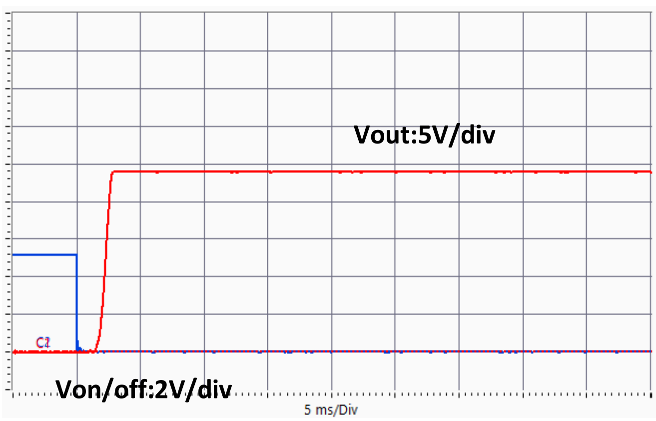
## Typical Waveforms: i9C2W050A240V Fully Regulated Mode Vo = 24V



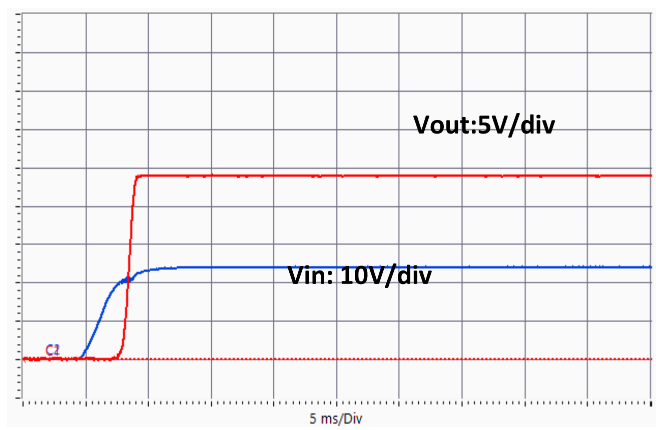
Typical Output ripple with 24V input, 24 V output, 45A load and Cout = Comin at Ta = 25 °C.



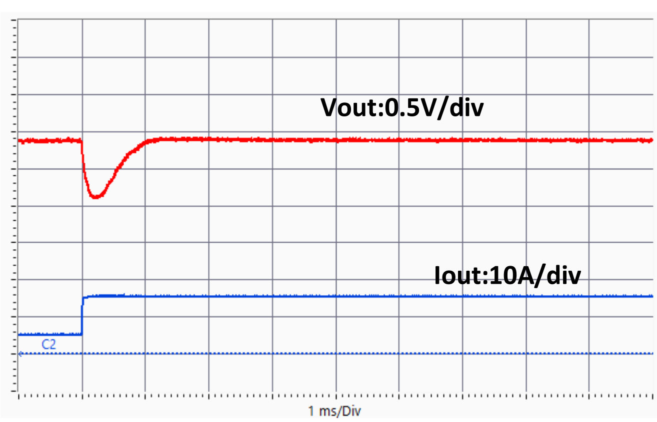
Typical Output ripple with 40V input, 24 V output, 25A load and Cout = Comin at Ta = 25 °C.



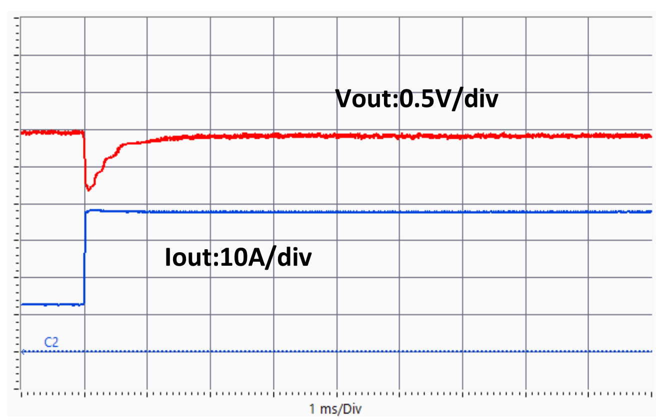
Typical startup characteristic from On/Off with 24V input, 24V output at full load; Cout = Comin at Ta = 25°C. Ch1 = Vout, Ch2 = On/Off.



Typical startup characteristic from Input Voltage application with 24V input, 24V output at full load; Cout = Comin at Ta = 25°C. Ch1 = Vout, Ch2 = Vin.

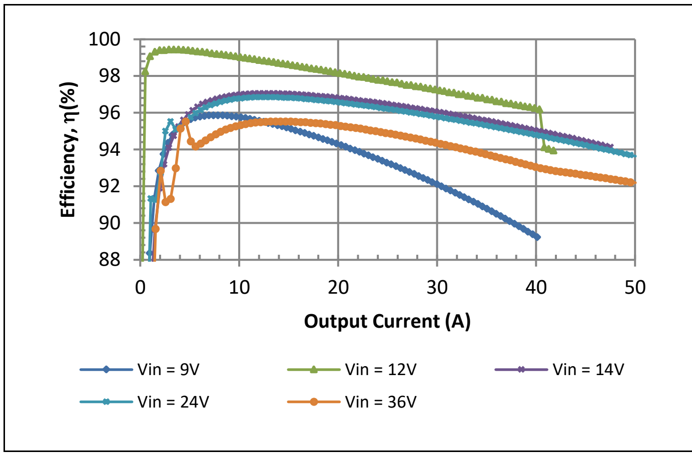


Typical Load transient response with step-up mode;
Load Step from 5A to 15.5A
Vin=12V, Vo=24V Cout = 3 x 330uF electrolytic cap

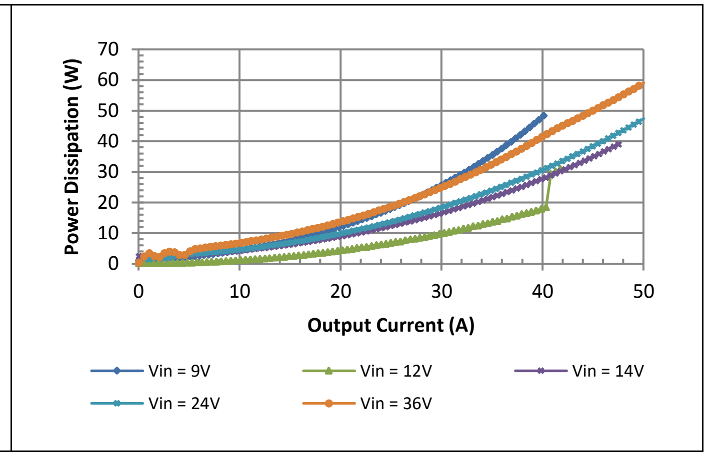


Typical Load transient response with step-down mode;
Load Step from 12.5A to 37.5A
Vin=36V, Vo=24V Cout = 3 x 330uF electrolytic cap

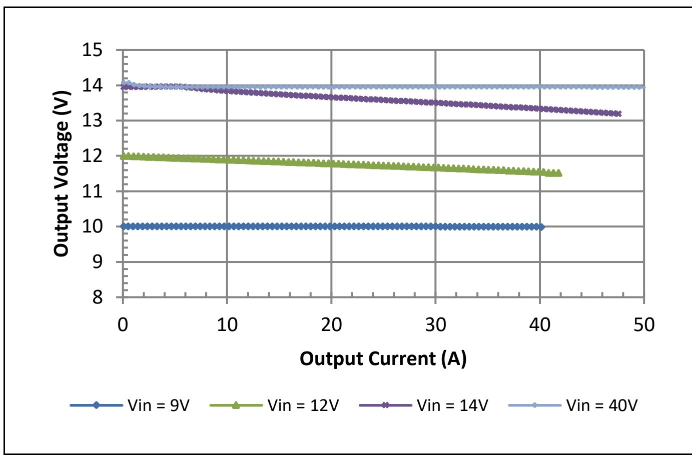
## <u>Static Characteristic</u>: i9C2W050A240V PHEPT Mode Vo_L= 10V Vo_H = 14V



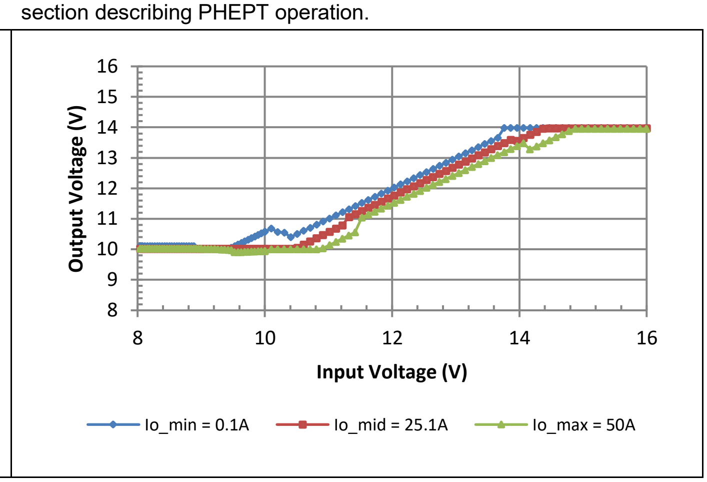

Typical efficiency versus output current at Tamb = 25 ˚C.



