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## Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832

Email & Skype: [info@chipsmall.com](mailto:info@chipsmall.com) Web: [www.chipsmall.com](http://www.chipsmall.com)

Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China



## SLDN-20D1Ax Series

### Non-Isolated DC-DC Converter

The SLDN-20D1Ax modules are non-isolated DC-DC converters that can deliver up to 20A of output current. These modules operate over a wide range of input voltage ( $V_{IN} = 3 \text{ VDC} - 14.4 \text{ VDC}$ ) and provide a precisely regulated output voltage from 0.6 VDC to 5.5 VDC, programmable via an external resistor and PMBus™ control. Features include a digital interface using the PMBus™ protocol, remote On/Off, adjustable output voltage, over current and over temperature protection. The PMBus™ interface supports a range of commands to both control and monitor the module. The module also includes the Tunable Loop™ feature that allows the user to optimize the dynamic response of the converter to match the load with reduced amount of output capacitance leading to savings on cost and PWB area.



#### Key Features & Benefits

- 3 VDC – 14.4 VDC Input
- 0.45 VDC – 5.5 VDC / 20 A Outputs
- Power Good signal
- Remote On/Off
- Over temperature protection
- Cost efficient open frame design
- Ability to sink and source current
- DOSA based
- Compatible in a Pb-free or SnPb reflow environment
- Output voltage programmable from 0.6 VDC to 2.0 VDC via external resistor
- Tunable Loop™ to optimize dynamic output voltage response
- Flexible output voltage sequencing EZ-SEQUENCE
- Fixed switching frequency with capability of external synchronization
- Output overcurrent protection (non-latching)
- Small size: 20.32 x 11.43 x 8.5 mm (0.8 x 0.45 x 0.334 in)
- Wide operating temperature range -40°C to 85°C

#### Applications

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

## 1. MODEL SELECTION

OUTPUT VOLTAGE	INPUT VOLTAGE	MAX. OUTPUT CURRENT	MAX. OUTPUT POWER	TYPICAL EFFICIENCY	MODEL NUMBER ACTIVE LOW	MODEL NUMBER ACTIVE HIGH
0.45 - 5.5 VDC	3 - 14.4 VDC	20 A	110W	95.2%	SLDN-20D1A0	SLDN-20D1AL

**NOTE:** 1. Add "R" suffix at the end of the model number to indicate tape and reel packaging (Standard).  
2. Add "G" suffix at the end of the model number to indicate tray packaging (Option).

### PART NUMBER EXPLANATION

S	LDN	-	20	D	1A	0	x
Mounting type	Series code		Output current	Wide input voltage range	Sequencing	Logic status	Package
Surface mount	SLDN series		20A	3-14.4V	With sequencing	0 – active high L – active low	G – Tray R – Tape&Reel

## 2. ABSOLUTE MAXIMUM RATINGS

PARAMETER	DESCRIPTION	MIN	TYP	UNITS
Continuous Input Voltage		-0.3	15	V
Voltage on SEQ ,SYNC,VS+		-	7	V
Voltage on CLK,DATA,SMBALERT terminal		-	3.6	V
Operating Ambient Temperature	see Thermal Considerations section	-40	85	°C
Storage Temperature		-55	125	°C
Altitude		-	2000	m

**NOTE:** Stresses in excess of the absolute maximum ratings can cause permanent damage to the device. These are absolute stress ratings only, 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 data sheet. Exposure to absolute maximum ratings for extended periods can adversely affect the device reliability.

## 3. INPUT SPECIFICATIONS

PARAMETER	DESCRIPTION	MIN	TYP	MAX	UNIT
Operating Input Voltage		3	-	14.4	V
Input Current	VIN=3V to 14 V, IO=IO, max	-	-	19	A
Input Current (no load)	VO,set = 0.6 VDC	-	69	-	mA
	VO,set = 5 VDC	-	134	-	mA
Input Stand-by Current	VIN = 12V, module disabled	-	16.5	-	mA
Input Reflected Ripple Current (pk-pk)	1. 5Hz to 20MHz, 1μH source impedance; VIN =0 to 14V, IO= IOmax	-	50	-	mA
	2. See Test Configurations				
I2t Inrush Current Transient		-	-	1	A2s
Input Ripple Rejection (120Hz)		-	-64	-	dB

**NOTE:** Unless otherwise indicated, specifications apply overall operating input voltage, resistive load, and temperature conditions.



