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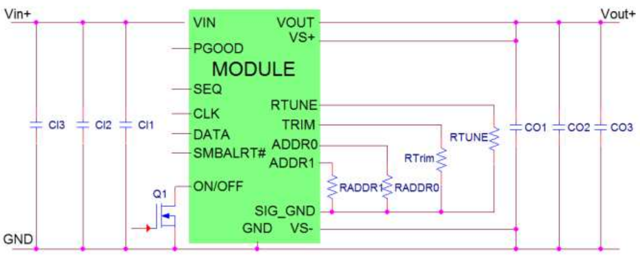
# 120A TeraDLynx™: Non-Isolated DC-DC Power Modules

## 7Vdc –14Vdc input; 0.4Vdc to1.5Vdc output; 120A Output Current


**RoHS Compliant**

## Applications

- Networking equipment
- Telecommunications equipment
- Servers and storage applications
- Distributed power architectures
- Intermediate bus voltage applications
- Industrial equipment




## Features

- Compliant to RoHS EU Directive 2002/95/EC (Z versions)
- Compliant to IPC-9592 (September 2008), Category 2
- Compatible in a Pb-free or SnPb reflow environment (Z versions)
- Wide Input voltage range (7Vdc-14 Vdc)
- Output voltage programmable from 0.4Vdc to 1.5Vdc via external resistor or PMBus™ # commands
- Digital interface through the PMBus protocol
- Ability to parallel multiple modules (optional)
- Digital sequencing
- Fast digital loop control
- Power Good signal
- Fixed switching frequency with capability of external synchronization
- Output overcurrent protection (non-latching)
- Output overvoltage protection
- Over temperature protection
- Remote On/Off
- Ability to sink and source current
- Cost efficient open frame design
- Small size: 53.8 x 31.7 x 13.3 mm [ 2.118" x 1.248" x 0.524"]
- Wide operating temperature range [-40°C to 85°C]
- *UL** 60950-1 2nd Ed. Recognized, *CSA*† C22.2 No. 60950-1-07 Certified, and *VDE*‡ (EN60950-1 2nd Ed.) Licensed
- ISO** 9001 and ISO 14001 certified manufacturing facilities

## Description

The 120A Digital TeraDLynx™ power modules are non-isolated dc-dc converters that can deliver up to 120A of output current. These modules operate over a 7 to 14Vdc input range and provide a precisely regulated output voltage from 0.4 to 1.5Vdc. The output voltage is programmable via an external resistor and/or PMBus control. Features include a digital interface using the PMBus protocol, remote On/Off, adjustable output voltage, Power Good signal and overcurrent, overvoltage and overtemperature protection. The PMBus interface supports a range of commands to both control and monitor the module. The module also includes a real time compensation loop that allows optimizing the dynamic response of the converter to match the load with reduced amount of output capacitance leading to savings on cost and PWB area.

* *UL* is a registered trademark of Underwriters Laboratories, Inc.
† *CSA* is a registered trademark of Canadian Standards Association.
‡ *VDE* is a trademark of Verband Deutscher Elektrotechniker e.V.
** ISO is a registered trademark of the International Organization of Standards
# The PMBus name and logo are registered trademarks of the System Management Interface Forum (SMIF)

imagination at work

# 120A TeraDLynx™: Non-Isolated DC-DC Power Modules

**7Vdc –14Vdc input; 0.4Vdc to 1.5Vdc output; 120A Output Current**

## Absolute Maximum Ratings

Stresses in excess of the absolute maximum ratings can cause permanent damage to the device. These are only absolute stress ratings, functional operation of the device is not implied at these or any other conditions in excess of those given in the operations sections of the technical requirements. Exposure to absolute maximum ratings for extended periods can adversely affect the device reliability.

| Parameter | Device | Symbol | Min | Max | Unit |
|---|---|---|---|---|---|
| Input Voltage - Continuous | All | $V_{IN}$ | -0.3 | 15 | V |
| SEQ, ADDR0, ADDR1, RTUNE, RTRIM, SYNC, VS+, ON/OFF | All | | -0.3 | 3.6 | V |
| CLK, DATA, SMBALERT# | All | | -0.3 | 3.6 | V |
| Operating Ambient Temperature<br>(see Thermal Considerations section) | All | $T_A$ | -40 | 85 | °C |
| Storage Temperature | All | $T_{stg}$ | -55 | 125 | °C |

## Electrical Specifications

Unless otherwise indicated, specifications apply over all operating input voltage, resistive load, and temperature conditions.

| Parameter | Device | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Operating Input Voltage | All | $V_{IN}$ | 7 | — | 14 | Vdc |
| Maximum Input Current<br>($V_{IN}$=7V to 14V, $I_O$=$I_{O,\,max}$) | All | $I_{IN,max}$ | | | 29 | Adc |
| Input No Load Current<br>($V_{IN}$ = 12Vdc, $I_O$ = 0, module enabled) | $V_{O,set}$ = 0.6 Vdc | $I_{IN,No\ load}$ | | 160 | | mA |
| | $V_{O,set}$ = 1.5Vdc | $I_{IN1No\ load}$ | | 200 | | mA |
| Input Stand-by Current<br>($V_{IN}$ = 12Vdc, module disabled) | All | $I_{IN,stand\text{-}by}$ | | 62 | | mA |
| Inrush Transient | All | $I^2t$ | | 1 | | $A^2s$ |
| Input Reflected Ripple Current, peak-to-peak<br>(5Hz to 20MHz, 1μH source impedance; $V_{IN}$ =0 to 14V, $I_O$= $I_{Omax}$ ; See Test Configurations) | All | | | 5 | | mAp-p |
| Input Ripple Rejection (120Hz) | All | | | -54 | | dB |

# 120A TeraDLynx™: Non-Isolated DC-DC Power Modules

## 7Vdc –14Vdc input; 0.4Vdc to 1.5Vdc output; 120A Output Current

## Electrical Specifications (continued)

| Parameter | Device | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage Set-point (with 0.1% tolerance external resistor used to set output voltage). Tolerances apply over output voltage range from 0.5 to 1.5V | | | | | | |
| -40 to 85°C | All | $V_{O, set}$ | -1.0 | | +1.0 | % $V_{O, set}$ |
| 0 to 85°C | All | | -0.7 | | +0.7 | % $V_{O, set}$ |
| Output Voltage (Over all operating input voltage, resistive load, and temperature conditions until end of life) | All | $V_{o, set}$ | -2.0 | | +2.0 | % $V_{O, set}$ |
| Adjustment Range (selected by an external resistor) | All | $V_{OUT}$ | 0.4 | | 1.5 | Vdc |
| PMBus Adjustable Output Voltage Range | All | $V_{OUT}$ | 0.4 | | 1.5 | %$V_{O,set}$ |
| PMBus Output Voltage Adjustment Step Size | All | | | 98 | | µV |
| Remote Sense Range | All | | | | 0.3 | Vdc |
| Output Regulation | | | | | | |
| Line ($V_{IN}$=$V_{IN, min}$ to $V_{IN, max}$) | All | | | | 5 | mV |
| Load ($I_O$=$I_{O, min}$ to $I_{O, max}$) | All | | | | 5 | mV |
| Temperature ($T_{ref}$=$T_{A, min}$ to $T_{A, max}$) | All | | | | 5 | mV |
| Output Ripple and Noise on nominal output ($V_{IN}$=$V_{IN, nom}$ and $I_O$=$I_{O, min}$ to $I_{O, max}$ Co = 1500 µF | | | | | | |
| Peak-to-Peak (Full bandwidth) | | | | | 30 | $mV_{pk-pk}$ |
| RMS (Full bandwidth) | All | | | | 12 | $mV_{rms}$ |
| External Capacitance | | | | | | |
| Minimum output capacitance | All | $C_{O,min}$ | 1500 | — | — | µF |
| Maximum output capacitance | All | $C_{O, max}$ | — | — | 40000 | µF |
| Output Current (in either sink or source mode) | All | $I_o$ | 0.005* | | 120 | Adc |
| Output Current Limit Inception (Hiccup Mode) (current limit does not operate in sink mode) | All | $I_{O, lim}$ | | 110 | | % $I_{o,max}$ |
| Output Short-Circuit Current ($V_O$≤250mV) (Hiccup Mode) | All | $I_{O1, s/c}$ , $I_{O1, s/c}$ | | 40 | | Arms |
| Efficiency | $V_{O,set}$ = 0.6Vdc | η | | 88.2 | | % |
| | $V_{O, set}$ = 0.8Vdc | η | | 90.9 | | % |
| $V_{IN}$= 12Vdc, $T_A$=25°C | $V_{O,set}$ = 1.0Vdc | η | | 92.1 | | % |
| $I_O$=$I_{O, max}$ , $V_O$= $V_{O,set}$ | $V_{O,set}$ = 1.2Vdc | η | | 93.0 | | % |
| | $V_{O, set}$ = 1.5Vdc | η | | 94.0 | | % |
| Switching Frequency | All | $f_{sw}$ | - | 400 | - | kHz |
| Frequency Synchronization | All | | | | | |
| Synchronization Frequency Range | All | | -15 | | +15 | % |
| High-Level Input Voltage | All | $V_{IH,SYNC}$ | 2.5 | | | V |
| Low-Level Input Voltage | All | $V_{IL,SYNC}$ | | | 1.1 | V |
| Minimum Pulse Width, SYNC | All | $t_{SYNC}$ | 256 | | | ns |

* Minimum load on module should be 5mA

# 120A TeraDLynx™: Non-Isolated DC-DC Power Modules

**7Vdc –14Vdc input; 0.4Vdc to 1.5Vdc output; 120A Output Current**

## General Specifications

| Parameter | Device | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Calculated MTBF ($I_O$=0.8$I_{O, max}$, $T_A$=40°C) Telecordia Issue 2 Method 1 Case 3 | All | | 11,556,226 | | Hours |
| Weight - Module with SMT Pins | | | 57 (2.01) | | g (oz.) |
| Module with Through Hole Pins | | | 59 (2.08) | | g (oz.) |

## Feature Specifications

Unless otherwise indicated, specifications apply over all operating input voltage, resistive load, and temperature conditions. See Feature Descriptions for additional information.

| Parameter | Device | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| On/Off Signal Interface ($V_{IN}$=$V_{IN, min}$ to $V_{IN, max}$ ; open collector or equivalent, Signal referenced to GND) | | | | | | |
| Device Code with no suffix - Negative Logic (See Ordering Information) (On/OFF pin is open collector/drain logic input with external pull-up resistor; signal referenced to GND) | | | | | | |
| Logic High (Module OFF) | | | | | | |
| Input High Current | All | $I_{IH}$ | — | — | 1 | mA |
| Input High Voltage | All | $V_{IH}$ | 2 | — | $V_{IN, max}$ | Vdc |
| Logic Low (Module ON) | | | | | | |
| Input low Current | All | $I_{IL}$ | — | — | 10 | µA |
| Input Low Voltage | All | $V_{IL}$ | -0.2 | — | 0.4 | Vdc |
| Device Code with suffix "4" - Positive Logic (See Ordering Information) (On/OFF pin is open collector/drain logic input with external pull-up resistor; signal referenced to GND) | | | | | | |
| Logic High (Module ON) | | | | | | |
| Input High Current | All | $I_{IH}$ | — | — | 10 | µA |
| Input High Voltage | All | $V_{IH}$ | 2 | — | $V_{IN, max}$ | Vdc |
| Logic Low (Module OFF) | | | | | | |
| Input low Current | All | $I_{IL}$ | — | — | 10 | µA |
| Input Low Voltage | All | $V_{IL}$ | -0.2 | — | 0.4 | Vdc |
| Turn-On Delay and Rise Times | | | | | | |
| ($V_{IN}$=$V_{IN, nom}$, $I_O$=$I_{O, max}$, $V_O$ to within ±1% of steady state) Case 1: On/Off input is enabled and then input power is applied (delay from instant at which $V_{IN}$ = $V_{IN, min}$ until $V_o$ = 10% of $V_{O, set}$) | All | Tdelay | — | 10 | — | ms |
| Case 2: Input power is applied for at least one second and then the On/Off input is enabled (delay from instant at which Von/Off is enabled until $V_o$ = 10% of $V_{O, set}$) | All | Tdelay | — | 2 | — | ms |
| Output voltage Rise time (time for $V_o$ to rise from 10% of Vo, set to 90% of Vo, set) | All | Trise | — | 5 | — | msec |
| Output voltage overshoot ($T_A$ = 25°C $V_{IN}$= $V_{IN, min}$ to $V_{IN, max}$,$I_O$ = $I_{O, min}$ to $I_{O, max}$) With or without maximum external capacitance | | Output | | | 3.0 | % $V_{O, set}$ |
| Over Temperature Protection (See Thermal Considerations section) | All | $T_{ref}$ | | 135 | | °C |
| PMBus Over Temperature Warning Threshold | All | $T_{WARN}$ | | 125 | | °C |