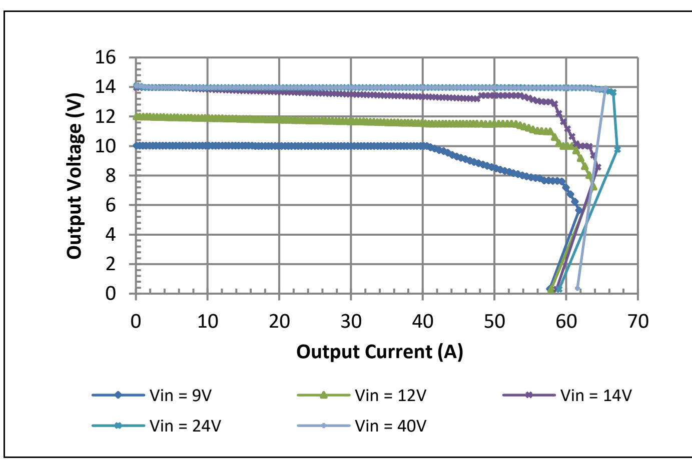

Typical power dissipation versus output current at Tamb = 25 ˚C. Power loss increase at low voltage and heavy load is expected, refer to section describing PHEPT operation.



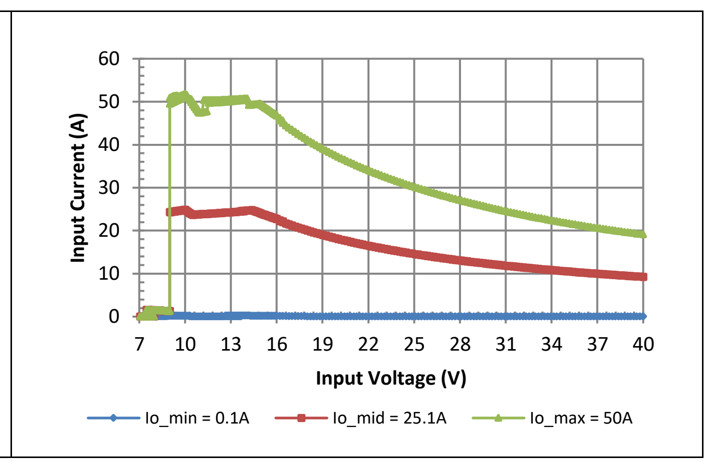

Typical load regulation at 25 ˚C.




Typical line regulation at 25 ˚C.

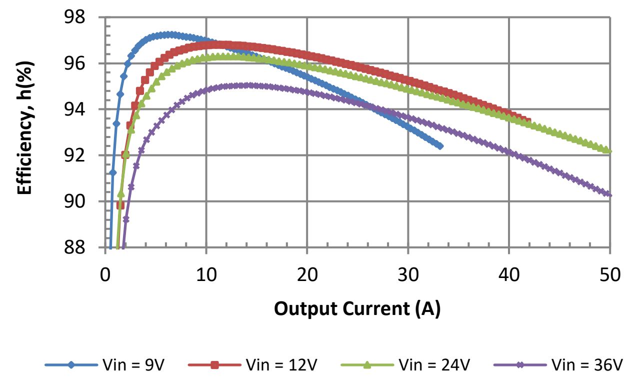



Typical Output voltage versus Output Current characteristics at 25 ˚C with Itrim tied to SGND pin.

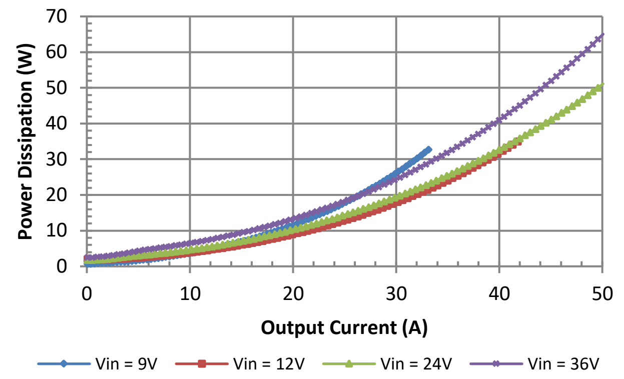



Typical Input current versus input voltage at 25 ˚C.

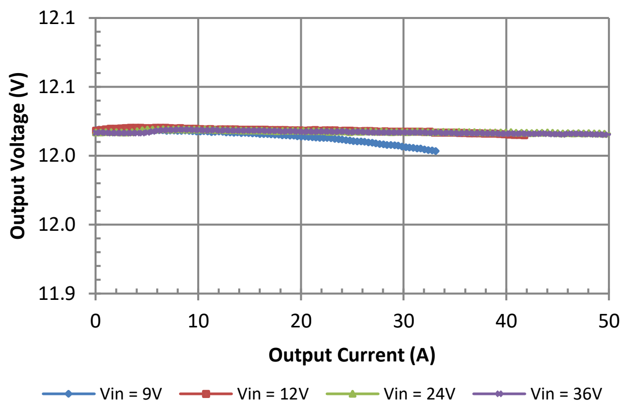
## Static Characteristic: i9C2W050A240V_Fully Regulated Mode Vo = 12V



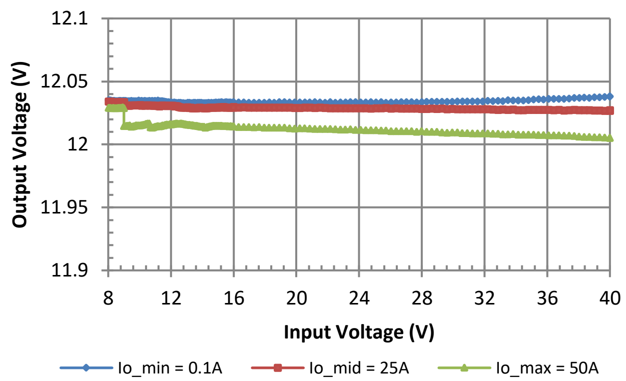

Typical efficiency versus output current at Tamb = 25 ˚C.



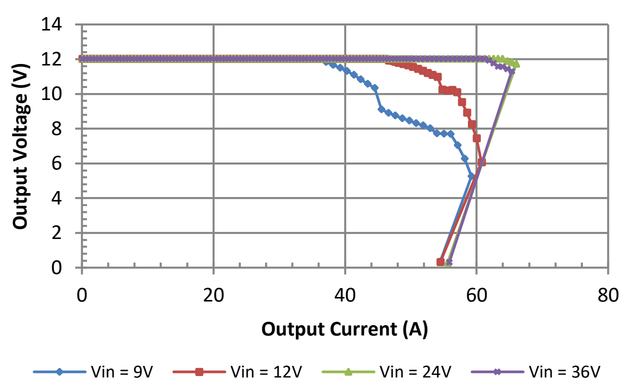

Typical power dissipation versus output current at Tamb = 25 ˚C.




Typical load regulation at 25 ˚C.




Typical line regulation at 25 ˚C.




Typical Output voltage versus Output Current characteristics at 25 ˚C with Itrim tied to SGND pin.

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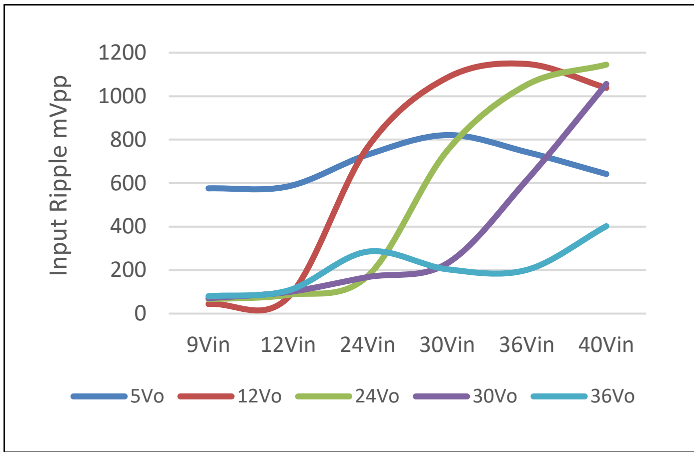
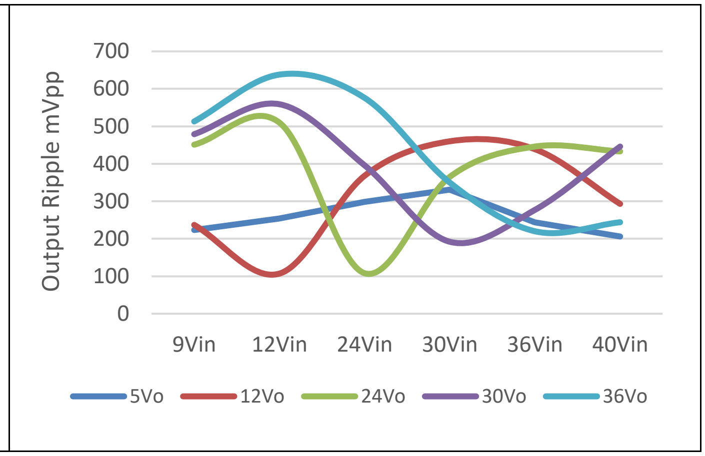
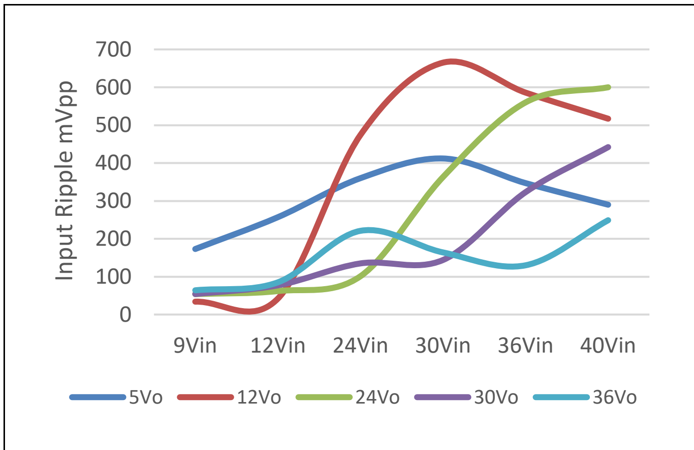
## Typical Noise Characteristics: i9C2W050A240V



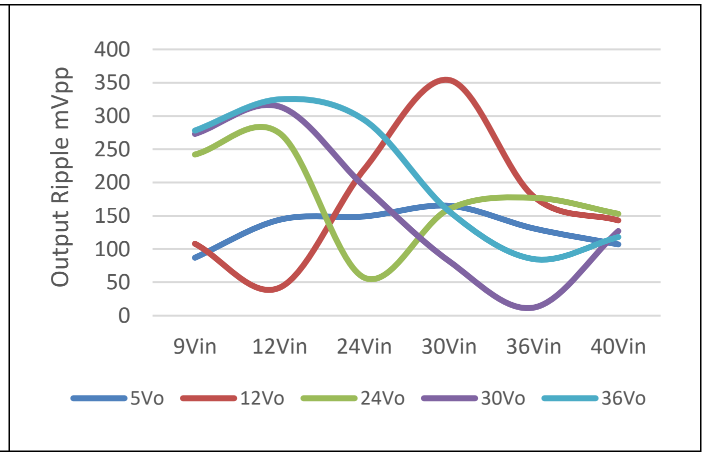

Typical Input ripple, fully regulated mode at full load.