#### 4. OUTPUT SPECIFICATIONS

PARAMETER	DESCRIPTION	MIN	TYP	MAX	UNIT
Output Voltage Set Point	with 0.1% tolerance for external resistor used to set output voltage	-1.0	-	+1.0	%Vo,set
Output Voltage	Over all operating input voltage, resistive load, and temperature conditions until end of life	-3.0	-	+3.0	%Vo,set
PMBus Adjustable Output Voltage Range		-25	0	+25	%Vo,set
PMBus Output Voltage Adjustment Step Size		-	0.4	-	
Adjustment Range	1. Selected by an external resistor 2. Some output voltages may not be possible depending on the input voltage – see Feature Descriptions Section	0.6	-	5.5	V
Remote Sense Range		-	-	0.5	V
Line Regulation	VO ≥ 2.5V	±0.17	±0.27	0.4	%Vo,set
	VO < 2.5V	-	-	5	mV
Load Regulation	VO ≥ 2.5V	-	-	10	mV
	VO < 2.5V	-	-	10	mV
Temperature Regulation	Tref=TA, min to TA, max	-	-	0.4	%Vo,set
Output Current	In either sink or source mode	0	-	20	mV
Output Ripple and Noise (pk-pk)	5Hz to 20MHz BW, VIN=VIN, nom and IO=IO, min to IO, max Co = 0.1µF // 22 µF ceramic capacitors)	-	50	100	mV
Output Ripple and Noise (rms)		-	20	38	mV
Output Short-Circuit Current	Vo≤250mV, Hiccup Mode	1.4	2.5	3.6	Arms
Turn-On Delay and Rise Times (VIN=VIN, nom, IO=IO, max, VO to within ±1% of steady state.)	Case 1: On/Off input is enabled and then input power is applied (delay from instant at which VIN = VIN, min until Vo = 10% of Vo, set)	1.0	1.1	1.7	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 Vo = 10% of Vo, set)	600	700	1800	µs
Output voltage Rise time	Time for Vo to rise from 10% of Vo, set to 90% of Vo, set.	1.2	1.5	2.7	msec
Output Capacitance	ESR ≥ 1 mΩ Without the Tunable Loop™	2x47	-	2x47	µF
	ESR ≥ 0.15 mΩ With the Tunable Loop™	2x47	-	1000	
	ESR ≥ 10 mΩ With the Tunable Loop™	2x47	-	10000	
Output Current Limit Inception	Current limit does not operate in sink mode	110	130	150	% Io,max

**NOTE:** Unless otherwise indicated, specifications apply over all operating input voltage, resistive load, and temperature conditions. External capacitors may require using the new Tunable Loop™ feature to ensure that the module is stable as well as getting the best transient response. See the Tunable Loop™ section for details.

### 3. GENERAL SPECIFICATIONS

PARAMETER			DESCRIPTION	MIN	TYP	MAX	UNIT
Efficiency	Vo=0.6V		Vin= 12VDC, TA=25°C Io=Io, max , Vo= Vo,set	76.0	79.1	-	%
	Vo=1.2V			84.3	87.1	-	
	Vo=1.8V			87.2	90.4	-	
	Vo=2.5V			90.3	92.6	-	
	Vo=3.3V			91.4	93.8	-	
	Vo=5.0V			92.8	95.2	-	
Switching Frequency				475	500	525	kHz
Synchronization Frequency Range				425	-	600	kHz
High-Level Input Voltage				2.0	-	-	V
Low-Level Input Voltage				-	-	0.4	V
Input Current, SYNC				-	-	100	nA
Minimum Pulse Width, SYNC				100			ns
Maximum SYNC rise time				100			ns
PMBus Over Temperature Warning Threshold				120	130	140	°C
PMBus Adjustable Input Under Voltage Lockout Thresholds				2.5	-	14	V
Resolution of Adjustable Input Under Voltage Threshold				-	-	500	mV
Over Temperature Protection			Tref-Q1	123	133	143	°C
			Tref-Q4	121	131	141	
Tracking Accuracy	Power-Up: 2V/ms		Vin, min to Vin, max; Io, min to Io, max, VSEQ < Vo	-	-	100	mV
	Power-Down: 2V/ms			-	-	100	
PGOOD (Power Good)	Overvoltage threshold for PGOOD ON			103	108	113	%Vo, set
	Overvoltage threshold for PGOOD OFF			100	105	110	%Vo, set
	Undervoltage threshold for PGOOD ON			105	110	115	%Vo, set
	Undervoltage threshold for PGOOD OFF			85	90	95	%Vo, set
	Pulldown resistance of PGOOD pin			-	-	50	Ω
	Sink current capability into PGOOD pin			-	-	5	mA
Weight				4.086	4.54	4.994	g
Input Undervoltage Lockout		Turn-on Threshold	2.7	-	2.95	V	
		Turn-off Threshold	2.4	-	2.75		
		Hysteresis	0.05	-	0.4		
MTBF			Calculated MTBF (IO=0.8IO, max, TA=40°C) Telecordia Issue 2 Method 1 Case 3			15,455,614	hours
Dimensions (L × W × H)				0.800 x 0.450 x 0.334			in
				20.32 x 11.43 x 8.50			mm