# 120A TeraDLynx™: Non-Isolated DC-DC Power Modules

**7Vdc –14Vdc input; 0.4Vdc to 1.5Vdc output; 120A Output Current**

## Feature Specifications (cont.)

| Parameter | Device | Symbol | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Tracking Accuracy (Power-Up: 0.5V/ms) | All | $V_{SEQ} - V_o$ | | | 100 | mV |
| (Power-Down: 0.5V/ms) | All | $V_{SEQ} - V_o$ | | | 100 | mV |
| ($V_{IN, min}$ to $V_{IN, max}$; $I_{O, min}$ to $I_{O, max}$ $V_{SEQ} < V_o$) | | | | | | |
| Input Undervoltage Lockout | | | | | | |
| Turn-on Threshold | All | | | | 7 | Vdc |
| Turn-off Threshold | All | | 6.75 | | | Vdc |
| Hysteresis | All | | | 0.25 | | Vdc |
| PMBus Adjustable Input Under Voltage Lockout Thresholds | All | | 7 | | 14 | Vdc |
| Resolution of Adjustable Input Under Voltage Threshold | All | | | | 5.8 | mV |
| PGOOD (Power Good) | | | | | | |
| Signal Interface Open Drain, $V_{supply} \leq 5VDC$ | | | | | | |
| Overvoltage threshold for PGOOD ON | All | | | 110 | | $\%V_{O, set}$ |
| Overvoltage threshold for PGOOD OFF | All | | | 110 | | $\%V_{O, set}$ |
| Undervoltage threshold for PGOOD ON | All | | | 90 | | $\%V_{O, set}$ |
| Undervoltage threshold for PGOOD OFF | All | | | 90 | | $\%V_{O, set}$ |
| Pulldown resistance of PGOOD pin | All | | | | 2 | Ω |
| Sink current capability into PGOOD pin | All | | | | 50 | mA |

## Digital Interface Specifications

Unless otherwise indicated, specifications apply over all operating input voltage, resistive load, and temperature conditions. See Feature Descriptions for additional information.

| Parameter | Conditions | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **PMBus Signal Interface Characteristics** | | | | | | |
| Input High Voltage (CLK, DATA) | | $V_{IH}$ | 2.1 | | | V |
| Input Low Voltage (CLK, DATA) | | $V_{IL}$ | | | 1.1 | V |
| Input high level current (CLK, DATA) | | $I_{IH}$ | | | 0.5 | μA |
| Input low level current (CLK, DATA) | | $I_{IL}$ | | | 4 | mA |
| Output Low Voltage (CLK, DATA, SMBALERT#) | $I_{OUT}$=4mA | $V_{OL}$ | | | 0.25 | V |
| Output high level open drain leakage current (DATA, SMBALERT#) | $V_{OUT}$=3.6V | $I_{OH}$ | 5 | | 55 | nA |
| Pin capacitance | | $C_o$ | | | 10 | pF |
| PMBus Operating frequency range | Slave Mode | $F_{PMB}$ | 10 | | 1000 | kHz |
| Data hold time | | $t_{HD:DAT}$ | | 0 | | ns |
| Data setup time | | $t_{SU:DAT}$ | | 100 | | ns |
| **Measurement System Characteristics** | | | | | | |
| Read delay time | | $t_{DLY}$ | | 110 | | μs |
| Output current measurement range | | $I_{RNG}$ | 0 | | 135 | A |
| Output current measurement resolution | | $I_{RES}$ | | 250 | | mA |
| Output current measurement accuracy | -40°C to +85°C | $I_{ACC}$ | | | ±5 | % of Io,max |
| $V_{OUT}$ measurement range | | $V_{OUT}$ | 0 | | 2.0 | V |
| $V_{OUT}$ measurement accuracy | | $V_{OUT(gain)}$ | | ±1 | | % of Vo,max |
| $V_{OUT}$ measurement resolution | | $V_{OUT(res)}$ | | 0.61 | | mV |
| $V_{IN}$ measurement range | | $V_{IN}$ | 0 | | 16 | V |
| $V_{IN}$ measurement accuracy | | $V_{IN(gain)}$ | | ±2 | | % |
| $V_{IN}$ measurement resolution | | $V_{IN(res)}$ | | 5.8 | | mV |
| Temperature measurement range | | $T_{MEAS}$ | -25 | | 150 | °C |
| Temperature measurement accuracy | | $T_{MEAS(gain)}$ | -8 | | 8 | °C |
| Temperature measurement resolution | | $T_{MEAS(res)}$ | | 0.08 | | °C |

# 120A TeraDLynx™: Non-Isolated DC-DC Power Modules

**7Vdc –14Vdc input; 0.4Vdc to 1.5Vdc output; 120A Output Current**

## Characteristic Curves

The following figures provide typical characteristics for the 120A Digital TeraDLynx™ at 0.6Vo and 25°C.

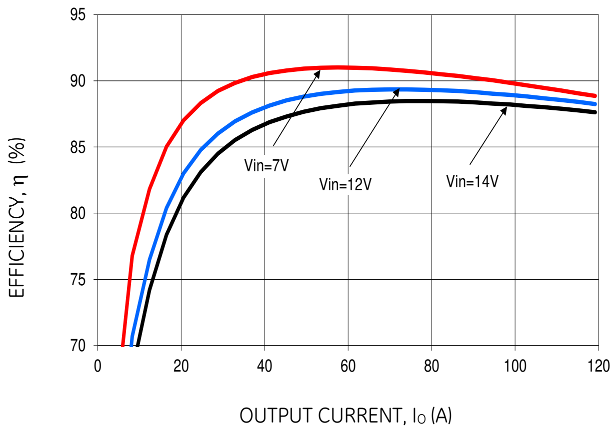



**Figure 1. Converter Efficiency versus Output Current.**

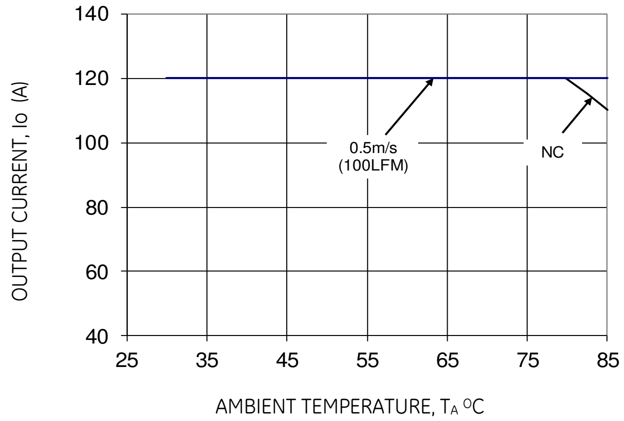



**Figure 2. Derating Output Current versus Ambient Temperature and Airflow.**

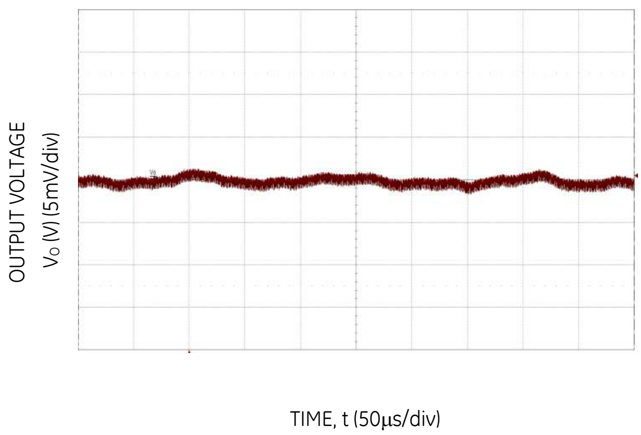



**Figure 3. Typical output ripple and noise ($C_O$=12x47µF ceramic + 10x470µF polymer, $V_{IN}$ = 12V, $I_o$ = $I_{o,max,}$).**

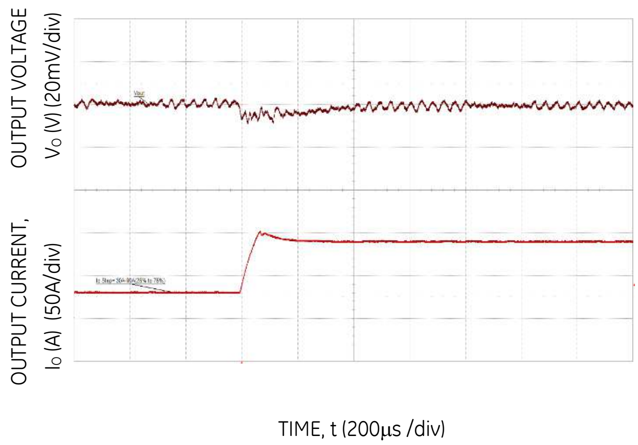



**Figure 4. Transient Response to Dynamic Load Change from 25% to 75% at 12Vin, Co= 12 x 47µF + 10 x 1000µF, $R_{TUNE}$ = 3.01kΩ.**

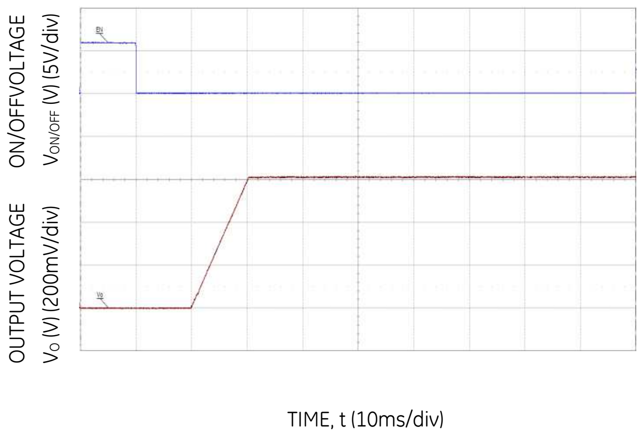



**Figure 5. Typical Start-up Using On/Off Voltage ($I_o$ = $I_{o,max}$).**

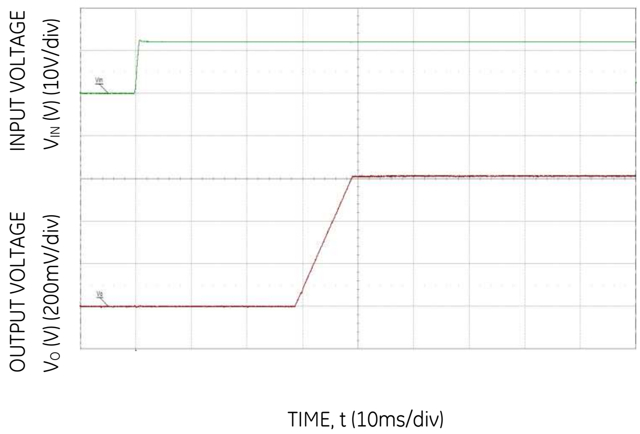



**Figure 6. Typical Start-up Using Input Voltage ($V_{IN}$ = 12V, $I_o$ = $I_{o,max}$).**

## Characteristic Curves

The following figures provide typical characteristics for the 120A TeraDLynxTM at 0.8Vo and 25°C

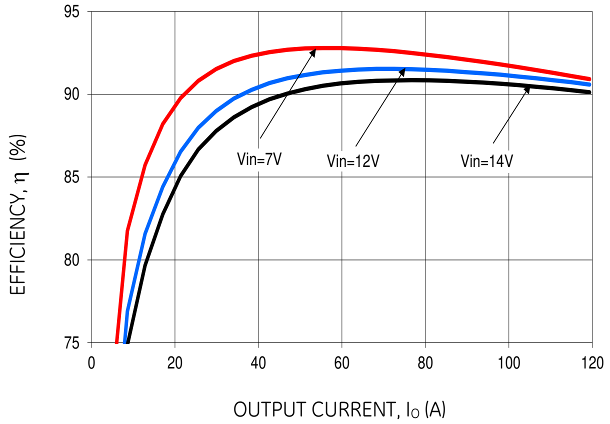



**Figure 7. Converter Efficiency versus Output Current.**

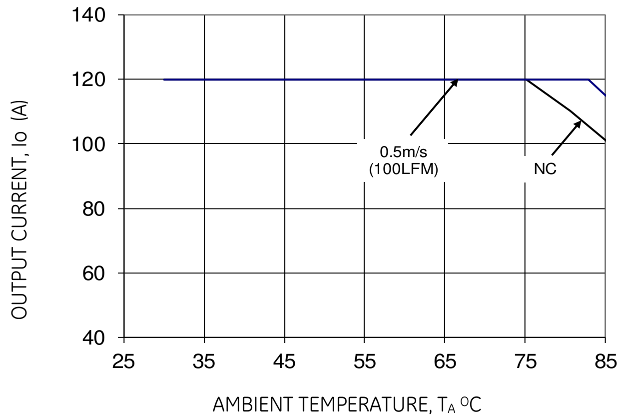



**Figure 8. Derating Output Current versus Ambient Temperature and Airflow.**

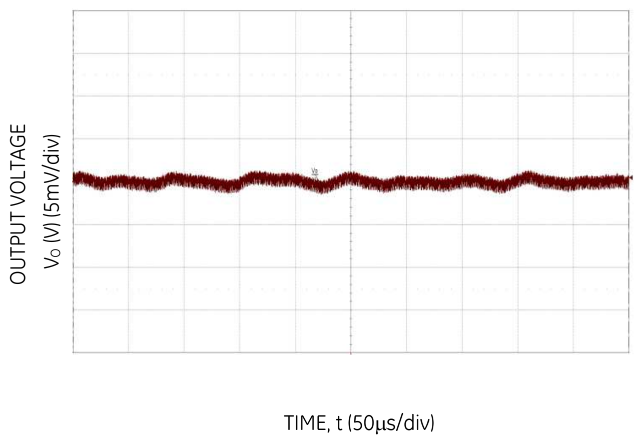



**Figure 9. Typical output ripple and noise ($C_O$=12x47µF ceramic + 10x470µF polymer, $V_{IN}$ = 12V, $I_o$ = $I_{o,max}$,)**