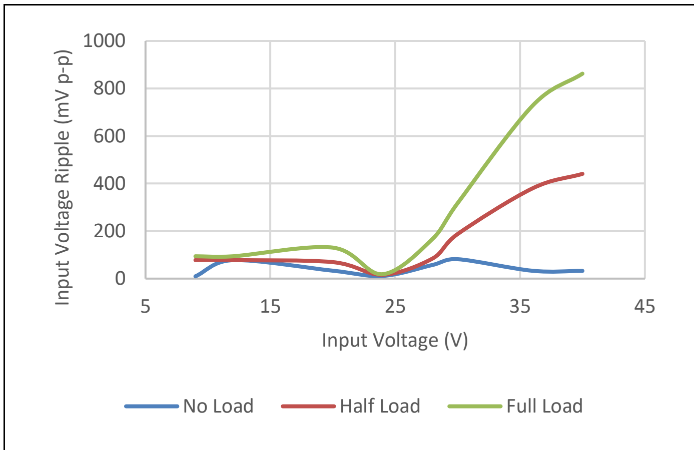

Typical Output ripple, fully regulated mode at full load.



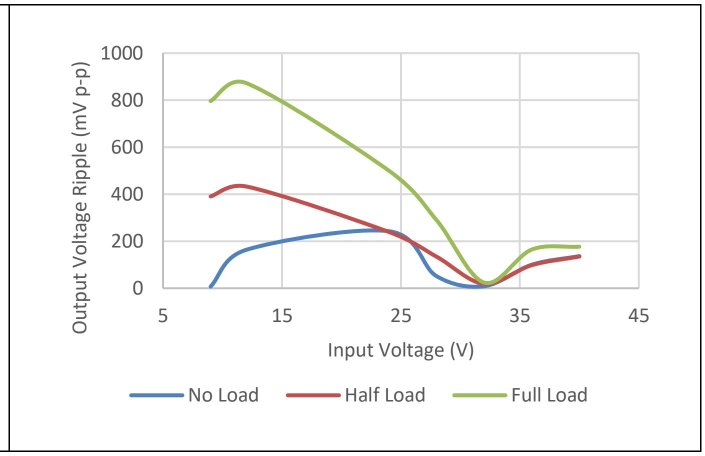

Typical Input ripple, fully regulated mode at 50% load.




Typical Output ripple, fully regulated mode at 50% load.




Typical Input ripple PHEPT mode Vo_L= 20V Vo_H = 28V.

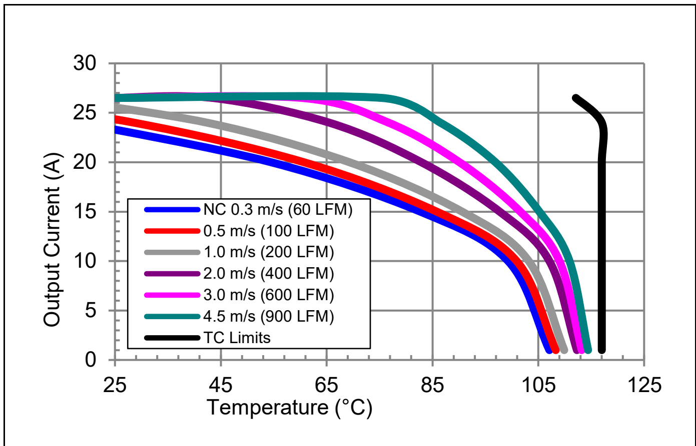



Typical Output ripple PHEPT mode Vo_L= 20V Vo_H = 28V.

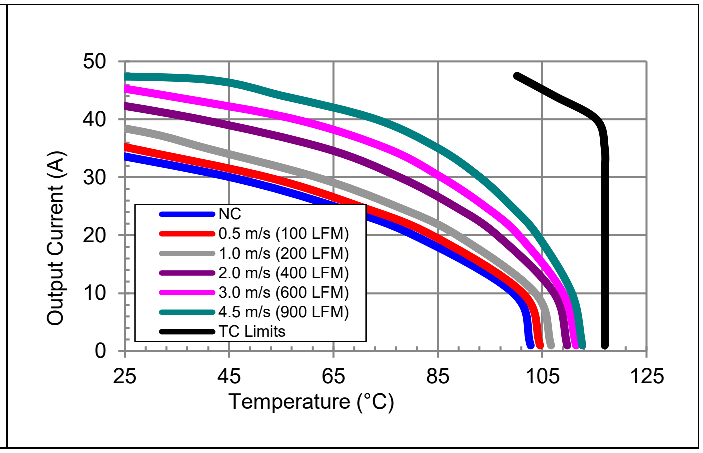
Charts based on typical data collected at room temperature on TDK-Lambda evaluation board with:
Cinput = 10 x 22uF ceramic, 3 x 330uF electrolytic and Coutput = 2 x 22uF ceramic, 3 x 330uF electrolytic

# Thermal Performance: i9C2W050A240V PHEPT Mode

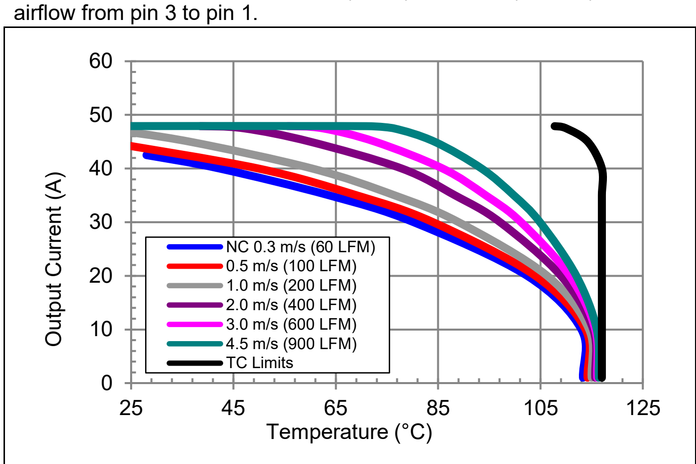
### Vo_L= 20V Vo_H = 28V



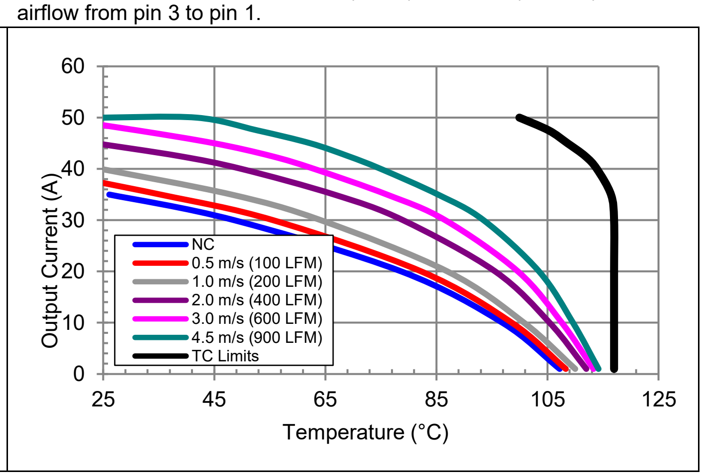

Vin=12V, Vo=20V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 4.5m/s (900 lfm) with airflow from pin 3 to pin 1.




Vin=20V, Vo=20V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 4.5m/s (900 lfm) with airflow from pin 3 to pin 1.




Vin=24V, Vo=24V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 4.5m/s (900 lfm) with airflow from pin 3 to pin 1.




Vin=40V, Vo=28V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 4.5m/s (900 lfm) with airflow from pin 3 to pin 1.