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

#### 4. DIGITAL INTERFACE SPECIFICATIONS

PARAMETER	DESCRIPTION	MIN	TYP	MAX	UNIT
<b>PMBUS SIGNAL INTERFACE CHARACTERISTICS</b>					
Input High Voltage (CLK, DATA)		2.1	-	3.6	V
Input Low Voltage (CLK, DATA)		-	-	0.8	V
Input high level current (CLK, DATA)		-10	-	10	μA
Input low level current (CLK, DATA)		-10	-	10	μA
Output Low Voltage (CLK, DATA, SMBALERT#)	$I_{out} = 2 \text{ mA}$	-	-	0.4	V
Output high level open drain leakage current (DATA, SMBALERT#)	$V_{out} = 3.6 \text{ V}$	0	-	10	μA
Pin capacitance		-	0.7	-	pF
Data hold time	Receive Mode	0	-	-	ns
	Transmit Mode	300	-	-	ns
Data setup time		250	-	-	ns
PMBus Operating frequency range		10	-	400	kHz
<b>MEASUREMENT SYSTEM CHARACTERISTICS</b>					
Read delay time		153	192	231	μs
Output current measurement range		0	-	26	A
Output current measurement resolution		62.5	-	-	mA
Output current measurement gain accuracy		-	-	±5	%
Output current measurement offset		-	-	0.1	A
VOUT measurement range		0	-	5.5	V
VOUT measurement resolution		-	15.625	-	mV
VOUT measurement gain accuracy		-15	-	5	%
VOUT measurement offset		-3	-	3	%
VIN measurement range		0	-	14.4	V
VIN measurement resolution		-	32.5	-	mV
VIN measurement gain accuracy		-15	-	5	%
VIN measurement offset		-5.5	-2	1.4	LSB