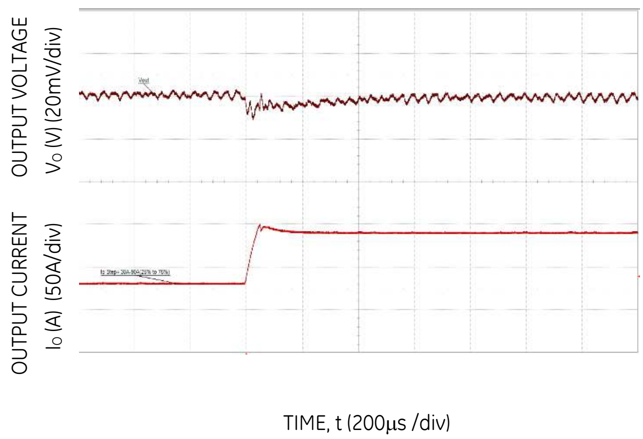



**Figure 10. Transient Response to Dynamic Load Change from 25% to 75% at 12Vin, Co= 12 x 47µF + 10 x 1000µF, $R_{TUNE}$ = 3.01kΩ.**

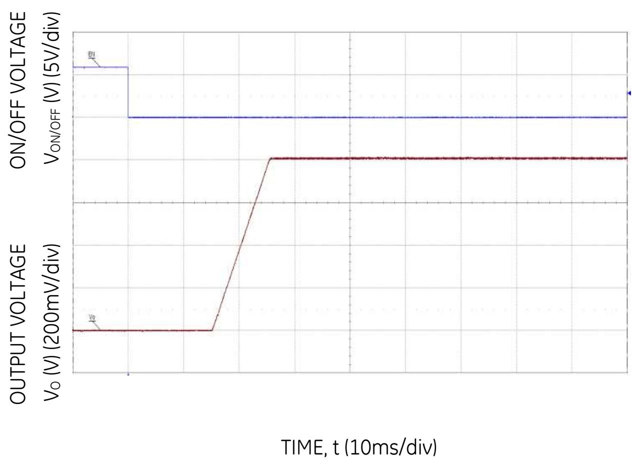



**Figure 11. Typical Start-up Using On/Off Voltage ($I_o$ = $I_{o,max}$).**

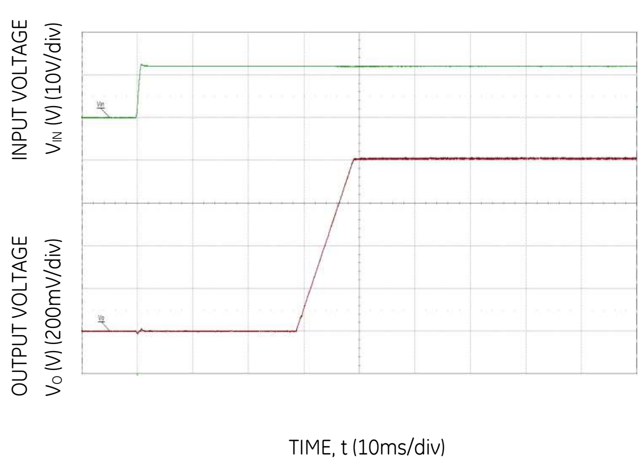



**Figure 12. Typical Start-up Using Input Voltage ($V_{IN}$ = 12V, $I_o$ = $I_{o,max}$).**

# 120A TeraDLynx™: Non-Isolated DC-DC Power Modules

**7Vdc –14Vdc input; 0.4Vdc to 1.5Vdc output; 120A Output Current**

## Characteristic Curves

The following figures provide typical characteristics for the 120A Digital TeraDLynx™ at 1.0Vo and 25°C.

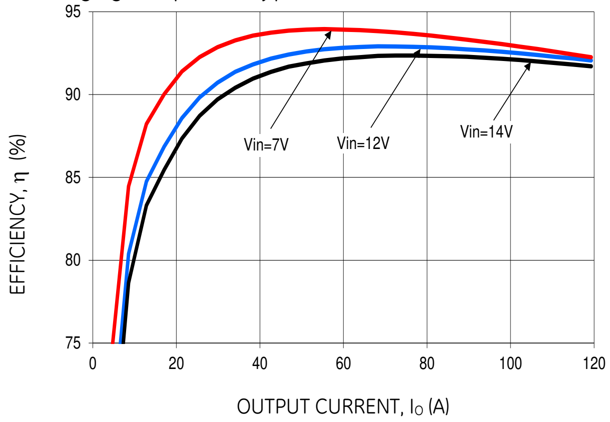



**Figure 13. Converter Efficiency versus Output Current.**

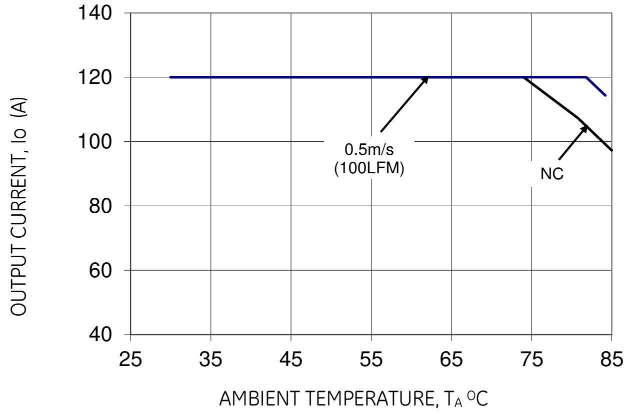



**Figure 14. Derating Output Current versus Ambient Temperature and Airflow.**

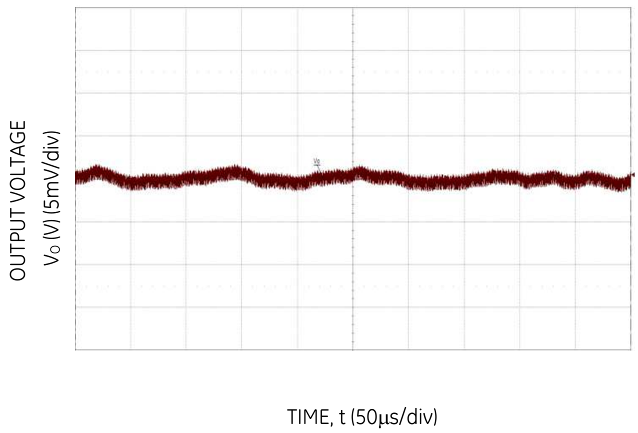



**Figure 15. Typical output ripple and noise ($C_O$=12x47µF ceramic + 10x470µF polymer, $V_{IN}$ = 12V, $I_o$ = $I_{o,max}$,)**

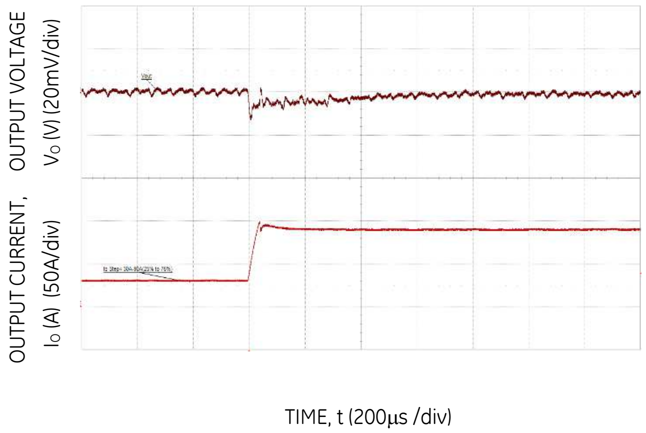



**Figure 16. Transient Response to Dynamic Load Change from 25% to 75% at 12Vin, Co= 12 x 47µF + 10 x 1000µF, $R_{TUNE}$ = 3.01kΩ.**

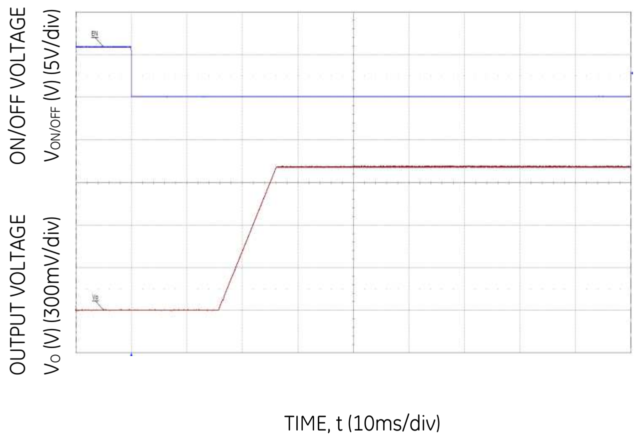



**Figure 17. Typical Start-up Using On/Off Voltage ($I_o$ = $I_{o,max}$).**

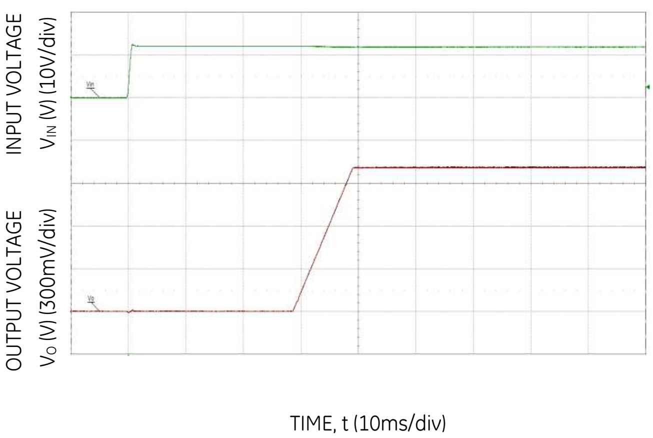



**Figure 18. Typical Start-up Using Input Voltage ($V_{IN}$ = 12V, $I_o$ = $I_{o,max}$).**

# 120A TeraDLynx™: Non-Isolated DC-DC Power Modules

**7Vdc –14Vdc input; 0.4Vdc to 1.5Vdc output; 120A Output Current**

## Characteristic Curves

The following figures provide typical characteristics for the 120A Digital TeraDLynx™ at 1.2Vo and 25°C.

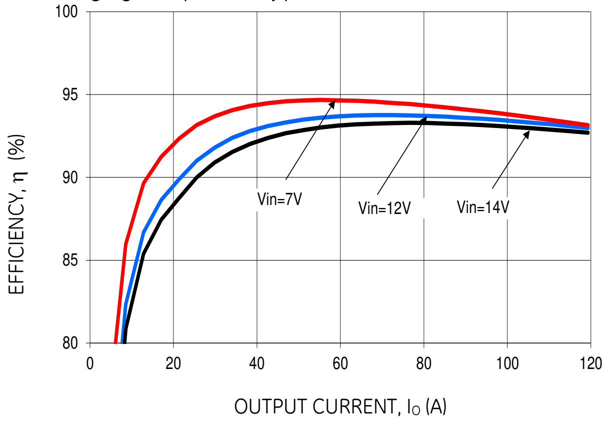



**Figure 19. Converter Efficiency versus Output Current.**

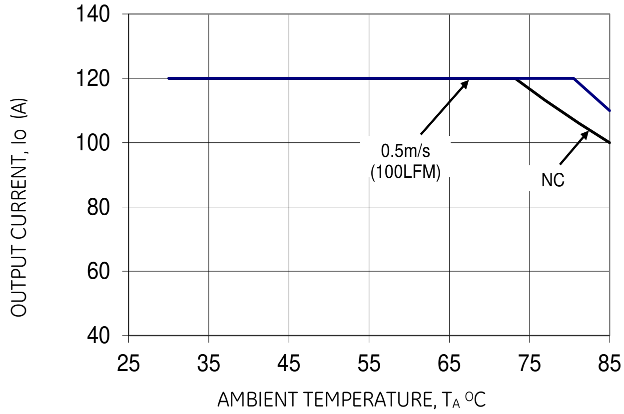



**Figure 20. Derating Output Current versus Ambient Temperature and Airflow.**

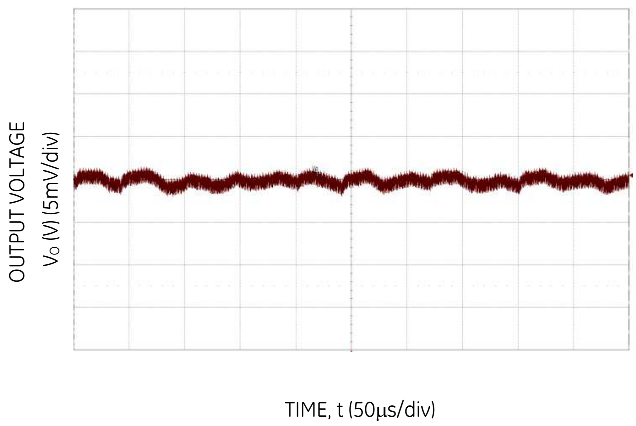



**Figure 21. Typical output ripple and noise ($C_O$=12x47µF ceramic + 10x470µF polymer, $V_{IN}$ = 12V, $I_o$ = $I_{o,max,}$)**