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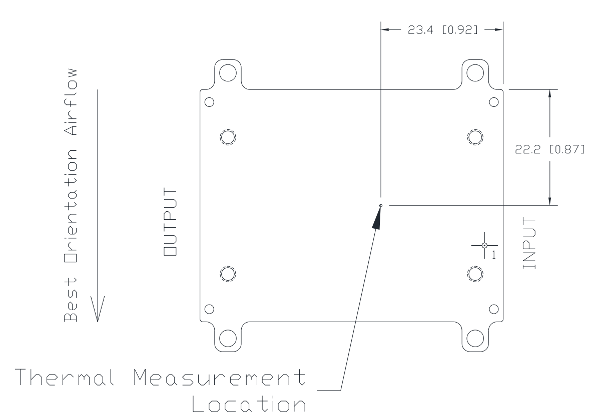
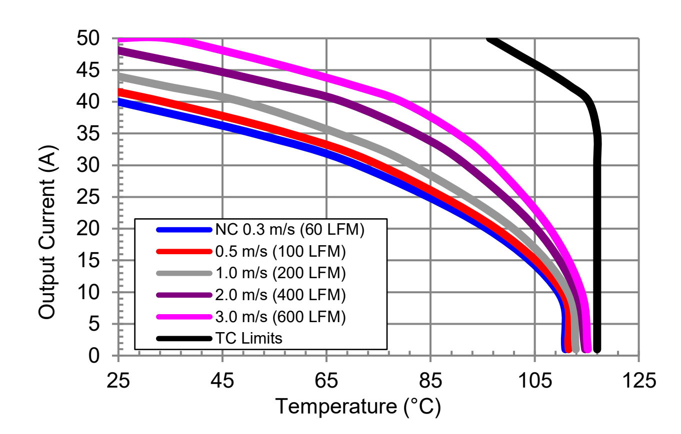
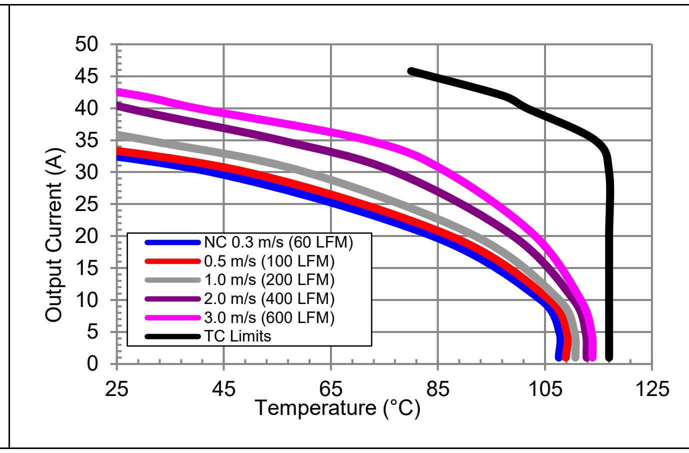



Thermal Measurement Location.

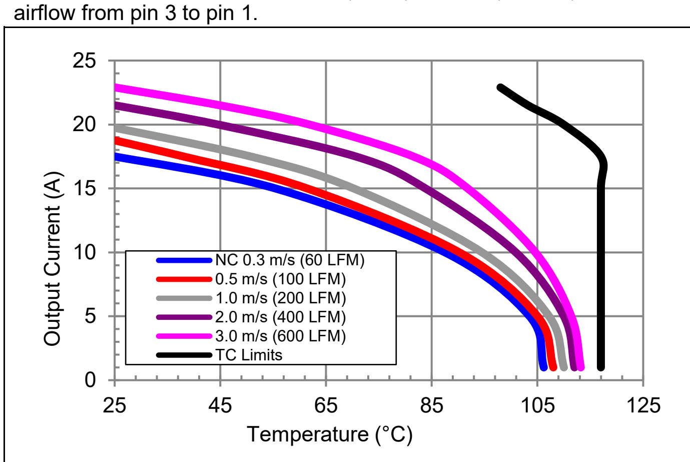
## Thermal Performance: i9C2W050A240V Fully Regulated Mode



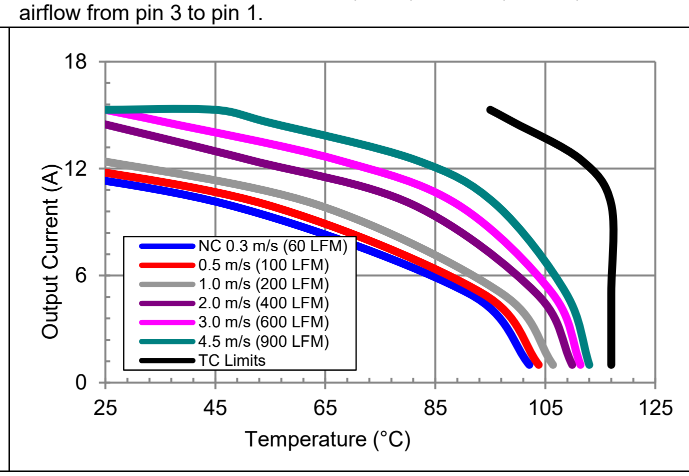

Vin=12V, Vo=5V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



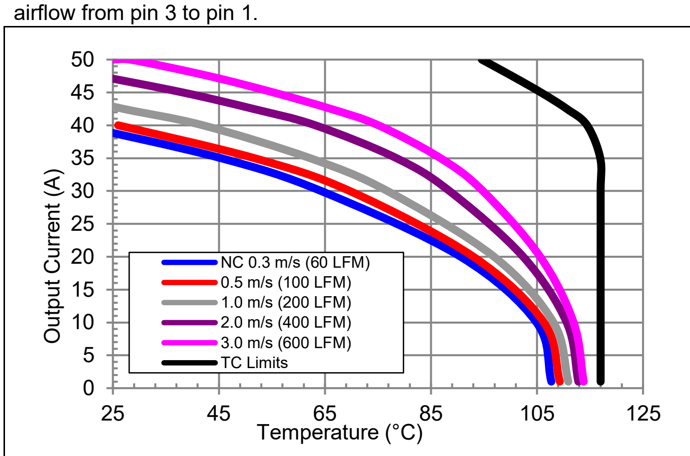

Vin=12V, Vo=12V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



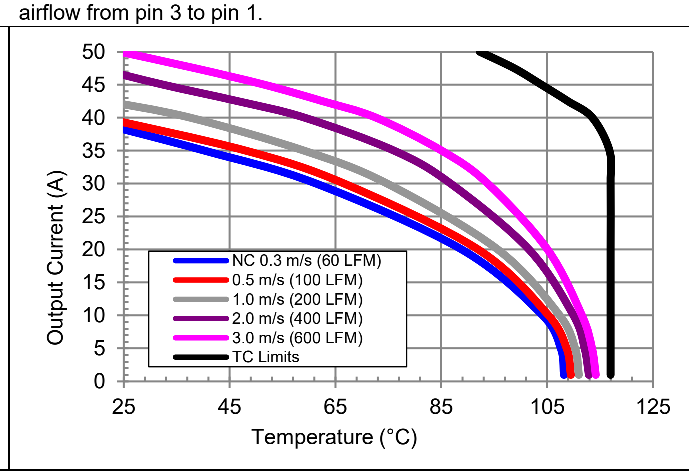

Vin=12V, Vo=24V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.




Vin=12V, Vo=36V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 4.5m/s (900 lfm) with airflow from pin 3 to pin 1.

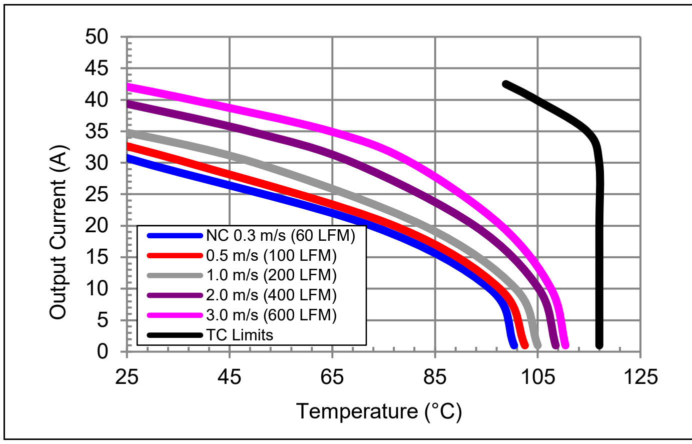



Vin=24V, Vo=5V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.

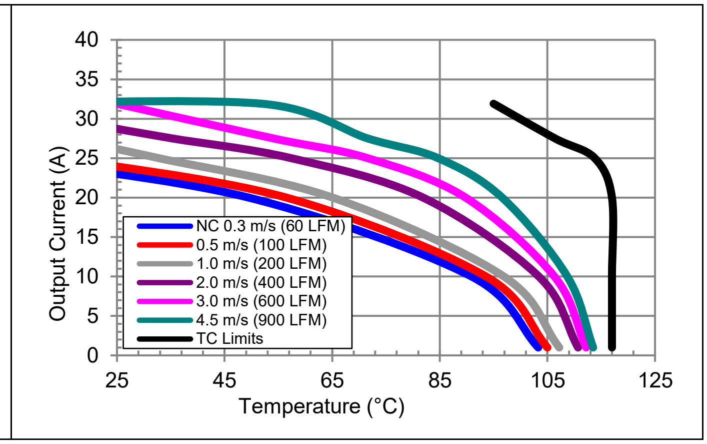



Vin=24V, Vo=12V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.