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

## 5. EFFICIENCY DATA

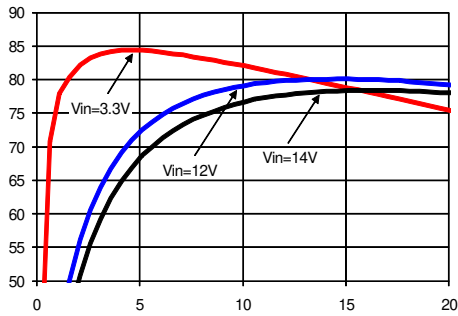


Figure 1.  $V_o=0.6V$

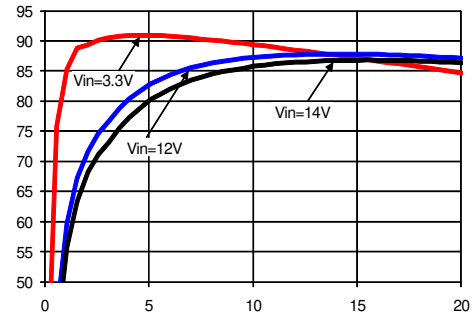


Figure 2.  $V_o=1.2V$

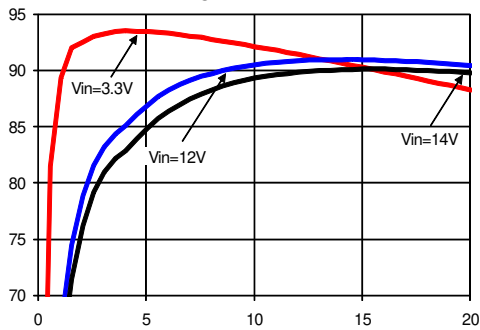


Figure 3.  $V_o=1.8V$

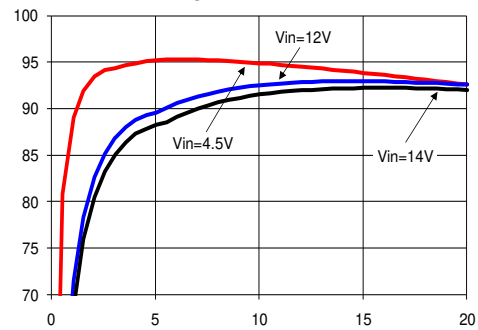


Figure 4.  $V_o=2.5V$

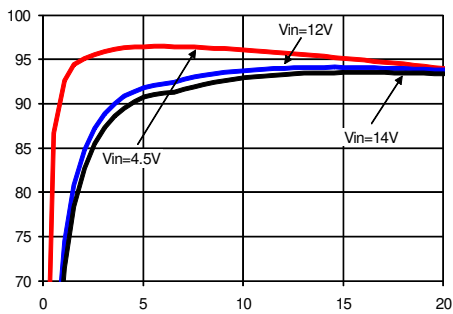


Figure 5.  $V_o=3.3V$

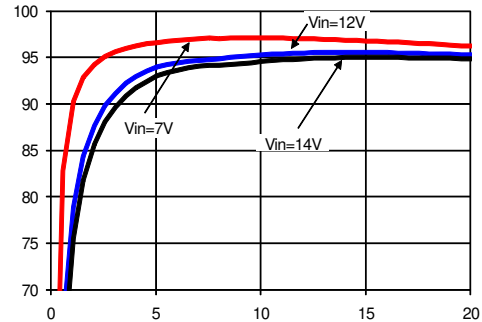


Figure 6.  $V_o=5.0V$

## 6. THERMAL DERATING CURVES

Ambient Temperature,  $T_A$  °C

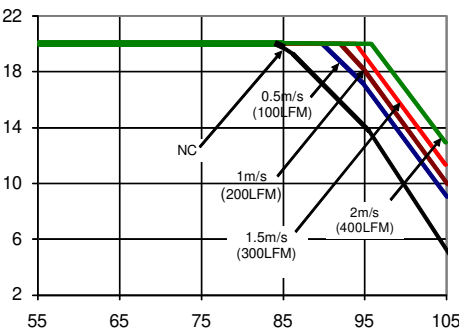


Figure 7.  $V_o=0.6V$

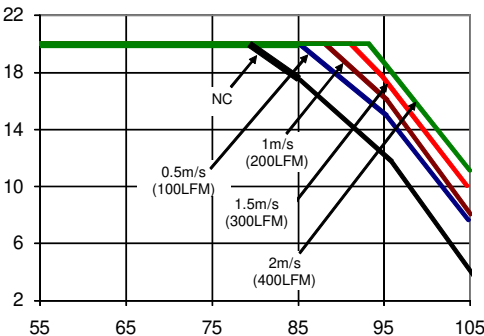


Figure 9.  $V_o=1.8V$

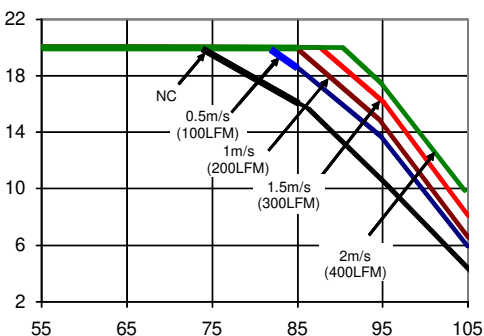


Figure 11.  $V_o=3.3V$

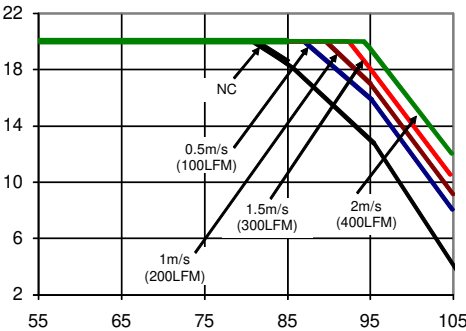


Figure 8.  $V_o=1.2V$

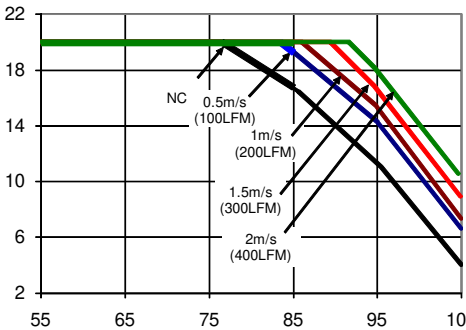


Figure 10.  $V_o=2.5V$

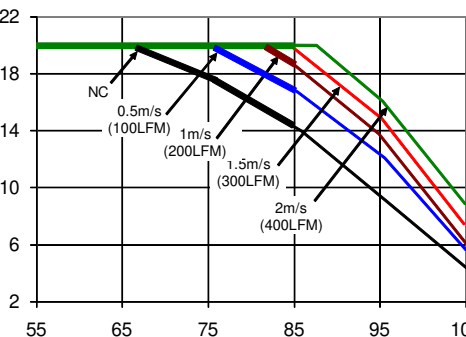


Figure 12.  $V_o=5.0V$



## 7. ANALOG FEATURE DESCRIPTIONS

### Remote On/Off

PARAMETER		DESCRIPTION	MIN	TYP	MAX	UNIT
Signal Low (Unit On)	Active Low	The remote on/off pin open, Unit on.	-0.2	-	0.6	V
Signal High (Unit Off)			2.0	-	V <sub>In,max</sub>	
Signal Low (Unit Off)	Active High	The remote on/off pin open, Unit on.	-0.2	-	0.6	V
Signal High (Unit On)			2.0	-	V <sub>In,max</sub>	

For negative logic On/Off modules, the circuit configuration is shown in Figure. 9.

The SLDN-20D1Ax 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 two ON/OFF inputs:

- Module ON/OFF can be controlled only through the analog interface (digital interface ON/OFF commands are ignored)