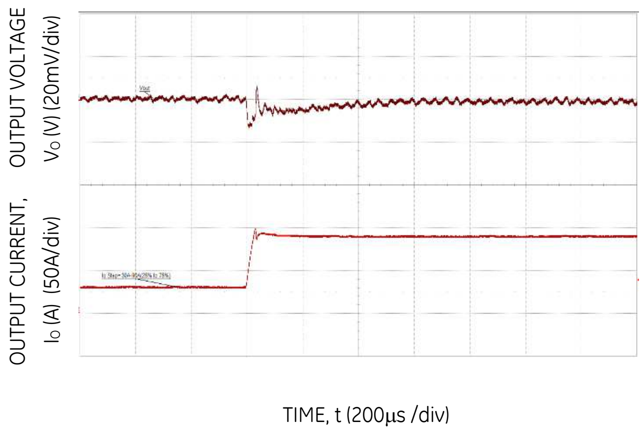



**Figure 22. Transient Response to Dynamic Load Change from 25% to 75% at 12Vin, Co= 12 x 47µF + 10 x 1000µF, $R_{TUNE}$ = 3.01kΩ.**

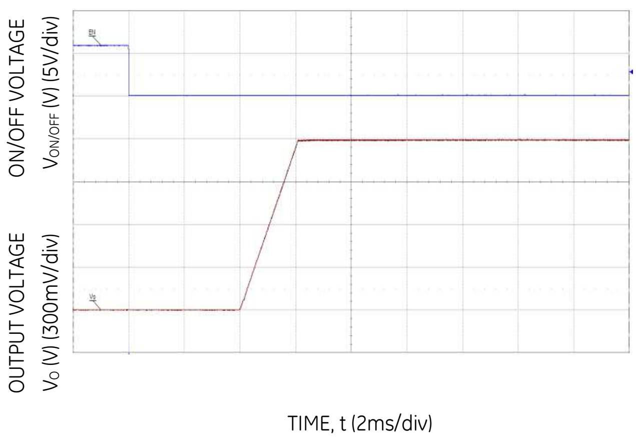



**Figure 23. Typical Start-up Using On/Off Voltage ($I_o$ = $I_{o,max}$).**

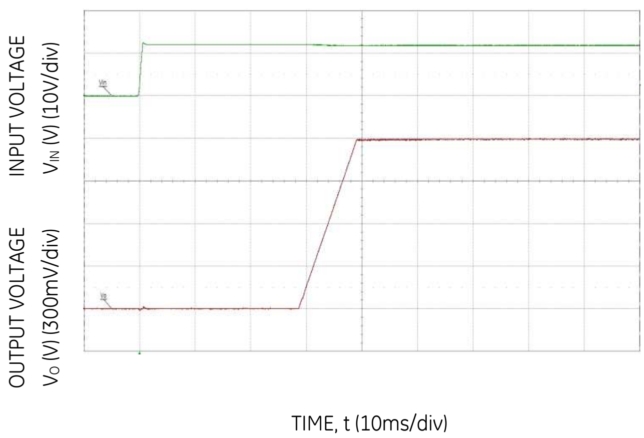



**Figure 24. Typical Start-up Using Input Voltage ($V_{IN}$ = 12V, $I_o$ = $I_{o,max}$).**

# 120A TeraDLynx$^{TM}$: Non-Isolated DC-DC Power Modules

**7Vdc –14Vdc input; 0.4Vdc to 1.5Vdc output; 120A Output Current**

## Characteristic Curves

The following figures provide typical characteristics for the 120A Digital TeraDLynx$^{TM}$ at 1.5Vo and 25$^{o}$C.

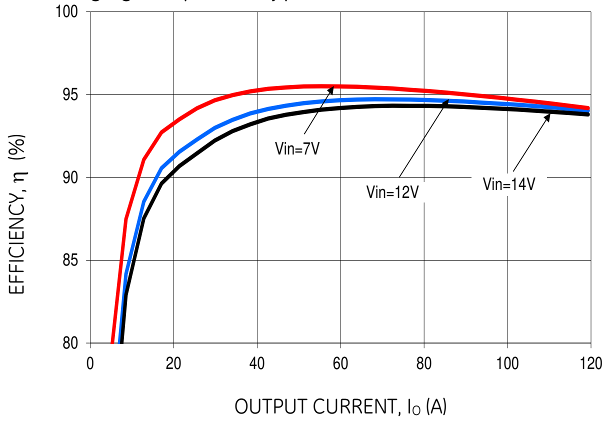



**Figure 25. Converter Efficiency versus Output Current.**

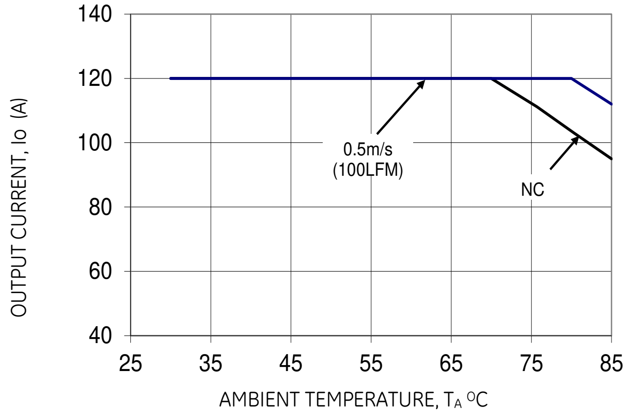



**Figure 26. Derating Output Current versus Ambient Temperature and Airflow.**

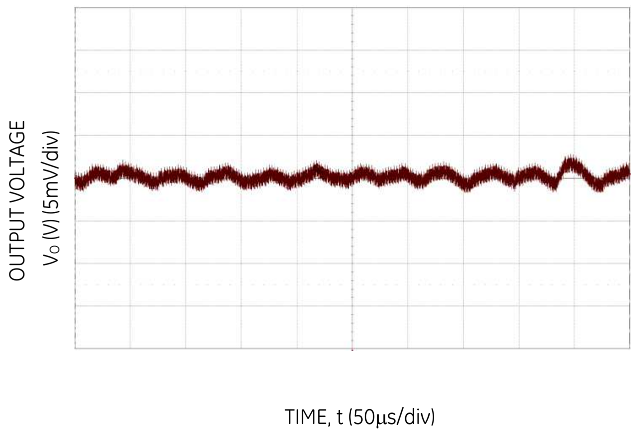



**Figure 27. Typical output ripple and noise ($C_O$=12x47μF ceramic + 10x470μF polymer, $V_{IN}$ = 12V, $I_o$ = $I_{o,max}$,)**

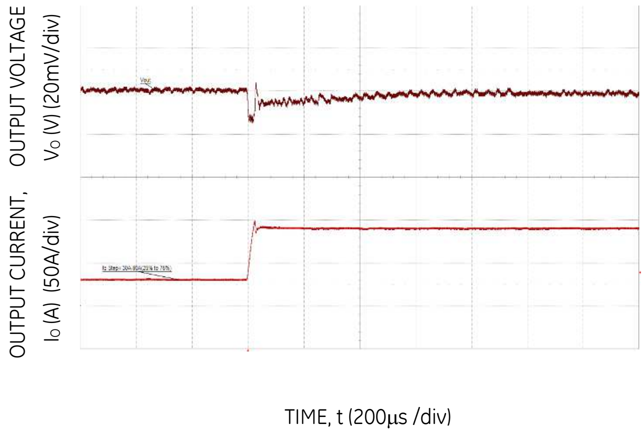



**Figure 28. Transient Response to Dynamic Load Change from 25% to 75% at 12Vin, Co= 12 x 47μF + 10 x 1000μF, $R_{TUNE}$ = 3.01kΩ.**

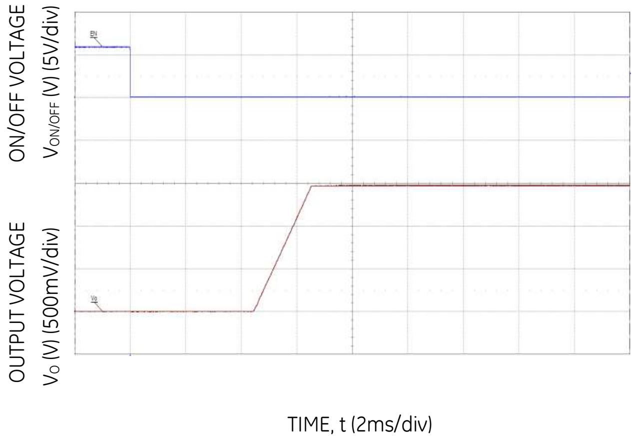



**Figure 29. Typical Start-up Using On/Off Voltage ($I_o$ = $I_{o,max}$).**

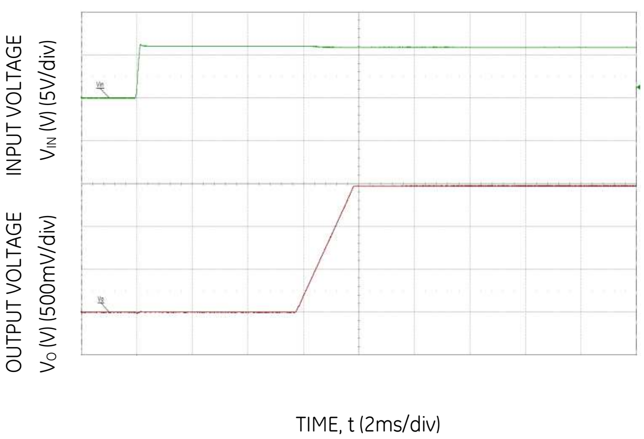



**Figure 30. Typical Start-up Using Input Voltage ($V_{IN}$ = 12V, $I_o$ = $I_{o,max}$).**

## Design Considerations

### Input Filtering

The 120A TeraDLynx™ module should be connected to a low ac-impedance source. A highly inductive source can affect the stability of the module. An input capacitance must be placed directly adjacent to the input pins of the module, to minimize input ripple voltage and ensure module stability.

To minimize input voltage ripple, ceramic capacitors are recommended at the input of the module. Figure 31 shows the input ripple voltage for various output voltages at 120A of load current with 4x470 + 12x22 + 12x4.7 µF and 2x470 + 6x22 + 12x4.7 µF input capacitor combinations.

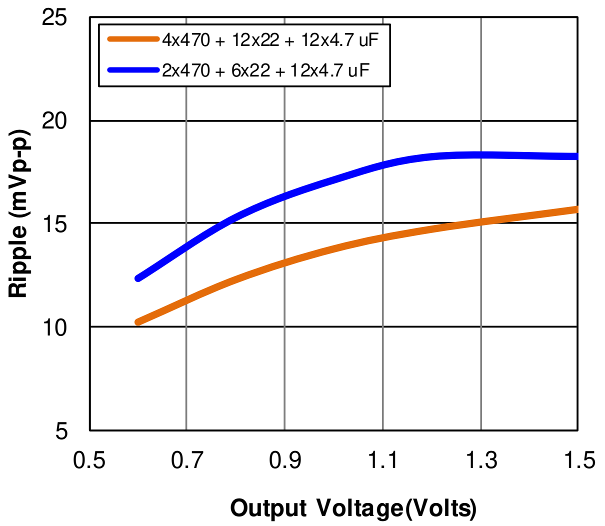



**Figure 31. Input ripple voltage for various output voltages with two input capacitor combinations at 120A load. Input voltage is 12V.**

### Output Filtering

These modules are designed for low output ripple voltage and will meet the maximum output ripple specification with minimum of 12 x 22 µF ceramic capacitors at the output of the module. However, additional output filtering may be required by the system designer for a number of reasons. First, there may be a need to further reduce the output ripple and noise of the module. Second, the dynamic response characteristics may need to be customized to a particular load step change.

To reduce the output ripple and improve the dynamic response to a step load change, additional capacitance at the output can be used. Low ESR polymer and ceramic capacitors are recommended to improve the dynamic response of the module. Figure 32 provides output ripple information for capacitance of ~3574uF (47µF (1210 ceramic) x 12 + 10µF (0805 ceramic) + 0.1µF (0402) x4 + 1000µF (polymer) x 3) at various Vo and a full load current of 120A. For stable operation of the module, limit the capacitance to less than the maximum output capacitance as specified in the electrical specification table. Optimal performance of the module can be achieved by using the Tunable Loop™ feature described later in this data sheet.

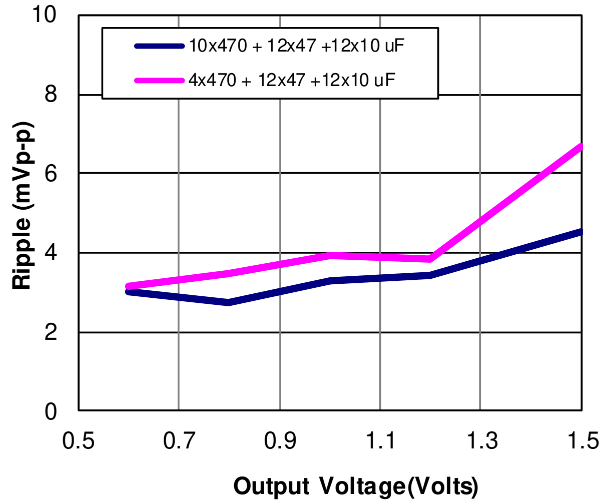



**Figure 32. Peak to peak output ripple voltage for various output voltages with external capacitors at the output (120A load). Input voltage is 12V.**

## Safety Considerations

For safety agency approval the power module must be installed in compliance with the spacing and separation requirements of the end-use safety agency standards, i.e., UL 60950-1 2nd, CSA C22.2 No. 60950-1-07, DIN EN 60950-1:2006 + A11 (VDE0805 Teil 1 + A11):2009-11; EN 60950-1:2006 + A11:2009-03.