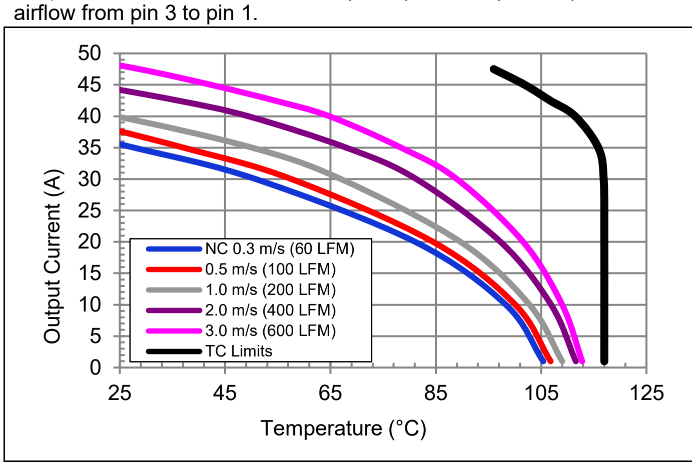
## <u>Thermal Performance</u>: i9C2W050A240V Fully Regulated Mode



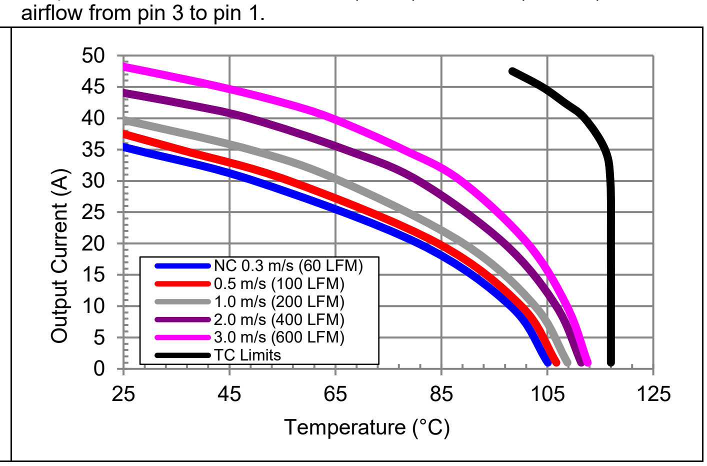

Vin=24V, Vo=24V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



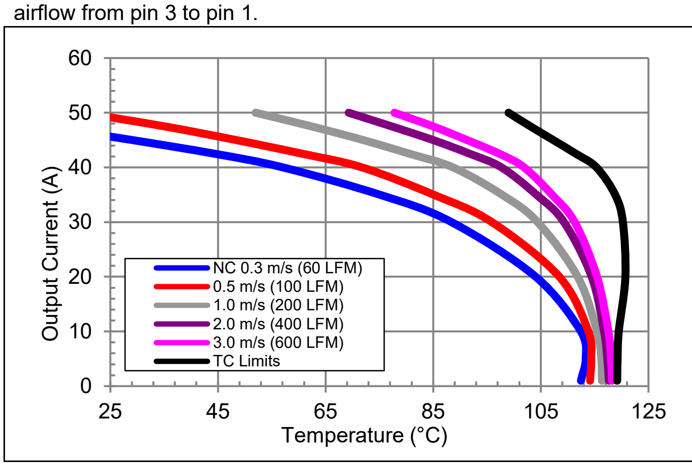

Vin=24V, Vo=36V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 4.5m/s (900 lfm) with airflow from pin 3 to pin 1.



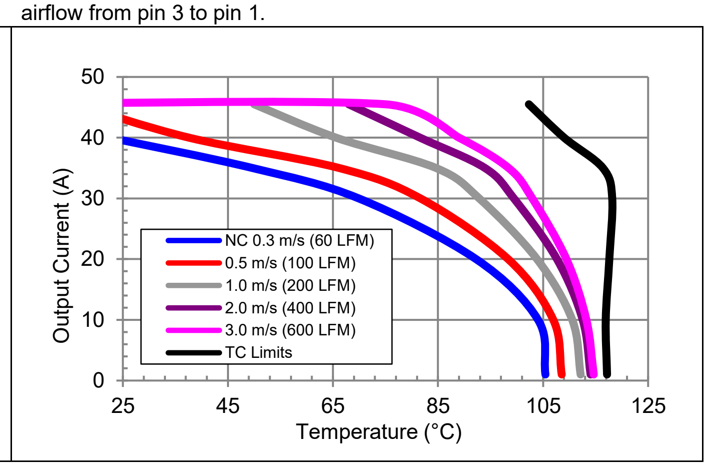

Vin=36V, Vo=12V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.




Vin=36V, Vo=24V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1.



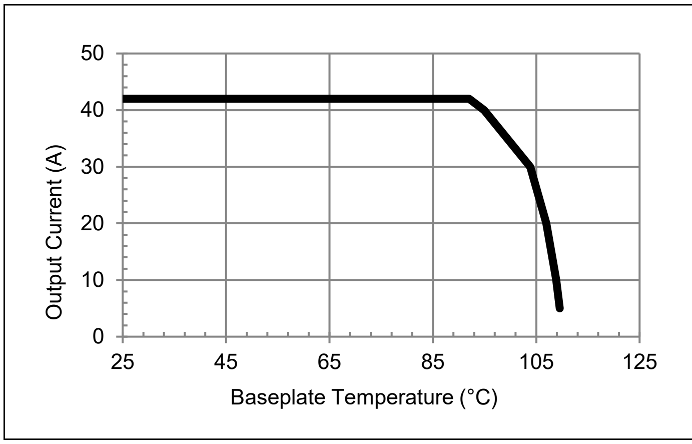

Vin=24V, Vo=12V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1 **with 1" transverse heatsink**.



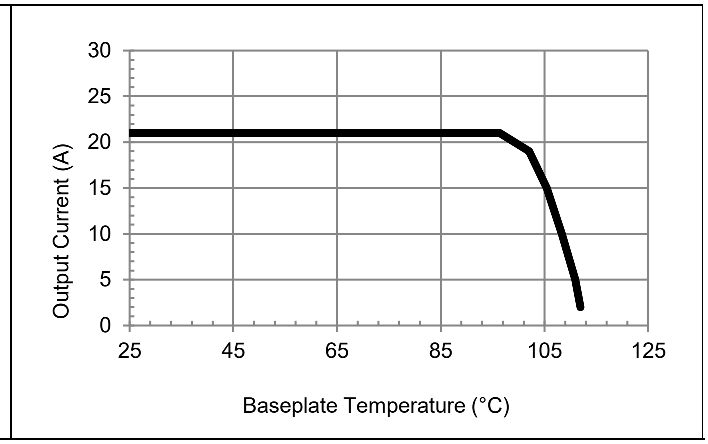

Vin=24V, Vo=24V preliminary maximum output current vs. ambient temperature for natural convection (60lfm) to 3m/s (600 lfm) with airflow from pin 3 to pin 1 **with 1" transverse heatsink**.

The thermal curves provided are based on measurements made in TDK-Lambda's test setup that is described in the Thermal Management section. Due to the large number of variables in system design and the extremely wide operating range of the module. TDK-Lambda recommends that the user verify the module's thermal performance in the end application. The critical component should be thermocoupled, monitored and should not exceed the temperature limit specified in the derating curve above. It is critical that the thermocouple be mounted in a manner that gives direct thermal contact or significant measurement errors may result. TDK-Lambda can provide modules with a thermocouple pre-mounted to the critical component for system verification tests.

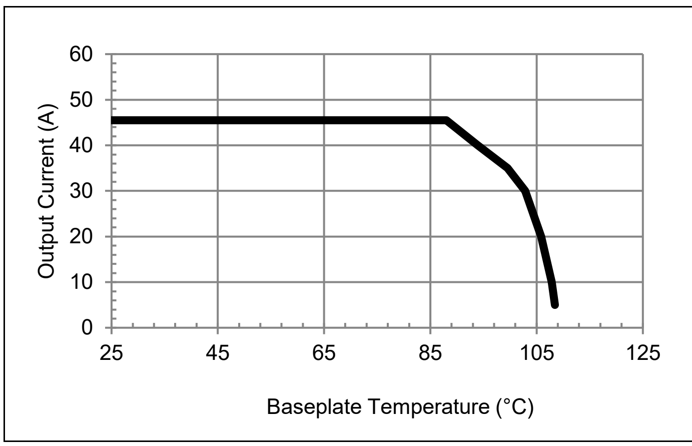
## Thermal Performance: i9C2W050A240V_Fully Regulated Mode_Conduction Cooling



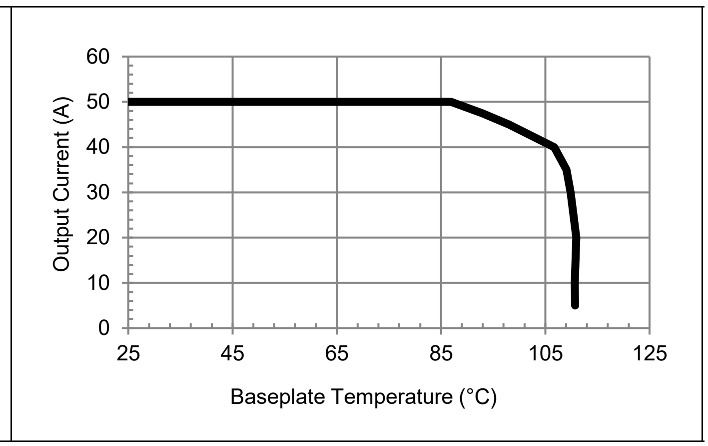

Vin=12V, Vo=12V preliminary maximum output current vs. baseplate temperature with enclosed environment and Ta = 85 ˚C.



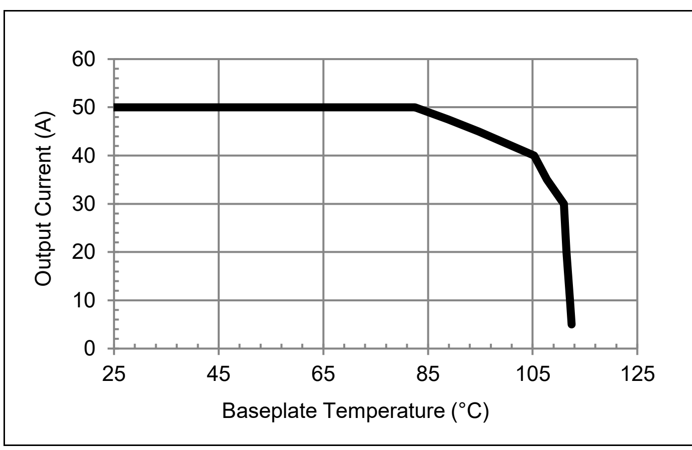

Vin=12V, Vo=24V preliminary maximum output current vs. baseplate temperature with enclosed environment and Ta = 85 ˚C.