- Module ON/OFF can be 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 SLDN-20D1Ax modules feature an On/Off pin for remote On/Off operation. Two On/Off logic options are available. In the Positive Logic On/Off option, (device code suffix “0” – see Ordering Information), the module turns ON during a logic High on the On/Off pin and turns OFF during a logic Low. With the Negative Logic On/Off option, (device code suffix “L” – 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. For either On/Off logic option, leaving the On/Off pin disconnected will turn the module ON when input voltage is present.

For positive logic modules, the circuit configuration for using the On/Off pin is shown in Figure 39. When the external transistor Q2 is in the OFF state, the internal transistor Q7 is turned OFF, which keeps Q6 OFF and Q5 OFF. This allows the internal PWM #Enable signal to be pulled up by the internal 3.3V, thus turning the module ON. When transistor Q2 is turned ON, the On/Off pin is pulled low, which turns Q7, Q6 and Q5 ON and the internal PWM #Enable signal is pulled low and the module is OFF. A suggested value for R<sub>pullup</sub> is 20kΩ.

For negative logic On/Off modules, the circuit configuration is shown in Fig. 40. The On/Off pin should be pulled high with an external pull-up resistor (suggested value for the 3V to 14V input range is 20Kohms). When transistor Q2 is in the OFF state, the On/Off pin is pulled high, transistor Q3 is turned ON. This turns Q6 ON, followed by Q5 turning ON which pulls the internal ENABLE low and the module is OFF. To turn the module ON, Q2 is turned ON pulling the On/Off pin low, turning transistor Q3 OFF, which keeps Q6 and Q5 OFF resulting in the PWM Enable pin going high.