For the converter output to be considered meeting the requirements of safety extra-low voltage (SELV), the input must meet SELV requirements. The power module has extra-low voltage (ELV) outputs when all inputs are ELV.

The input to these units is to be provided with a slow-blow fuse. When the input voltage is ≤ 8V, the recommendation is to use two 25A Littelfuse 456 series or equivalent fuses in parallel. For input voltages > 8V, a single 40A Littelfuse series 456 or equivalent fuse is recommended.

# 120A TeraDLynx$^{TM}$: Non-Isolated DC-DC Power Modules

**7Vdc –14Vdc input; 0.4Vdc to 1.5Vdc output; 120A Output Current**

## Analog Feature Descriptions

### Remote On/Off

The TeraDLynx 120A module can be turned ON and OFF either by using the ON/OFF pin (Analog interface) or through the PMBus interface (Digital). The module can be configured in a number of ways through the PMBus interface to react to the ON/OFF input:

- Module ON/OFF can controlled only through the analog interface (digital interface ON/OFF commands are ignored)
- Module ON/OFF can controlled only through the PMBus interface (analog interface is ignored)
- Module ON/OFF can be controlled by either the analog or digital interface

The default state of the module (as shipped from the factory) is to be controlled by the analog interface only. If the digital interface is to be enabled, or the module is to be controlled only through the digital interface, this change must be made through the PMBus. These changes can be made and written to non-volatile memory on the module so that it is remembered for subsequent use.

### Analog On/Off

The 120A Digital TeraDLynx$^{TM}$ power modules feature an On/Off pin for remote On/Off operation. With the Negative Logic On/Off option, (see Ordering Information), the module turns OFF during logic High and ON during logic Low. The On/Off signal should be always referenced to ground. Leaving the On/Off pin disconnected will turn the module ON when input voltage is present. With the positive logic on/off option, the module turns ON during logic high and OFF during logic low.

### Digital On/Off

**Please see the Digital Feature Descriptions section.**

### Monotonic Start-up and Shutdown

The module has monotonic start-up and shutdown behavior on the output for any combination of rated input voltage, output current and operating temperature range.

### Startup into Pre-biased Output

The module will start into a pre biased output on output as long as the pre bias voltage is 0.5V less than the set output voltage.

### Analog Output Voltage Programming

The output voltage of the module is programmable to any voltage from 0.4 to 1.5Vdc, as shown in Table 1, by connecting a resistor between the Trim and SIG_GND pins of the module as shown in Fig 33.

Without an external resistor between the Trim pin and SIG_GND pins, the output of the module will be 0.1 Vdc. The value of the trim resistor, $R_{Trim}$ for a desired output voltage, should be selected as shown in Table 1.

The trim resistor is only determined during module initialization and hence cannot be used for dynamic output voltage adjustment

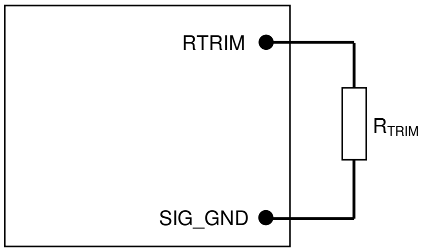



**Figure 33. Circuit configuration for programming output voltage using an external resistor.**

**Table 1**

| $V_{O, set}$ (V) | Rtrim (Ω) | $V_{O, set}$ (V) | Rtrim (Ω) | $V_{O, set}$ (V) | Rtrim (Ω) |
|---|---|---|---|---|---|
| **0.400** | 665 | **0.800** | 1740 | **1.200** | 5900 |
| **0.420** | 706 | **0.820** | 1820 | **1.220** | 6420 |
| **0.440** | 741 | **0.840** | 1930 | **1.240** | 6980 |
| **0.460** | 787 | **0.860** | 2030 | **1.260** | 7680 |
| **0.480** | 825 | **0.880** | 2130 | **1.280** | 8450 |
| **0.500** | 866 | **0.900** | 2230 | **1.300** | 9420 |
| **0.520** | 909 | **0.920** | 2340 | **1.320** | 10400 |
| **0.540** | 953 | **0.940** | 2460 | **1.340** | 11700 |
| **0.560** | 1000 | **0.960** | 2610 | **1.360** | 13500 |
| **0.580** | 1040 | **0.980** | 2710 | **1.380** | 15800 |
| **0.600** | 1090 | **1.000** | 2870 | **1.400** | 18900 |
| **0.620** | 1140 | **1.020** | 3050 | **1.420** | 23200 |
| **0.640** | 1180 | **1.040** | 3240 | **1.440** | 29800 |
| **0.660** | 1230 | **1.060** | 3480 | **1.460** | 40200 |
| **0.680** | 1290 | **1.080** | 3700 | **1.480** | 60400 |
| **0.700** | 1330 | **1.100** | 3920 | **1.500** | 115000 |
| **0.720** | 1380 | **1.120** | 4220 | | |
| **0.740** | 1470 | **1.140** | 4530 | | |
| **0.760** | 1560 | **1.160** | 4990 | | |
| **0.780** | 1640 | **1.180** | 5360 | | |

### Digital Output Voltage Adjustment

**Please see the Digital Feature Descriptions section.**

### Remote Sense

The power module has a differential Remote Sense feature to minimize the effects of distribution losses by regulating the voltage between the sense pins (VS+ and VS-) for the output. The voltage drop between the sense pins and the VOUT and GND pins of the module should not exceed 0.3V.

### Digital Output Voltage Margining

**Please see the Digital Feature Descriptions section.**

## Output Voltage Sequencing

The power module includes a sequencing feature, EZ-SEQUENCE that enables users to implement various types of output voltage sequencing in their applications. This is accomplished via an additional sequencing pin. When not using the sequencing feature, leave it unconnected.

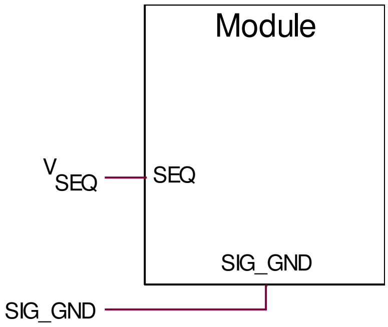



**Figure 34. Circuit showing connection of the sequencing signal to the SEQ pin.**

When the sequencing voltage is applied to the SEQ pin, the output voltage tracks this voltage until the output reaches the set-point voltage. The final value of the sequencing voltage must be set higher than the set-point voltage of the module. The output voltage follows the sequencing voltage on a one-to-one basis. By connecting multiple modules together, multiple modules can track their output voltages to the voltage applied on the SEQ pin.

The module's output can track the SEQ pin signal with slopes of up to 0.5V/msec during power-up or power-down.

To initiate simultaneous shutdown of the modules, the SEQ pin voltage is lowered in a controlled manner. The output voltage of the modules tracks the voltages below their set-point voltages on a one-to-one basis. A valid input voltage must be maintained until the tracking and output voltages reach ground potential.

## Digital Sequencing

The module can support digital sequencing by allowing control of the turn-on delay and rise times as well as turn-off and fall times,

## Digital Output Voltage Margining

**Please see the Digital Feature Descriptions section.**

## Overcurrent Protection (OCP)

To provide protection in a fault (output overload) condition, the unit is equipped with internal current-limiting circuitry on output and can endure current limiting continuously. The module overcurrent response is non-latching shutdown with automatic recovery. OCP response time is programmable through manufacturer specific commands. The unit operates normally once the output current is brought back into its specified range.

## Digital Adjustable Overcurrent Warning

**Please see the Digital Feature Descriptions section.**

## Overtemperature Protection

To provide protection in a fault condition, the unit is equipped with a thermal shutdown circuit. The unit will shut down if the overtemperature threshold of 135 °C (typ) is exceeded at the thermal reference point $T_{ref}$. Once the unit goes into thermal shutdown it will then wait to cool before attempting to restart.

## Digital Adjustable Overcurrent Warning/Shutdown

**Please see the Digital Feature Descriptions section.**

## Digital Temperature Status via PMBus

**Please see the Digital Feature Descriptions section.**

## Digitally Adjustable Output Over and Under Voltage Protection

**Please see the Digital Feature Descriptions section.**

## Input Undervoltage Lockout

At input voltages below the input undervoltage lockout limit, module operation for the associated output is disabled. The module will begin to operate at an input voltage above the undervoltage lockout turn-on threshold.

## Digitally Adjustable Input Undervoltage Lockout

**Please see the Digital Feature Descriptions section.**

## Digitally Adjustable Power Good Thresholds

**Please see the Digital Feature Descriptions section.**

## Synchronization

The module switching frequency is capable of being synchronized to an external signal frequency within a specified range. Synchronization is done by using the external signal applied to the SYNC pin of the module as shown in Fig. 35, with the converter being synchronized by the rising edge of the external signal. The Electrical Specifications table specifies the requirements of the external SYNC signal. If the SYNC pin is not used, the module should free run at the default switching frequency.

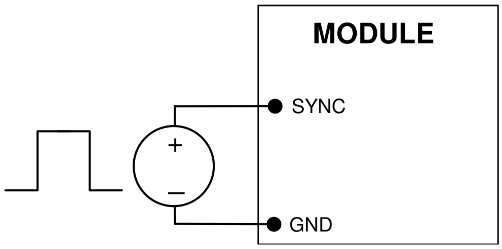



**Figure 35. External source connections to synchronize switching frequency of the module.**

## Measuring Output Current, Output Voltage and Input Voltage

**Please see the Digital Feature Descriptions section.**

## Digital Compensator

The TJT120 module uses digital control to regulate the output voltage. As with all POL modules, external capacitors are usually added to the output of the module for two reasons: to reduce output ripple and noise and to reduce output voltage deviations from the steady-state value in the presence of dynamic load current changes. Adding external capacitance however affects the voltage control loop of the module, typically causing the loop to slow down with sluggish response. Larger values of external capacitance could also cause the module to become unstable.

The TJT120 comes with default compensation values programmed into the non-volatile memory of the module. These digital compensation values can be adjusted externally to optimize transient response and also ensure stability for a wide range of external capacitance, as well as with different types of output capacitance. This can be done by two different methods.

1. By allowing the user to select among several pre-tuned compensation choices to select the one most suited to the transient response needs of the load. This selection is made via a resistor RTune connected between the RTUNE and SIG_GND pins as shown in Fig. 35. Table 2 shows various pre-tuned compensation combinations recommended for various external capacitor combinations.
2. Using PMBus to change compensation parameters in the module.

Note that during initial startup of the module, compensation values that are stored in non-volatile memory are used. If a resistor RTune is connected to the module, then the compensation values are changed to ones that correspond to the value of RTUNE. If RTUNE is open however, no change in compensation values is made. Finally, if the user chooses to do so, they can overwrite the compensation values via PMBus commands.

Recommended values of $R_{TUNE}$ for different output capacitor combinations are given in Table 2. If no RTUNE is used, the default compensation values are used.

The TJT120 pre-tuned compensation can be divided into three different banks (COMP1, COMP2, COMP3) that are available to the user to compensate the control loop for various values and combinations of output capacitance and to obtain reliable and stable performance under different conditions. Each bank consists of 20 different sets of compensation coefficients pre-calculated for different values of output capacitance. The three banks are set up as follows:

- COMP1: Recommended for the case where all of the output capacitance is composed of only ceramic capacitors. The range of external output capacitance is from 1470 µF to a maximum value of 17640 µF)
- COMP2: For the most commonly used mix of ceramic and polymer type capacitors that have higher output capacitance in a smaller size. The range of output capacitance is from 2564 µF to a maximum of 30564 uF. This is the combination of output capacitance and compensation that can achieve the best transient response at lowest cost and smallest size. For example, with the maximum output capacitance of 12 x 47µF ceramics + 25 x 1000 µF polymer capacitors, and selecting RTUNE = 5.36kΩ, transient deviation can be as low as 25 mV, for a 50% load step (0 to 85A).
- COMP3: Suitable for a mix of ceramic and higher ESR polymers or electrolytic capacitors, with output capacitance ranging from a minimum of 2204 µF to a maximum of 30084 µF.

Selecting $R_{TUNE}$ according to Table 2 will ensure stable operation of the module with sufficient stability margin as well as yield optimal transient response.

In applications with tight output voltage limits in the presence of dynamic current loading, additional output capacitance will be required. Table 3 lists recommended values of $R_{TUNE}$ in order to meet 2% output voltage deviation limits for some common output voltages in the presence of an 60A to 120A step change (50% of full load), with an input voltage of 12V. Please contact your GE technical representative to obtain more details of this feature as well as for guidelines on how to select the right value of external RTUNE to tune the module for best transient performance and stable operation for other output capacitance values. Simulation models are also available via the GE Power Module Wizard to predict stability characteristics and transient response.