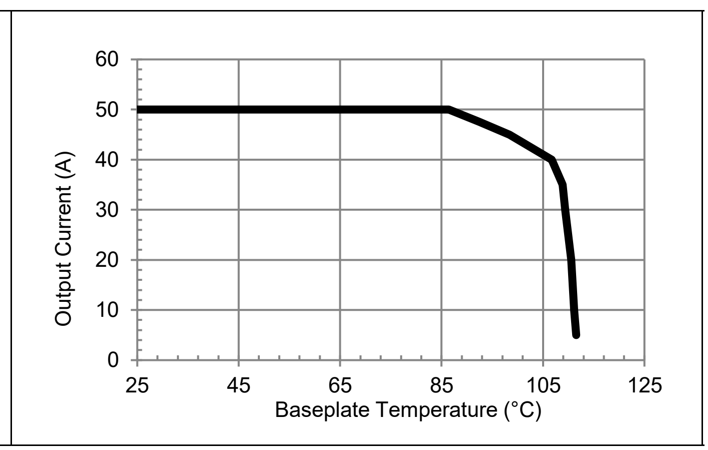

Vin=24V, Vo=24V preliminary maximum output current vs. baseplate temperature with enclosed environment and Ta = 85 ˚C.




Vin=24V, Vo=12V preliminary maximum output current vs. baseplate temperature with enclosed environment and Ta = 85 ˚C.




Vin=40V, Vo=24V preliminary maximum output current vs. baseplate temperature with enclosed environment and Ta = 85 ˚C.




Vin=24V, Vo=5V preliminary maximum output current vs. baseplate temperature with enclosed environment and Ta = 85 ˚C.

The thermal curves provided are based on measurements made in TDK-Lambda's test setup that is described in the Thermal Management section. Due to the large number of variables in system design and the extremely wide operating range of the module. TDK-Lambda recommends that the user verify the module's thermal performance in the end application. The critical component should be thermocoupled, monitored and should not exceed the temperature limit specified in the derating curve above. It is critical that the thermocouple be mounted in a manner that gives direct thermal contact or significant measurement errors may result. TDK-Lambda can provide modules with a thermocouple pre-mounted to the critical component for system verification tests.

## Thermal Management:

An important part of the overall system design process is thermal management; thermal design must be considered at all levels to ensure good reliability and lifetime of the final system. Superior thermal design and the ability to operate in severe application environments are key elements of a robust, reliable power module.

A finite amount of heat must be dissipated from the power module to the surrounding environment. This heat is transferred by the three modes of heat transfer: convection, conduction and radiation. While all three modes of heat transfer are present in every application, convection is the dominant mode of heat transfer in most applications. However, to ensure adequate cooling and proper operation, all three modes should be considered in a final system configuration.

Power modules with an open frame design offer a direct air path to individual power dissipating components. This air path improves convection cooling to the surrounding environment, which reduces areas of heat concentration and resulting hot spots.

For power modules featuring a metal baseplate or enclosed construction, the design provides a low thermal impedance path to key components on the power module, facilitating efficient heat transfer through conduction. This method of heat transfer can be further enhanced by affixing the power module to an external cold plate or system chassis.

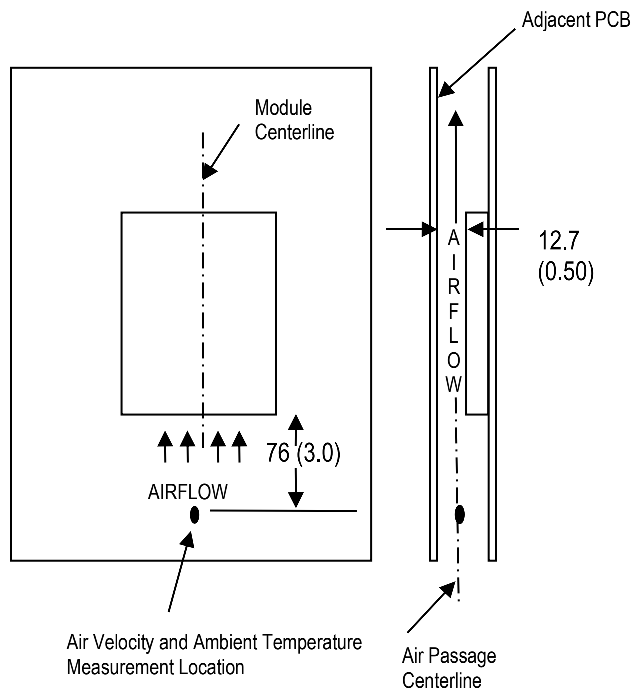
### Test Setup (Convection):

The thermal performance data of the power module is based upon measurements obtained from a wind tunnel test with the setup shown in the wind tunnel figure. This thermal test setup replicates the typical thermal environments encountered in many modern electronic systems with distributed power architectures. The electronic equipment in networking, telecom, wireless, and advanced computer systems operate in similar environments and utilize vertically mounted PCBs or circuit cards in cabinet racks.

The power module, as shown in the Wind Tunnel Test Setup figure, is mounted on a printed circuit board (PCB) and is vertically oriented within the wind tunnel. The cross section of the airflow passage is rectangular. The spacing between the top of the module and a parallel facing PCB is kept at a constant (0.5 in). The power module’s orientation with respect to the airflow direction can have a significant impact on the module’s thermal performance.

Heat transfer by convection can be enhanced by increasing the airflow rate that the power module experiences. The maximum output current of the power module is a function of ambient temperature (Ta) and airflow rate as shown in the thermal performance figures on the thermal performance page for the power module of interest.

The curves in the figures are shown for natural convection through 3 m/s (600 ft/min). The data for the natural convection condition has been collected at 0.3 m/s (60 ft/min) of airflow, which is the typical airflow generated by other heat dissipating components in many of the systems that these types of modules are used in. In the final system configurations, the airflow rate for the natural convection condition can vary due to temperature gradients from other heat dissipating components.




**Wind Tunnel Test Setup Figure**
*(Dimensions are in millimeters and (inches)*

### Test Setup (Conduction):

The thermal performance of the power module was also evaluated using measurements obtained from testing with the setup shown in the conduction cooling figure. This thermal test setup replicates the thermal configuration encountered by products in many industrial, medical, and avionics systems which utilize circuit cards mounted in clamshells or thermally connected to system enclosures.

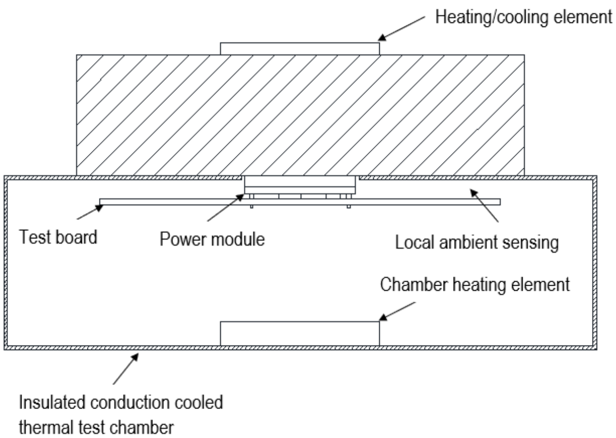
For applications where the power module is used in sealed box/cold plate configuration, the dominant mode of heat transfer is conduction cooling. Heat dissipated from the power module is conducted primarily through the cold plate/chassis.

The power module, as shown in the Conduction Cooling Test Setup figure, is mounted on a printed circuit board

## <u>Thermal Management</u>: *(continued)*

(PCB) and is horizontally oriented within an insulated sealed test chamber. The space between the top of the module and the parallel facing large heat sink is filled with a thin gap pad to improve the thermal connection.

On the thermal performance page for the power module of interest, curves are shown with the power module being tested over various line and load conditions with the sealed chamber's internal ambient temperature maintained at 85°C. The power module's case is attached to large heatsink to achieve the targeted case temperature




**Conduction Cooling Test Setup**

Variables such as the mounting PCB's thickness and copper weight, the power loss of other surrounding components, and the heat transfer capacity of the metal plate can all have a significant impact on the module's thermal performance.

### Thermal De-rating:

For proper application of the power module in a given thermal environment, output current de-rating curves are provided as a design guideline on the Thermal Performance section for the power module of interest. The module temperature should be measured in the final system configuration to ensure proper thermal management of the power module. For thermal performance verification, the module temperature should be measured at the location specified on the thermal measurement location figure on the thermal performance page for the power module of interest.

In all conditions, the power module should be operated below the maximum operating temperature shown on the de-rating curve. For improved design margins and enhanced system reliability, the power module may be operated at temperatures below the maximum rated operating temperature.

## Operating Information:

### Over-Current Protection:

The power modules have output overload protection to protect the module during severe overload conditions. During overload conditions, the power modules may protect themselves by reducing output voltage to limit power or by entering a fold back current limit mode. The modules will operate normally once the output current returns to the specified operating range. Long term operation outside the rated conditions and prior to the protection engaging is not recommended unless measures are taken to ensure the module's thermal limits are being observed.

### Thermal Protection:

When the power modules exceed the maximum operating temperature, the modules may turn-off to safeguard the power unit against thermal damage. The module will auto restart as the unit is cooled below the over temperature threshold.