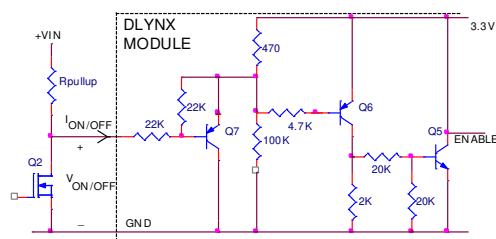


Figure 13. Circuit configuration for using positive On/Off logic

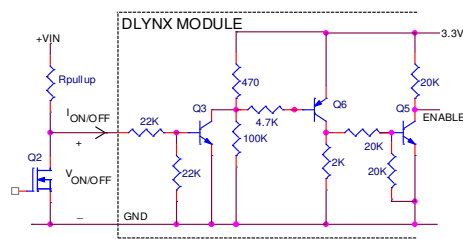


Figure 14. Circuit configuration for using positive On/Off logic

## Digital On/Off

Please see the Digital Feature Descriptions section.

## 8. MONOTONIC START-UP AND SHUTDOWN

The SLDN-20D1Ax module has monotonic start-up and shutdown behavior for any combination of rated input voltage, output current and operating temperature range.

## 9. STARTUP INTO PRE-BIASED OUTPUT

The SLDN-20D1Ax module can start into a prebiased output as long as the prebias voltage is 0.5V less than the set output voltage.

## 10. ANALOG OUTPUT VOLTAGE PROGRAMMING

The output voltage of the module is programmable to any voltage from 0.6VDC to 5.5VDC by connecting a resistor between the Trim and SIG\_GND pins of the module. Certain restrictions apply on the output voltage set point depending on the input voltage. These are shown in the Output Voltage vs. Input Voltage Set Point Area plot in Fig. 15. The Upper Limit curve shows that for output voltages lower than 1V, the input voltage must be lower than the maximum of 14.4V. The Lower Limit curve shows that for output voltages higher than 0.6V, the input voltage needs to be larger than the minimum of 3V.

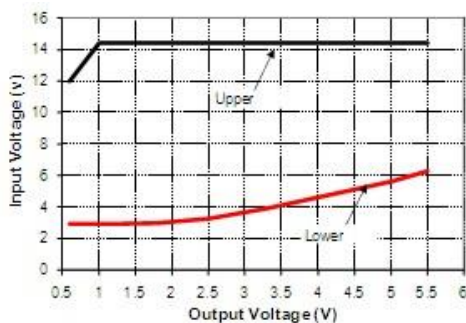


Figure 15.

**NOTE:** Output Voltage vs. Input Voltage Set Point Area plot showing limits where the output voltage can be set for different input voltages.

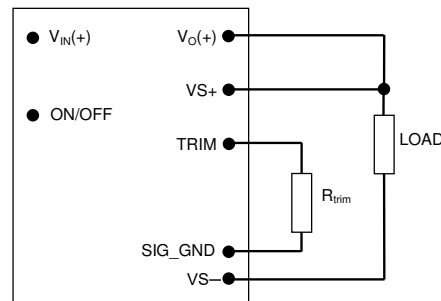


Figure 16.

**CAUTION** – Do not connect SIG\_GND to GND elsewhere in the layout  
Circuit configuration for programming output voltage using an external resistor.

Without an external resistor between Trim and SIG\_GND pins, the output of the module will be 0.6 VDC. To calculate the value of the trim resistor, Rtrim for a desired output voltage, should be as per the following equation:

$$R_{trim} = \left[ \frac{12}{(V_o - 0.6)} \right] k\Omega$$

Rtrim is the external resistor in kΩ

Vo is the desired output voltage.

Table 1 provides Rtrim values required for some common output voltages.

VO, set (V)	RTRIM (KΩ)
0.6	Open
0.9	40
1.0	30
1.2	20
1.5	13.33
1.8	10
2.5	6.316
3.3	4.444
5.0	2.727

Table 1.

## 11. DIGITAL OUTPUT VOLTAGE ADJUSTMENT

Please see the Digital Feature Descriptions section.

## 12. REMOTE SENSE

The SLDN-20D1Ax power module has a Remote Sense feature to minimize the effects of distribution losses by regulating the voltage between the sense pins (VS+ and VS-). The voltage drop between the sense pins and the VOUT and GND pins of the module should not exceed 0.5V.

## 13. ANALOG VOLTAGE MARGINING

Output voltage margining can be implemented in the module by connecting a resistor, Rmargin-up, from the Trim pin to the ground pin for margining-up the output voltage and by connecting a resistor, Rmargin-down, from the Trim pin to the output pin for margining-down. Figure 17 shows the circuit configuration for output voltage margining. Please consult your local Bel Power technical representative for additional details.