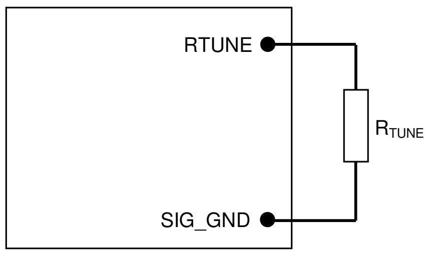



**Figure 36. Circuit diagram showing connection of $R_{TUNE}$ to tune the control loop of the module.**

Table 2. Recommended $R_{TUNE}$ Compensation.

| Output Capacitance Type | Number of Output Capacitors** | Total Output Capacitance (μF)** | $R_{TUNE}$ resistor (Ω) | $R_{TUNE}$ Index | KD | KI | KP | AP |
|---|---|---|---|---|---|---|---|---|
| Default Compensation Values | | | OPEN | | 375 | 2 | 37 | 150 |
| Ceramic | 10 x 47μF + 10 x 100μF | 1398 | 29.1 | 0 | 375 | 2 | 37 | 150 |
| Ceramic | 12 x 47μF + 12 x 100μF | 1644 | 88.7 | 1 | 441 | 3 | 44 | 150 |
| Ceramic | 14 x 47μF + 14 x 100μF | 1890 | 150 | 2 | 506 | 3 | 51 | 150 |
| Ceramic | 16 x 47μF + 16 x 100μF | 2136 | 213 | 3 | 572 | 3 | 57 | 150 |
| Ceramic | 19 x 47μF + 19 x 100μF | 2505 | 280 | 4 | 671 | 3 | 67 | 150 |
| Ceramic | 22 x 47μF + 22 x 100μF | 2874 | 348 | 5 | 770 | 4 | 77 | 150 |
| Ceramic | 25 x 47μF + 25 x 100μF | 3243 | 417 | 6 | 869 | 4 | 87 | 150 |
| Ceramic | 28 x 47μF + 28 x 100μF | 3612 | 493 | 7 | 968 | 4 | 97 | 150 |
| Ceramic | 31 x 47μF + 31 x 100μF | 3981 | 569 | 8 | 1067 | 4 | 107 | 150 |
| Ceramic | 34 x 47μF + 34 x 100μF | 4350 | 642 | 9 | 1166 | 4 | 117 | 150 |
| Ceramic | 38 x 47μF + 38 x 100μF | 4842 | 723 | 10 | 1297 | 5 | 130 | 150 |
| Ceramic | 42 x 47μF + 42 x 100μF | 5334 | 806 | 11 | 1429 | 5 | 143 | 150 |
| Ceramic | 48 x 47μF + 48 x 100μF | 6072 | 898 | 12 | 1627 | 5 | 163 | 150 |
| Ceramic | 55 x 47μF + 55 x 100μF | 6933 | 938 | 13 | 1858 | 5 | 186 | 150 |
| Ceramic | 63 x 47μF + 63 x 100μF | 7917 | 1090 | 14 | 2121 | 6 | 212 | 150 |
| Ceramic | 72 x 47μF + 72 x 100μF | 9024 | 1180 | 15 | 2418 | 6 | 242 | 150 |
| Ceramic | 82 x 47μF + 82 x 100μF | 10254 | 1290 | 16 | 2748 | 7 | 275 | 150 |
| Ceramic | 93 x 47μF + 93 x 100μF | 11607 | 1400 | 17 | 3110 | 7 | 311 | 150 |
| Ceramic | 105 x 47μF + 105 x 100μF | 13083 | 1520 | 18 | 3506 | 7 | 351 | 150 |
| Ceramic | 120 x 47μF + 120 x 100μF | 14928 | 1640 | 19 | 4000 | 8 | 400 | 150 |
| Ceramic + Polymer | 12 x 47μF + 2 x 1000μF | 2672 | 1760 | 20 | 501 | 3 | 300 | 220 |
| Ceramic + Polymer | 12 x 47μF + 3 x 1000μF | 3672 | 1890 | 21 | 688 | 3 | 413 | 220 |
| Ceramic + Polymer | 12 x 47μF + 4 x 1000μF | 4672 | 2030 | 22 | 876 | 3 | 525 | 220 |
| Ceramic + Polymer | 12 x 47μF + 5 x 1000μF | 5672 | 2150 | 23 | 1063 | 4 | 638 | 220 |
| Ceramic + Polymer | 12 x 47μF + 6 x 1000μF | 6672 | 2320 | 24 | 1250 | 4 | 750 | 220 |
| Ceramic + Polymer | 12 x 47μF + 7 x 1000μF | 7672 | 2460 | 25 | 1438 | 4 | 860 | 220 |
| Ceramic + Polymer | 12 x 47μF + 8 x 1000μF | 8672 | 2640 | 26 | 1625 | 5 | 975 | 220 |
| Ceramic + Polymer | 12 x 47μF + 9 x 1000μF | 9672 | 2840 | 27 | 1813 | 5 | 1088 | 220 |
| Ceramic + Polymer | 12 x 47μF + 10 x 1000μF | 10672 | 3010 | 28 | 2000 | 5 | 1200 | 220 |
| Ceramic + Polymer | 12 x 47μF + 11 x 1000μF | 11672 | 3200 | 29 | 2187 | 5 | 1312 | 220 |
| Ceramic + Polymer | 12 x 47μF + 12 x 1000μF | 12672 | 3400 | 30 | 2375 | 5 | 1425 | 220 |
| Ceramic + Polymer | 12 x 47μF + 13 x 1000μF | 13672 | 3650 | 31 | 2562 | 6 | 1537 | 220 |
| Ceramic + Polymer | 12 x 47μF + 15 x 1000μF | 15672 | 3880 | 32 | 2937 | 6 | 1762 | 220 |
| Ceramic + Polymer | 12 x 47μF + 17 x 1000μF | 17672 | 4120 | 33 | 3312 | 6 | 1987 | 220 |
| Ceramic + Polymer | 12 x 47μF + 19 x 1000μF | 19672 | 4420 | 34 | 3687 | 7 | 2212 | 220 |
| Ceramic + Polymer | 12 x 47μF + 21 x 1000μF | 21672 | 4700 | 35 | 4061 | 7 | 2437 | 220 |
| Ceramic + Polymer | 12 x 47μF + 23 x 1000μF | 23672 | 5050 | 36 | 4436 | 7 | 2662 | 220 |
| Ceramic + Polymer | 12 x 47μF + 25 x 1000μF | 25672 | 5360 | 37 | 4811 | 8 | 2887 | 220 |
| Ceramic + Polymer | 12 x 47μF + 27 x 1000μF | 27672 | 5760 | 38 | 5186 | 8 | 3112 | 220 |
| Ceramic + Polymer | 12 x 47μF + 30 x 1000μF | 30672 | 6120 | 39 | 5748 | 8 | 3449 | 220 |

** Total output capacitance includes the capacitance inside the module is 4 x 47μF (3mΩ ESR).

Note: The capacitors used in the digital compensation Loop tables are 47μF/3 mΩ ESR ceramic, 100uF/3.2mΩ ceramic, 1000 μF/6mΩ ESR polymer capacitor and 820uF/19mΩ ESR Polymer capacitor.

Table 2 (continued). $R_{TUNE}$ compensation table

| Output Capacitance Type | Number of Output Capacitors** | Total Output Capacitance (μF)** | $R_{TUNE}$ resistor (Ω) | $R_{TUNE}$ Index | KD | KI | KP | AP |
|---|---|---|---|---|---|---|---|---|
| Ceramic + Electrolytic | 12 x 47μF + 2 x 820μF | 2312 | 6570 | 40 | 176 | 2 | 176 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 3 x 820μF | 3312 | 7060 | 41 | 238 | 3 | 238 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 4 x 820μF | 3952 | 7590 | 42 | 301 | 3 | 301 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 5 x 820μF | 4772 | 8160 | 43 | 363 | 3 | 363 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 6 x 820μF | 5592 | 8870 | 44 | 426 | 4 | 426 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 7 x 820μF | 6412 | 9530 | 45 | 488 | 4 | 488 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 8 x 820μF | 7312 | 10400 | 46 | 550 | 4 | 550 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 9 x 820μF | 8052 | 11300 | 47 | 613 | 4 | 613 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 10 x 820μF | 8872 | 12400 | 48 | 675 | 5 | 675 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 11 x 820μF | 9692 | 13700 | 49 | 738 | 5 | 738 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 12 x 820μF | 10512 | 15000 | 50 | 800 | 5 | 800 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 14 x 820μF | 12152 | 16700 | 51 | 925 | 5 | 925 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 16 x 820μF | 13792 | 18700 | 52 | 1050 | 6 | 1050 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 18 x 820μF | 15432 | 21000 | 53 | 1174 | 6 | 1174 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 20 x 820μF | 17072 | 24000 | 54 | 1299 | 6 | 1299 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 23 x 820μF | 19532 | 28000 | 55 | 1486 | 7 | 1486 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 26 x 820μF | 21992 | 33000 | 56 | 1674 | 7 | 1674 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 29 x 820μF | 24452 | 40200 | 57 | 1861 | 8 | 1861 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 32 x 820μF | 26912 | 50500 | 58 | 2048 | 8 | 2048 | 220 |
| Ceramic + Electrolytic | 12 x 47μF + 36 x 820μF | 30192 | 68000 | 59 | 2298 | 8 | 2298 | 220 |

** Total output capacitance includes the capacitance inside the module is 4 x 47μF (3mΩ ESR).

Note: The capacitors used in the digital compensation Loop tables are 47μF/3 mΩ ESR ceramic, 100uF/3.2mΩ ceramic, 1000 μF/6mΩ ESR polymer capacitor and 820uF/19mΩ ESR Electrolytic capacitor.

# Digital Feature Descriptions

## PMBus Interface Capability

The 120A TeraDLynx power modules have a PMBus interface that supports both communication and control. The PMBus Power Management Protocol Specification can be obtained from www.pmbus.org. The modules support a subset of version 1.1 of the specification (see Table 4 for a list of the specific commands supported). Most module parameters can be programmed using PMBus and stored as defaults for later use.

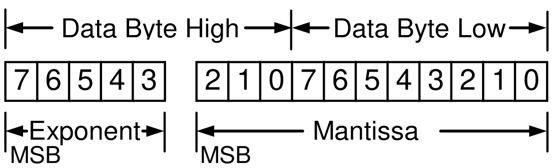
Communication over the module PMBus interface supports the Packet Error Checking (PEC) scheme. The PMBus master must generate the correct PEC byte for all transactions, and check the PEC byte returned by the module.

The module also supports the SMBALERT# response protocol whereby the module can alert the bus master if it wants to talk. For more information on the SMBus alert response protocol, see the System Management Bus (SMBus) specification.

The module has non-volatile memory that is used to store configuration settings. Not all settings programmed into the device are automatically saved into this non-volatile memory, only those specifically identified as capable of being stored can be saved (see Table 4 for which command parameters can be saved to non-volatile storage).

## PMBus Data Format

For commands that set thresholds, voltages or report such quantities, the module supports the "Linear" data format among the three data formats supported by PMBus. The Linear Data Format is a two-byte value with an 11-bit, two's complement mantissa and a 5-bit, two's complement exponent. The format of the two data bytes is shown below:




The value is of the number is then given by

$$\text{Value} = \text{Mantissa} \times 2^{\text{Exponent}}$$

## PMBus Addressing

The power module is addressed through the PMBus using a device address. The module supports 128 possible addresses (0 to 127 in decimal) which can be set using resistors connected from the ADDR0 and ADDR1 pins to SIG_GND. Note that some of these addresses (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 12, 40, 44, 45, 55 in decimal) are reserved according to the SMBus specification and may not be useable. The address is set in the form of two octal (0 to 7) digits, with each pin setting one digit. The ADDR1 pin sets the high order digit and ADDR0 sets the low order digit. The resistor values suggested for each digit are shown in Table 3 (E96 series resistors are recommended). Note that if either address resistor value is outside the range specified in Table 4, the module will respond to address 127.

The user must know which I$^2$C addresses are reserved in a system for special functions and set the address of the module to avoid interfering with other system operations. Both 100kHz and 400kHz bus speeds are supported by the module. Connection for the PMBus interface should follow the High Power DC specifications given in section 3.1.3 in the SMBus specification V2.0 for the 400kHz bus speed or the Low Power DC specifications in section 3.1.2. The complete SMBus specification is available from the SMBus web site, smbus.org.