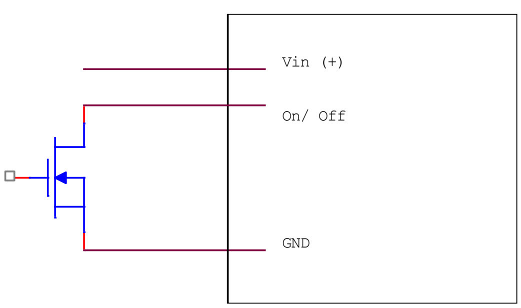
### Remote On/Off:

The power modules have an internal Remote On/Off circuit. The user must supply a compatible switch between the GND pin and the On/Off pin. The maximum voltage generated by the power module at the On/Off terminal is 12V. The maximum allowable leakage current of the switch is 10 µA for negative logic and 5uA for positive logic. The switch must be capable of maintaining a low signal Von/off < 0.5V while sinking 1mA. A voltage source should not be applied to the On/Off terminal.

The standard Remote On/Off is negative logic. In the circuit configuration shown the power module will turn on if the external switch is on and it will be off if the external switch is off. If the negative logic feature is not being used, terminal 2 should be connected to ground.

An optional positive logic On/Off logic is available. In the circuit configuration shown the power module will turn off if the external switch is on and it will be on if the switch is off and the On/Off pin is open. If the positive logic feature is not being used, terminal should be left open.

To avoid possible maloperation, external filtering capacitors should not be added to the on/off terminal.




**On/Off Circuit for Positive or Negative Logic**

### Remote Sense:

The power modules feature remote sense to compensate for the effect of output distribution drops. The output voltage sense range defines the maximum voltage allowed between the output power and sense terminals, and it is found on the electrical data page for the power module of interest. If the remote sense feature is not being used, the Sense terminal should be connected to the Vo terminal.

The output voltage at the Vo terminal can be increased by either the remote sense or the output voltage adjustment feature. The maximum voltage increase allowed is the larger of the remote sense range or the output voltage adjustment range; it is not the sum of both. As the output voltage increases due to the use of the remote sense, the maximum output current may need to be decreased for the power module to remain below its maximum power rating.

### Power Good:

The power module features an open-drain power good signal which indicates if the output voltage is being regulated. When power is applied to the module, and the output voltage is more than ±12% away from the nominal voltage set point the Power Good will be pulled to ground through a 250-ohm maximum impedance. When the voltage is within the range the Power Good pin will revert to a high impedance state and will be internally lightly pulled up to 3.3V through a diode. The Power Good can be externally pulled up to a different level; the pull-up resistor should limit current to less than 1mA. The voltage on the Power Good pin should be limited to less than 30V. If the power good feature is not used, the pin should be left open.

### SLEEP:

The power modules feature a sleep pin which allows the module to be put into a low power dissipation state when the load is inactive or at light load conditions. When the module is in sleep mode, the output voltage will be active and regulated, but the input current and power losses will be reduced. The maximum voltage generated by the power module on the sleep pin is 3.6V. A switch must be capable of maintaining a low signal less than 0.5V while sinking 0.1mA. The maximum allowable leakage current is 5uA.

To use sleep mode feature with PHEPT operation, the sleep pin should be left open and a switch should be added between MODE pin and SGND. To enable the sleep mode, the MODE pin should be pulled to ground. Pulling the MODE pin to ground will cause the unit to enter a low loss mode and the output voltage will be regulated to a midpoint between the programmed low and high settings. To wake the module up, and resume regular PHEPT operation, the switch should be opened.

If the sleep feature is not being used in PHEPT mode, both the SLEEP and MODE pins should be left open.

## Programmable Operation Mode:

The MODE pin provides a selectable setting to change between two output voltage regulation modes. The MODE pin should either be left open or tied to the signal ground pin to set the operating mode as desired.

| Feature Set | MODE = GND | MODE = OPEN |
|---|---|---|
| -xx3 | Fully Regulated Output Voltage | PHEPT |

When the MODE pin is tied to GND, the power module will behave as a typical fully regulated power supply. The output voltage will be regulated within the specified tolerance range over all rated line, load, and temperature conditions. The output voltage setpoint will be determined by the trim resistor values. The selection of the trim resistor values is described in the output voltage adjustment section of this document.

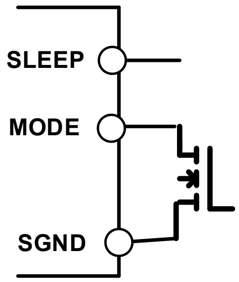
When the MODE pin is OPEN, a programmable high efficiency pass-through mode (PHEPT) mode is enabled. In this mode the module will regulate the voltage to a band where the lower threshold (Vo_L) is determined by output voltage adjustment resistor RTrim_L and the upper threshold (Vo_H) is determined by adjustment resistor RTrim_H.

When the input voltage is less than the lower threshold Vo_L, the power module will increase the voltage and regulate the output to be within the specified tolerance range around Vo_L. When the input voltage is greater than the upper threshold Vo_H, the power module will decrease the voltage and regulate the output to be within the specified tolerance range around Vo_H.

When the input voltage is determined to be between Vo_L and Vo_H, the power module switching ceases and the power path between input and output is turned fully on, and the module will act similar to a C-L-C noise filter. The over current and short circuit protection of the module remain active when operating in the PHEPT mode.

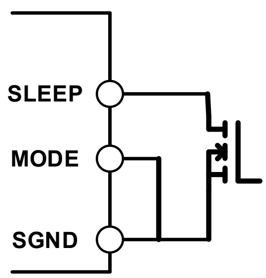
Due to the lack of switching, the power loss and noise in this mode are dramatically improved. Once the input voltage moves outside the programmed output voltage window, switching will automatically resume and the module will be regulated to Vo_L or Vo_H as appropriate.

When in PHEPT mode, if the voltage droop at the output with respect to the input becomes too much, typically on the order of 4%, the module will resume switching to raise the output voltage. This will typically only occur if PHEPT range is set to a low output voltage, and the load current is near the maximum.




**Circuit for SLEEP operation in PHEPT Mode**

To use the sleep mode feature with fully regulated operation, the MODE pin should be connected to SGND and a switch should be added between SLEEP pin and SGND. To enable sleep mode in a fully regulated mode, the switch should be in an open state. Opening the sleep pin will cause the unit to enter a low loss mode and the output voltage will remain fully regulated to the value set by the output voltage adjustment feature. To wake the module up, and resume regular operation, the switch should be closed to tie the SLEEP pin to SGND.




**Circuit for SLEEP operation in Fully Regulated Mode**

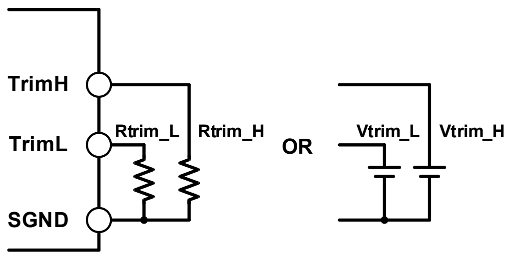
If the sleep feature is not being used in a fully regulated operating mode both the SLEEP and MODE pins should be tied to SGND

| Regulation Mode | MODE Pin | SLEEP Pin |
|---|---|---|
| PHEPT | OPEN = normal operation<br>GND = sleep mode | OPEN |
| Fully Regulated | GND | GND = normal operation<br>OPEN = sleep mode |

The i9C module is not intended to run in sleep mode under normal operation conditions with heavy loading. When a load is suddenly applied and unit is in sleep mode, there may be a significant voltage transient. This can be avoided by disabling sleep mode before the load step occurs or mitigated with output capacitance. This transient behavior should be evaluated in the final application.

## Output Voltage Adjustment (PHEPT Mode):

The output voltage of the power module may be adjusted by using external resistors or voltage sources connected between the Trim terminals and SGND terminal. Care should be taken to avoid injecting noise into the power module's trim pins.




**Circuit to adjust output voltage**

With a resistor between the trim and SGND terminals, the output voltage is adjusted up. To adjust the output voltage from Vo,nom to Vo the trim resistor should be chosen according to the following equation:

$$\text{Rtrim} = \left(\frac{F\ x\ Vref}{Vo - Vo,nom}\right) - G$$

A well-controlled voltage source can also be used between the trim and SGND terminals to set the output voltage. When trimming with a voltage source, care should be taken to avoid transient voltages and noise that could cause unexpected operation. After power up, the voltage source slew rate should be limited to 0.1V/ms. Assuming the voltage source has negligible output impedance, the voltage should be chosen according to the following equation:

$$\text{Vtrim} = \left(\frac{Vo,short - Vo}{Vo,short - Vo,nom}\right)$$

The values of Voshort, Vonom, G, and F are found in the electrical data section for the power module of interest. The maximum power available from the power module is fixed. As the output voltage is trimmed up, the maximum output current must be decreased to maintain the maximum rated power of the module.

**Example 1: Programming PHEPT operation by Resistor**
Non-switching window set between 20Vo and 28Vo

**Given:**

F = 28000
G = 510
Vref = 1.0
Vo,nom = 9.485 (*from Electrical Characteristic table*)
Vo_L =20V *(desired low output voltage)*
Vo_H =28V *(desired high output voltage)*

Then,

$$\text{Rtrim\_L} = \left(\frac{28000\ x\ 1.0}{20 - 9.485}\right) - 510 = \mathbf{2152\ \Omega}$$

$$\text{Rtrim\_H} = \left(\frac{28000\ x\ 1.0}{28 - 9.485}\right) - 510 = \mathbf{1002\ \Omega}$$

**Example 2: Programming PHEPT operation by Voltage Source**
Non-switching window set between 20Vo and 28Vo

**Given:**

Vo,nom = 9.485 (*from Electrical Characteristic table*)
Vo,short = 64.387 (*from Electrical Characteristic table*)
Vo_L =20V *(desired low output voltage)*
Vo_H =28V *(desired high output voltage)*

Then,

$$\text{Vtrim\_L} = \left(\frac{64.387 - 20.0}{64.387 - 9.485}\right) = \mathbf{0.808\ V}$$

$$\text{Vtrim\_H} = \left(\frac{64.387 - 28.0}{64.387 - 9.485}\right) = \mathbf{0.662\ V}$$

**Trim Table - i9C4W030A480V**

| Vout [V] | Rtrim(ohm) | Vtrim(V) |
|---|---|---|
| 9.485 | OPEN | 1.000 |
| 12.0 | 10623 | 0.954 |
| 15.0 | 4567 | 0.900 |
| 18.0 | 2778 | 0.845 |
| 20.0 | 2152 | 0.808 |
| 24.0 | 1419 | 0.736 |
| 28.0 | 1002 | 0.662 |
| 30.0 | 855 | 0.626 |
| 36.0 | 546 | 0.517 |
| 42.0 | 351 | 0.407 |
| 48.0 | 217 | 0.298 |
| 54.0 | 119 | 0.189 |
| 60.0 | 44 | 0.080 |

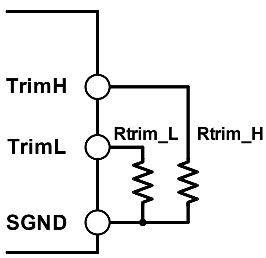
**Trim Table - i9C2W050A240V**

| Vout [V] | Rtrim(ohm) | Vtrim(V) |
|---|---|---|
| 5.0 | 10109 | 0.981 |
| 8.0 | 2319 | 0.921 |
| 12.0 | 1055 | 0.841 |
| 15.0 | 712 | 0.780 |
| 18.0 | 516 | 0.720 |
| 24.0 | 301 | 0.600 |
| 28.0 | 217 | 0.520 |
| 30.0 | 185 | 0.480 |
| 36.0 | 113 | 0.360 |

### Output Voltage Adjustment (Fully Regulated Mode):

The recommended method of setting the output voltage of the power module in fully regulated mode is to follow the exact same method described for PHEPT mode by using external resistors or voltage sources connected between the Trim terminals and SGND terminal. In fully regulated mode Vo,L will be equal to Vo_H.

It is important that independent resistors or voltage sources be connected to both the TrimL and TrimH terminals with values per the trim table provided to avoid unexpected operation. In fully regulated mode the value of the external trim resistors or voltages should be equal to one another in value. The TrimL and TrimH terminals should not be shorted together.



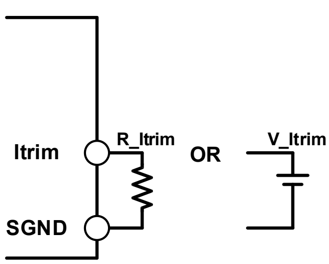

**Dual resistor RtrimL = RtrimH**

### Over Current Protection Adjustment:

The output current adjustment feature allows the module's over current protection trip point to be programmed to a lower level. Running the module beyond rated full load is not recommended, so this feature can be useful to reduce device stress and avoid possible over temperature conditions in situations were extended over loading may occur, such as charging large output capacitors.

To use the over current adjustment feature, a resistor, Ritrim, is added between Itrim (Pin 17), and SGND pin to reduce the over current protection set point. Care should be taken to avoid injecting noise into the power module's Itrim pin.

When using the i9C power module at high output voltages, the over current adjustment feature should be used to lower the trip point and reduce the possibility of the load generating excessive power surges well beyond the i9C ratings which could lead to over-heating or reduced reliability.




If the Itrim signal is left open, the over current protection level is reduced, so if this feature is not being used, the Itrim pin must be connected directly to SGND to achieve full current.

To adjust the Over Current Protection to a desired value, Iocp, the trim resistor should be chosen according to the following equation:

$$\text{R\_Itrim (kohm)} = \frac{\left(\frac{Ki}{Iocp} - 36.5\right) * 59.0}{\left(95.5 - \frac{Ki}{Iocp}\right)}$$

A well-controlled, low impedance voltage source can also be used between the Itrim and SGND terminals to set the over current protection setpoint. When trimming with a voltage source, care should be taken to avoid transient voltages and noise that could cause unexpected operation. After power up, the voltage source slew rate should be limited to 0.1V/ms. To adjust the Over Current Protection to a desired value, Iocp, the voltage should be chosen according to the following equation:

$$\text{V\_Itrim (V)} = 1 - \frac{Iocp}{Kc}$$

The external voltage source needs at least +/-2mA drive capability.

**Example1: Adjust i9C4W030A480V OCP to 20A by resistor**

$$\mathrm{R_{Itrim}} = \frac{\left(\frac{1450}{\mathbf{20}} - 36.5\right) * 59.0}{\left(95.5 - \frac{1450}{\mathbf{20}}\right)} = \mathbf{92.3\mathit{kohm}}$$

**Example2: Adjust i9C4W030A480V OCP to 20A by voltage source**

$$\text{V\_Itrim } = 1 - \frac{\mathbf{20}}{40} = \mathbf{0.500\mathit{V}}$$

The over current adjustment feature can also be used to achieve a current regulated mode of operation if both output voltage and output current remain within the specified operating range of the module. When using the module to regulate current, the MODE pin should be low to select the fully regulated output voltage mode of operation, and the output voltage adjustment pins should be set using the trim table. If the load impedance is high, the unit will limit the voltage to the level set by the trim resistors and resume operating in a constant voltage mode.

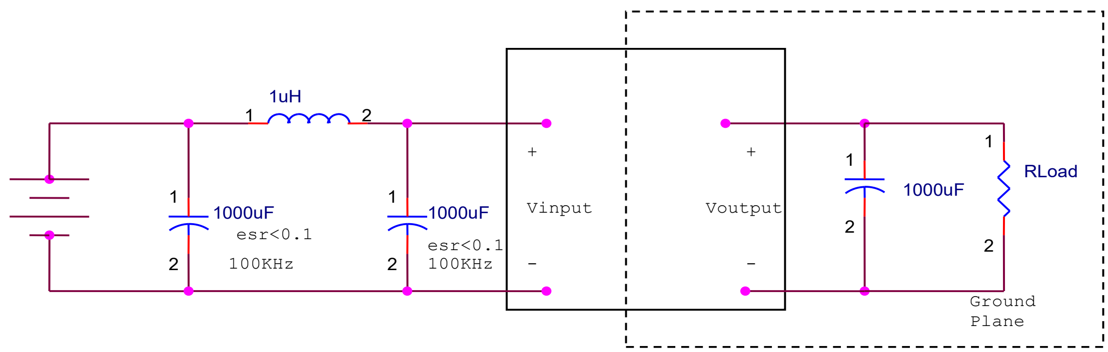
**Trim Table – i9C4W030A480V – Ki = 1450, Kc = 40**

| Iocp [A] | R_Itrim(ohm) | V_Itrim(V) |
|---|---|---|
| 40 | SHORT | 0 |
| 35 | 5400 | 0.125 |
| 30 | 14800 | 0.250 |
| 25 | 33800 | 0.375 |
| 20 | 92300 | 0.500 |
| 15 | OPEN | 0.625 |

**Trim Table – i9C2W050A240V – Ki = 2630, Kc = 70**

| Iocp [A] | R_Itrim(ohm) | V_Itrim(V) |
|---|---|---|
| 70 | SHORT | 0 |
| 61.25 | 7228 | 0.125 |
| 52.5 | 17666 | 0.250 |
| 43.75 | 39373 | 0.375 |
| 35 | 112000 | 0.500 |
| 26 | OPEN | 0.625 |

## Input / Output Ripple and Noise Measurements:




The output ripple measurement is made approximately 9 cm (3.5 in.) from the power module using an oscilloscope and BNC socket. The capacitor Cext is located about 5 cm (2 in.) from the power module; its value varies from code to code and is found on the electrical data page for the power module of interest under the ripple & noise voltage specification in the Notes & Conditions column

### EMC Considerations:

TDK-Lambda power modules are designed for use in a wide variety of systems and applications. For assistance with designing for EMC compliance, please contact TDK-Lambda technical support.

### Input Impedance:

The source impedance of the power feeding the DC/DC converter module will interact with the DC/DC converter. To minimize the interaction, low-ESR ceramic capacitors should be located at the input to the module. It is recommended that an input capacitor equivalent to or greater than 3 x 330uF be placed near the module.

### Reliability:

The power modules are designed using TDK-Lambda's stringent design guidelines for component derating, product qualification, and design reviews. The MTBF is calculated to be greater than 10 million hours at full output power and Ta = 40˚C using the Telcordia SR-332 calculation method.

### Quality:

TDK-Lambda's product development process incorporates advanced quality planning tools such as FMEA and Cpk analysis to ensure designs are robust and reliable. All products are assembled at ISO certified assembly plants.

## Safety Considerations:

As of the publishing date, certain safety agency approvals may have been received on the i9C series and others may still be pending. Check with TDK-Lambda for the latest status of safety approvals on the i9C product line.

For safety agency approval of the system in which the DC-DC power module is installed, the power module must be installed in compliance with the creepage and clearance requirements of the safety agency.

To preserve maximum flexibility, the power modules are not internally fused. An external input line fast blow fuse with a maximum value of 60A is required by safety agencies. A lower value fuse can be selected based upon the maximum dc input current and maximum inrush energy of the power module.

## Warranty:

TDK-Lambda's comprehensive line of power solutions includes efficient, high-density DC-DC converters backed by a three-year limited warranty. Full warranty details are available on our website or upon request.