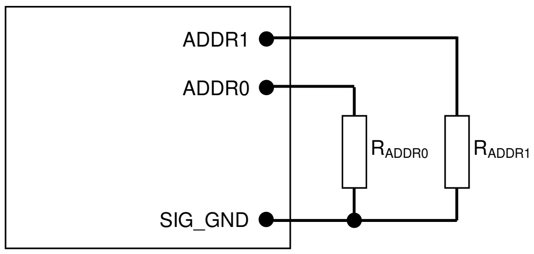



**Figure 37. Circuit showing connection of resistors used to set the PMBus address of the module.**

**Table 3**

| PMBus Address Table | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ADDR1 Resistor Values | | | | | | | | | | |
| ADDR0 Resistor Values | 4.99K | 15.4k | 27.4K | 41.2K | 54.9K | 71.5K | 90.9K | 110K | 137K | 162K | 191K |
| 4.99K | 1 | 13 | 25 | 37 | 49 | 61 | 73 | 85 | 97 | 109 | 121 |
| 15.4K | 2 | 14 | 26 | 38 | 50 | 62 | 74 | 86 | 98 | 110 | 122 |
| 27.4K | 3 | 15 | 27 | 39 | 51 | 63 | 75 | 87 | 99 | 111 | 123 |
| 41.2K | 4 | 16 | 28 | 40 | 52 | 64 | 76 | 88 | 100 | 112 | 124 |
| 54.9K | 5 | 17 | 29 | 41 | 53 | 65 | 77 | 89 | 101 | 113 | 125 |
| 71.5K | 6 | 18 | 30 | 42 | 54 | 66 | 78 | 90 | 102 | 114 | 126 |
| 90.9K | 7 | 19 | 31 | 43 | 55 | 67 | 79 | 91 | 103 | 115 | 127 |
| 110K | 8 | 20 | 32 | 44 | 56 | 68 | 80 | 92 | 104 | 116 | 64 |
| 137K | 9 | 21 | 33 | 45 | 57 | 69 | 81 | 93 | 105 | 117 | 64 |
| 162K | 10 | 22 | 34 | 46 | 58 | 70 | 82 | 94 | 106 | 118 | 64 |
| 191K | 11 | 23 | 35 | 47 | 59 | 71 | 83 | 95 | 107 | 119 | 64 |
| 232K | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 64 |

### Operation (01h)

This is a paged register. The OPERATION command can be used to turn the module on or off in conjunction with the ON/OFF pin input. It is also used to margin up or margin down the output voltage

### PMBus Enabled On/Off

The module can also be turned on and off via the PMBus interface. The OPERATION command is used to actually turn the module on and off via the PMBus, while the ON_OFF_CONFIG command configures the combination of analog ON/OFF pin input and PMBus commands needed to turn the module on and off. Bit [7] in the OPERATION command data byte enables the module, with the following functions:

0 : Output is disabled
1 : Output is enabled

This module uses the lower five bits of the ON_OFF_CONFIG data byte to set various ON/OFF options as follows:

| Bit Position | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|
| Access | r/w | r/w | r/w | r | r |
| Function | PU | CMD | CPR | POL | CPA |
| ***Default Value*** | ***1*** | ***0*** | ***1*** | ***x*** | ***1*** |

PU: Sets the default to either operate any time input power is present or for the ON/OFF to be controlled by the analog ON/OFF input and the PMBus OPERATION command. This bit is used together with the CP, CMD and ON bits to determine startup.

| Bit Value | Action |
|---|---|
| 0 | Module powers up any time power is present regardless of state of the analog ON/OFF pin |
| 1 | Module does not power up until commanded by the analog ON/OFF pin and the OPERATION command as programmed in bits [2:0] of the ON_OFF_CONFIG register. |

CMD: The CMD bit controls how the device responds to the OPERATION command.

| Bit Value | Action |
|---|---|
| 0 | Module ignores the ON bit in the OPERATION command |
| 1 | Module responds to the ON bit in the OPERATION command |

CPR: Sets the response of the analog ON/OFF pin. This bit is used together with the CMD, PU and ON bits to determine startup.

| Bit Value | Action |
|---|---|
| 0 | Module ignores the analog ON/OFF pin, i.e. ON/OFF is only controlled through the PMBUS via the OPERATION command |
| 1 | Module requires the analog ON/OFF pin to be asserted to start the unit |

CPA: Sets the action of the analog ON/OFF pin when turning the controller OFF. This bit is internally read and cannot be modified by the user

### PMBus Adjustable Soft Start Rise Time

The soft start rise time of module output is adjustable in the module via PMBus. The TON_RISE command can set the rise time in ms, and allows choosing soft start times between 0 and 1000ms. ~~While this is the settable range, the actual rise time should be set considering the charging current of the output capacitors and starting current required by the load. Setting the TON_RISE too low could trigger the overcurrent protection. The default setting for TON_RISE is 5msec.~~

### Output Voltage Adjustment Using the PMBus

Two PMBus commands are available to change the output voltage setting. The first, VOUT_COMMAND can set the output voltage directly. The second, VOUT_TRIM is used to apply an offset to the commanded output voltage.

Since the output voltage can be set using an external RTrim resistor as well, an additional PMBus command MFR_VOUT_SET_MODE is used to tell the module whether the VOUT_COMMAND is used to directly set output voltage or whether RTrim is to be used. If MFR_VOUT_SET_MODE is set to where bit position 7 is set at 1, then VOUT_COMMAND is ignored and output voltage is set solely by RTrim. If bit 7 of MFR_VOUT_SET_MODE is set to 0, then output voltage is set using VOUT_COMMAND, and the value of RTrim is only used at startup to set the output voltage.

The second output voltage adjustment command VOUT_TRIM works in either case to provide a fixed offset to the output voltage. This allows PMBus adjustment of the output voltage irrespective of how MFR_VOUT_SET_MODE is set and allows digital adjustment of the output voltage setting even when RTrim is used.

For all digital commands used to set or adjust the output voltage via PMBus, the resolution is 98µV.

### Output Voltage Margining Using the PMBus

The output voltage of the module can be margined via PMBus between 0.4 and 1.5V. The margining voltage can be adjusted in 98µV steps.

### PMBus Adjustable Overcurrent Warning

The module can provide an overcurrent warning via the PMBus. The threshold for the overcurrent warning can be set using the parameter IOUT_OC_WARN_LIMIT. This command uses the "Linear" data format with a two byte data word where the upper five bits [7:3] of the high byte represent the exponent and the remaining three bits of the high byte [2:0] and the eight bits in the low byte represent the mantissa. The value of the IOUT_OC_WARN_LIMIT can be stored to non-volatile memory using the STORE_DEFAULT_ALL command.

### Temperature Status via PMBus

The module provides information related to temperature of the module through standardized PMBus commands. Commands READ_TEMPERATURE1, READ_TEMPERATURE_2 are mapped to module temperature and internal temperature of the PWM controller, respectively. The temperature readings are returned in °C and in two bytes.

### PMBus Adjustable Output Over, Under Voltage Protection

The module has output over and under voltage protection capability. The PMBus command VOUT_OV_FAULT_LIMIT is used to set the output over voltage threshold. The default value is configured to be 112.5% of the commanded output. The command VOUT_UV_FAULT_LIMIT sets the threshold that detects an output under voltage fault. The default values are 87.5% of the commanded output voltage. Both commands use two data bytes formatted in the Linear format.

### PMBus Adjustable Input Undervoltage Lockout

The module allows adjustment of the input under voltage lockout and hysteresis. The command VIN_ON allows setting the input voltage turn on threshold, while the VIN_OFF command sets the input voltage turn off threshold. For the VIN_ON command possible values are 7 to 14V and for the VIN_OFF command, possible values are 6.75V to 14V. Both VIN_ON and VIN_OFF commands use the "Linear" format with two data bytes.

### Measurement of Output Current, Output Voltage and Input Voltage

The module can measure key module parameters such as output current, output voltage and input voltage and provide this information through the PMBus interface.

### Measuring Output Current Using the PMBus

The module measures output current by using a signal derived from the switching FET currents. The current gain factor is accessed using the IOUT_CAL_GAIN command, and consists of two bytes in the Linear data format. During manufacture, each module is calibrated by measuring and storing the current gain factor into non-volatile storage.

The current measurement accuracy is also improved by each module being calibrated during manufacture with the offset in the current reading. The IOUT_CAL_OFFSET command is used to store and read the current offset. The READ_IOUT command provides module average output current information. This command only supports positive output current, i.e. current sourced from the module. If the converter is sinking current a reading of 0 is provided. The READ_IOUT command returns two bytes of data in the Linear data format.

### Measuring Output Voltage Using the PMBus

The module provides output voltage information using the READ_VOUT command. The command returns two bytes of data in Linear format.

### Measuring Input Voltage Using the PMBus

The module provides input voltage information using the READ_VIN command. The command returns two bytes of data in the Linear format.

### Reading the Status of the Module using the PMBus

The module supports a number of status information commands implemented in PMBus. A 1 in the bit position indicates the fault that is flagged.

STATUS_BYTE: Returns one byte of information with a summary of the most critical device faults.

| Bit Position | Flag | Default Value |
|---|---|---|
| 7 | X | 0 |
| 6 | OFF | 0 |
| 5 | VOUT Overvoltage | 0 |
| 4 | IOUT Overcurrent | 0 |
| 3 | VIN Undervoltage | 0 |
| 2 | Temperature | 0 |
| 1 | CML (Comm. Memory Fault) | 0 |
| 0 | None of the above | 0 |

STATUS_WORD: Returns two bytes of information with a summary of the module's fault/warning conditions.

**Low Byte**

| Bit Position | Flag | Default Value |
|---|---|---|
| 7 | X | 0 |
| 6 | OFF | 0 |
| 5 | VOUT Overvoltage | 0 |
| 4 | IOUT Overcurrent | 0 |
| 3 | VIN Undervoltage | 0 |
| 2 | Temperature | 0 |
| 1 | CML (Comm. Memory Fault) | 0 |
| 0 | None of the above | 0 |

**High Byte**

| Bit Position | Flag | Default Value |
|---|---|---|
| 7 | VOUT fault or warning | 0 |
| 6 | IOUT fault or warning | 0 |
| 5 | X | 0 |
| 4 | X | 0 |
| 3 | POWER_GOOD# (is negated) | 0 |
| 2 | X | 0 |
| 1 | X | 0 |
| 0 | X | 0 |

STATUS_VOUT: Returns one byte of information relating to the status of the module's output voltage related faults.

| Bit Position | Flag | Default Value |
|---|---|---|
| 7 | VOUT OV Fault | 0 |
| 6 | VOUT_OV_WARNING | 0 |
| 5 | VOUT_UV_WARNING | 0 |
| 4 | VOUT UV Fault | 0 |
| 3 | X | 0 |
| 2 | X | 0 |
| 1 | X | 0 |
| 0 | X | 0 |

STATUS_IOUT: Returns one byte of information relating to the status of the module's output voltage related faults.

| Bit Position | Flag | Default Value |
|---|---|---|
| 7 | IOUT OC Fault | 0 |
| 6 | X | 0 |
| 5 | IOUT OC Warning | 0 |
| 4 | X | 0 |
| 3 | X | 0 |
| 2 | X | 0 |
| 1 | X | 0 |
| 0 | X | 0 |

STATUS_TEMPERATURE: Returns one byte of information relating to the status of the module's temperature related faults.

| Bit Position | Flag | Default Value |
|---|---|---|
| 7 | OT Fault | 0 |
| 6 | OT Warning | 0 |
| 5 | X | 0 |
| 4 | X | 0 |
| 3 | X | 0 |
| 2 | X | 0 |
| 1 | X | 0 |
| 0 | X | 0 |

STATUS_CML: Returns one byte of information relating to the status of the module's communication related faults.

| Bit Position | Flag | Default Value |
|---|---|---|
| 7 | Invalid/Unsupported Command | 0 |
| 6 | Invalid/Unsupported Data | 0 |
| 5 | Packet Error Check Failed | 0 |
| 4 | Memory Fault Detected | 0 |
| 3 | X | 0 |
| 2 | X | 0 |
| 1 | Other Communication Fault | 0 |
| 0 | X | 0 |

MFR_SPECIFIC_00: Returns information related to the type of module and revision number. Bits [7:2] in the Low Byte indicate the module type (001101 corresponds to the TJT120 series of module), while bits [7:3] in the high byte indicate the revision number of the module.

**Low Byte**

| Bit Position | Flag | Default Value |
|---|---|---|
| 7:2 | Module Name | 001101 |
| 1:0 | Reserved | 10 |

**High Byte**

| Bit Position | Flag | Default Value |
|---|---|---|
| 7:3 | Module Revision Number | None |
| 2:0 | Reserved | 000 |

## User-Programmable Compensation Coefficients

The output voltage control compensation coefficients can be changed by the user via PMBus commands. On startup, the module uses stored values of the four compensation parameters KD, KI, KP and ALPHA. If the module detects a valid value of RTUNE connected to the module, the values of KD, KI, KP and ALPHA are then changed to the appropriate values. Beyond this, the user can use the PMBus commands listed below to overwrite the values of KD, KP, KI and ALPHA.

MFR_SPECIFIC_KP: Allows the user to program the value of the KP compensation coefficient. The allowed range is -32768 to 32767. The entire 16 bits are used to enter this range of integer values in two's complement binary format.

MFR_SPECIFIC_KI: Allows the user to program the value of the KI compensation coefficient. The allowed range is -32768 to 32767. The entire 16 bits are used to enter this range of integer values in two's complement binary format.

MFR_SPECIFIC_KD: Allows the user to program the value of the KD compensation coefficient. The allowed range is -32768 to 32767. The entire 16 bits are used to enter this range of integer values in two's complement binary format.

MFR_SPECIFIC_ALPHA: Allows the user to program the value of the ALPHA compensation coefficient. The allowed range is -256 to 256. The entire 16 bits are used to enter this range of integer values in two's complement binary format.

## Summary of Supported PMBus Commands

Please refer to the PMBus 1.1 specification for more details of these commands. For the registers where a range is specified, any value outside the range is ignored and the module continues to use the previous value.

**Table 4**

<table>
<tr><th>Hex Code</th><th>Command</th><th>Brief Description</th><th>Non-Volatile Memory Storage</th></tr>
<tr><td>01</td><td>OPERATION</td><td>Turn Module on or off. Also used to margin the output voltage
<table>
<tr><th>Format</th><td colspan="8">Unsigned Binary</td></tr>
<tr><th>Bit Position</th><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><th>Access</th><td>r/w</td><td>r</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r</td><td>r</td></tr>
<tr><th>Function</th><td>On</td><td>X</td><td colspan="4">Margin</td><td>X</td><td>X</td></tr>
<tr><th>Default Value</th><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>X</td><td>X</td></tr>
</table></td><td>YES</td></tr>
<tr><td>02</td><td>ON_OFF_CONFIG</td><td>Configures the ON/OFF functionality as a combination of analog ON/OFF pin and PMBus commands
<table>
<tr><th>Format</th><td colspan="8">Unsigned Binary</td></tr>
<tr><th>Bit Position</th><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><th>Access</th><td>r</td><td>r</td><td>r</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r</td><td>r</td></tr>
<tr><th>Function</th><td>X</td><td>X</td><td>X</td><td>pu</td><td>cmd</td><td>cpr</td><td>X</td><td>cpa</td></tr>
<tr><th>Default Value</th><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td></tr>
</table></td><td>YES</td></tr>
<tr><td>03</td><td>CLEAR_FAULTS</td><td>Clear any fault bits that may have been set, also releases the SMBALERT# signal if the device has been asserting it.</td><td></td></tr>
<tr><td>10</td><td>WRITE_PROTECT</td><td>Used to control writing to the module via PMBus. Copies the current register setting in the module whose command code matches the value in the data byte into non-volatile memory (EEPROM) on the module
<table>
<tr><th>Format</th><td colspan="8">Unsigned Binary</td></tr>
<tr><th>Bit Position</th><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><th>Access</th><td>r/w</td><td>r/w</td><td>r/w</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><th>Function</th><td>bit7</td><td>bit6</td><td>bit5</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><th>Default Value</th><td>0</td><td>0</td><td>0</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
</table>
Bit5: 0 – Enables all writes as permitted in bit6 or bit7<br>
1 – Disables all writes except the WRITE_PROTECT, OPERATION and ON_OFF_CONFIG (bit 6 and bit7 must be 0)<br>
Bit 6: 0 – Enables all writes as permitted in bit5 or bit7<br>
1 – Disables all writes except for the WRITE_PROTECT and OPERATION commands (bit5 and bit7 must be 0)<br>
Bit7: 0 – Enables all writes as permitted in bit5 or bit6<br>
1 – Disables all writes except for the WRITE_PROTECT command (bit5 and bit6 must be 0)</td><td>YES</td></tr>
<tr><td>11</td><td>STORE_DEFAULT_ALL</td><td>Copies all current register settings in the module into non-volatile memory (EEPROM) on the module. Takes about 50ms for the command to execute.</td><td></td></tr>
<tr><td>12</td><td>RESTORE_DEFAULT_ALL</td><td>Restores all current register settings in the module from values in the module non-volatile memory (EEPROM)</td><td></td></tr>
<tr><td>20</td><td>VOUT_MODE</td><td>The module has MODE set to Linear and Exponent set to -14. These values cannot be changed
<table>
<tr><th>Bit Position</th><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><th>Access</th><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td></tr>
<tr><th>Function</th><td colspan="3">Mode</td><td colspan="5">2's complement Exponent</td></tr>
<tr><th>Default Value</th><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td></tr>
</table></td><td></td></tr>
<tr><td>21</td><td>VOUT_COMMAND</td><td>Set desired output voltage. Only 16-bit unsigned mantissa – implied exponent of -14 per VOUT_MODE command. Valid range is 0.4 to 1.5V.
<table>
<tr><th>Format</th><td colspan="8">Unsigned Mantissa</td></tr>
<tr><th>Bit Position</th><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td></tr>
<tr><th>Access</th><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><th>Function</th><td colspan="8">Mantissa</td></tr>
<tr><th>Default Value</th><td colspan="8">Variable</td></tr>
<tr><th>Bit Position</th><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><th>Access</th><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><th>Function</th><td colspan="8">Mantissa</td></tr>
<tr><th>Default Value</th><td colspan="8">Variable</td></tr>
</table></td><td>YES</td></tr>
</table>

**Table 4 (continued)**

<table>
<tr><th>Hex Code</th><th>Command</th><th>Brief Description</th><th>Non-Volatile Memory Storage</th></tr>
<tr><td>22</td><td>VOUT_TRIM</td><td>Apply a fixed offset voltage to the set output voltage from either the RTrim resistor or the VOUT_COMMAND. Implied exponent of -14 per VOUT_MODE command.<br>Allowed range is ±300mV.
<table>
<tr><td>Format</td><td colspan="8">Unsigned Mantissa</td></tr>
<tr><td>Bit Position</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Bit Position</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table></td><td>YES</td></tr>
<tr><td>23</td><td>VOUT_CAL_OFFSET</td><td>Applies an offset to the commanded output voltage to calibrate out errors in setting module output voltage (between -100mV and +100mV) and when output voltage is set via the PMBus command VOUT_COMMAND (21). Implied exponent of -14 per VOUT_MODE command.
<table>
<tr><td>Format</td><td colspan="8">Linear, two's complement binary</td></tr>
<tr><td>Bit Position</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td></tr>
<tr><td>Access</td><td>r/w</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable based on factory calibration</td></tr>
<tr><td>Bit Position</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Access</td><td>r</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable based on factory calibration</td></tr>
</table></td><td>YES</td></tr>
<tr><td>25</td><td>VOUT_MARGIN_HIGH</td><td>Sets the target voltage for margining the output high. Implied exponent of -14 per VOUT_MODE command. Allowed range is 0.4 to 1.5V
<table>
<tr><td>Format</td><td colspan="8">Linear, two's complement binary</td></tr>
<tr><td>Bit Position</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable</td></tr>
<tr><td>Bit Position</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable</td></tr>
</table></td><td>YES</td></tr>
<tr><td>26</td><td>VOUT_MARGIN_LOW</td><td>Sets the target voltage for margining the output low. Implied exponent of -14 per VOUT_MODE command. Allowed range is 0.4 to 1.5V.
<table>
<tr><td>Format</td><td colspan="8">Linear, two's complement binary</td></tr>
<tr><td>Bit Position</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable</td></tr>
<tr><td>Bit Position</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable</td></tr>
</table></td><td>YES</td></tr>
<tr><td>35</td><td>VIN_ON</td><td>Sets the value of input voltage at which the module turns on. Exponent is fixed at -6. Allowed range is 7 to 14V.
<table>
<tr><td>Format</td><td colspan="8">Linear, two's complement binary</td></tr>
<tr><td>Bit Position</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td></tr>
<tr><td>Access</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="5">Exponent</td><td colspan="3">Mantissa</td></tr>
<tr><td>Default Value</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>Bit Position</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table></td><td>YES</td></tr>
</table>

**Table 4 (continued)**

<table>
<tr><th>Hex Code</th><th>Command</th><th>Brief Description</th><th>Non-Volatile Memory Storage</th></tr>
<tr><td>36</td><td>VIN_OFF</td><td>Sets the value of input voltage at which the module turns off. Exponent is fixed at -6. Allowed range is 6.75 to 14V.
<table>
<tr><td>Format</td><td colspan="8">Linear, two's complement binary</td></tr>
<tr><td>Bit Position</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td></tr>
<tr><td>Access</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="5">Exponent</td><td colspan="3">Mantissa</td></tr>
<tr><td>Default Value</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>Bit Position</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table></td><td>YES</td></tr>
<tr><td>38</td><td>IOUT_CAL_GAIN</td><td>Applies a gain correction to the READ_IOUT command results to calibrate out gain errors in module measurements of the output current. The number in this register is divided by 8192 to generate the correction factor. Allowed range is 6553 to 9830.
<table>
<tr><td>Format</td><td colspan="8">Linear, two's complement binary</td></tr>
<tr><td>Bit Position</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td></tr>
<tr><td>Access</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Integer</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable based on factory calibration</td></tr>
<tr><td>Bit Position</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Integer</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable based on factory calibration</td></tr>
</table></td><td>YES</td></tr>
<tr><td>39</td><td>IOUT_CAL_OFFSET</td><td>Returns the value of the offset correction term used to correct the measured output current. The exponent is fixed at -2. The allowed range is -50 to +50A.
<table>
<tr><td>Format</td><td colspan="8">Linear, two's complement binary</td></tr>
<tr><td>Bit Position</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td></tr>
<tr><td>Access</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r/w</td><td>r</td><td>r</td></tr>
<tr><td>Function</td><td colspan="5">Exponent</td><td colspan="3">Mantissa</td></tr>
<tr><td>Default Value</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td colspan="3">Variable</td></tr>
<tr><td>Bit Position</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Access</td><td>r</td><td>r</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable based on factory calibration</td></tr>
</table></td><td>YES</td></tr>
<tr><td>40</td><td>VOUT_OV_FAULT_LIMIT</td><td>Sets the voltage level for an output overvoltage fault. Implied exponent of -14 per VOUT_MODE command. Allowed range is 0.4 to 2V.
<table>
<tr><td>Format</td><td colspan="8">Linear, two's compliment binary</td></tr>
<tr><td>Bit Position</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable</td></tr>
<tr><td>Bit Position</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable</td></tr>
</table></td><td>YES</td></tr>
<tr><td>41</td><td>VOUT_OV_FAULT_RESPONSE</td><td>Instructs the module on what action to take in response to an output overvoltage fault
<table>
<tr><td>Format</td><td colspan="8">Unsigned Binary</td></tr>
<tr><td>Bit Position</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r</td><td>r</td><td>r</td></tr>
<tr><td>Function</td><td>RSP [1]</td><td>RSP [0]</td><td>RS[2]</td><td>RS[1]</td><td>RS[0]</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Default Value</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
</table></td><td>YES</td></tr>
</table>

**Table 4 (continued)**

<table>
<tr><th>Hex Code</th><th>Command</th><th>Brief Description</th><th>Non-Volatile Memory Storage</th></tr>
<tr><td>42</td><td>VOUT_OV_WARN_LIMIT</td><td>Sets the value of output voltage at which the module generates warning for over-voltage. Exponent is fixed at -14. Allowed range is 0.4 to 2V.
<table>
<tr><td>Format</td><td colspan="8">Linear, two's complement binary</td></tr>
<tr><td>Bit Position</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td></tr>
<tr><td>Access</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="5">Exponent</td><td colspan="3">Mantissa</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable</td></tr>
<tr><td>Bit Position</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable</td></tr>
</table></td><td>YES</td></tr>
<tr><td>43</td><td>VOUT_UV_WARN_LIMIT</td><td>Sets the value of output voltage at which the module generates warning for under-voltage. Exponent is fixed at -14. Allowed range is 0.05 to 1.5V.
<table>
<tr><td>Format</td><td colspan="8">Linear, two's complement binary</td></tr>
<tr><td>Bit Position</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td></tr>
<tr><td>Access</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="5">Exponent</td><td colspan="3">Mantissa</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable</td></tr>
<tr><td>Bit Position</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable</td></tr>
</table></td><td>YES</td></tr>
<tr><td>44</td><td>VOUT_UV_FAULT_LIMIT</td><td>Sets the voltage level for an output undervoltage fault. Exponent is fixed at -14. Allowed range is 0.05 to 2V.
<table>
<tr><td>Format</td><td colspan="8">Linear, two's complement binary</td></tr>
<tr><td>Bit Position</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td></tr>
<tr><td>Access</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="5">Exponent</td><td colspan="3">Mantissa</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable</td></tr>
<tr><td>Bit Position</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td colspan="8">Variable</td></tr>
</table></td><td>YES</td></tr>
<tr><td>45</td><td>VOUT_UV_FAULT_RESPONSE</td><td>Instructs the module on what action to take in response to an output undervoltage fault
<table>
<tr><td>Format</td><td colspan="8">Unsigned Binary</td></tr>
<tr><td>Bit Position</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r</td><td>r</td><td>r</td></tr>
<tr><td>Function</td><td>RSP [1]</td><td>RSP [0]</td><td>RS[2]</td><td>RS[1]</td><td>RS[0]</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Default Value</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
</table></td><td>YES</td></tr>
<tr><td>46</td><td>IOUT_OC_FAULT_LIMIT</td><td>Sets the current level for an output overcurrent fault (can only be lowered below the maximum of 140A). The exponent is fixed at -2
<table>
<tr><td>Format</td><td colspan="8">Linear, two's complement binary</td></tr>
<tr><td>Bit Position</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td></tr>
<tr><td>Access</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="5">Exponent</td><td colspan="3">Mantissa</td></tr>
<tr><td>Default Value</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>Bit Position</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Access</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td><td>r/w</td></tr>
<tr><td>Function</td><td colspan="8">Mantissa</td></tr>
<tr><td>Default Value</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td></tr>
</table></td><td>YES</td></tr>
</table>