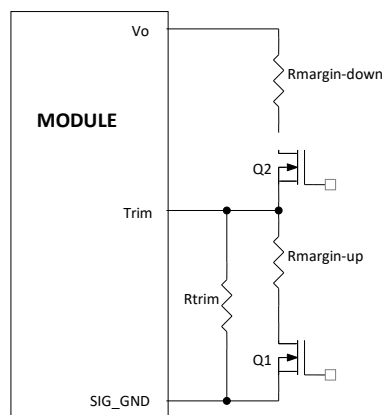


Figure 17. Circuit Configuration for margining Output voltage.

## 14. DIGITAL OUTPUT VOLTAGE MARGINING

Please see the Digital Feature Descriptions section.

## 15. OUTPUT VOLTAGE SEQUENCING

The SLDN-20D1Ax 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.

The voltage applied to the SEQ pin should be scaled down by the same ratio as used to scale the output voltage down to the reference voltage of the module. This is accomplished by an external resistive divider connected across the sequencing voltage before it is fed to the SEQ pin as shown in Fig. 18. In addition, a small capacitor (suggested value 100pF) should be connected across the lower resistor R1.

For SLDN-20D1Ax modules, the minimum recommended delay between the ON/OFF signal and the sequencing signal is 10ms to ensure that the module output is ramped up according to the sequencing signal. This ensures that the module soft-start routine is completed before the sequencing signal is allowed to ramp up.

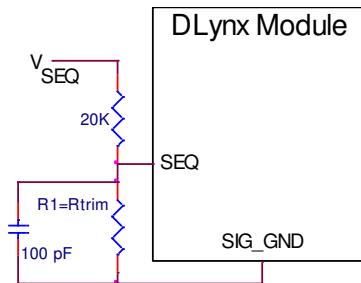


Figure 18. Circuit showing connection of the sequencing signal to the SEQ pin

When the scaled down 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.

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.

Note that in all digital Bel series of modules, the PMBus Output Undervoltage Fault will be tripped when sequencing is employed. This will be detected using the STATUS\_WORD and STATUS\_VOUT PMBus commands. In addition, the SMBALERT# signal will be asserted low as occurs for all faults and warnings. To avoid the module shutting down due to the Output Undervoltage Fault, the module must be set to continue operation without interruption as the response to this fault (see the description of the PMBus command VOUT\_UV\_FAULT\_RESPONSE for additional information).

## 16. OVERCURRENT PROTECTION

To provide protection in a fault (output overload) condition, the unit is equipped with internal current-limiting circuitry and can endure current limiting continuously. At the point of current-limit inception, the unit enters hiccup mode. The unit operates normally once the output current is brought back into its specified range.

## 17. DIGITAL ADJUSTABLE OVERCURRENT WARNING

Please see the Digital Feature Descriptions section.

## 18. 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  $128^{\circ}\text{C} \sim 130^{\circ}\text{C}$  is exceeded at the thermal reference point Tref. Once the unit goes into thermal shutdown it will then wait to cool before attempting to restart.

## 19. INPUT UNDERVOLTAGE LOCKOUT

Please see the Digital Feature Descriptions section.

## 20. DIGITAL TEMPERATURE STATUS VIA PMBUS

Please see the Digital Feature Descriptions section.

## 21. DIGITALLY ADJUSTABLE OUTPUT OVER AND UNDER VOLTAGE PROTECTION

Please see the Digital Feature Descriptions section.

## 22. INPUT UNDERVOLTAGE LOCKOUT

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

## 23. DIGITALLY ADJUSTABLE INPUT UNDERVOLTAGE LOCKOUT

Please see the Digital Feature Descriptions section.

## 24. DIGITALLY ADJUSTABLE POWER GOOD THRESHOLDS

Please see the Digital Feature Descriptions section.

## 25. SYNCHRONIZATION

The SLDN-20D1Ax module switching frequency can be synchronized to a signal with an external frequency within a specified range. Synchronization can be done by using the external signal applied to the SYNC pin of the module as shown in Fig. 19, 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. **If synchronization is not being used, connect the SYNC pin to GND.**

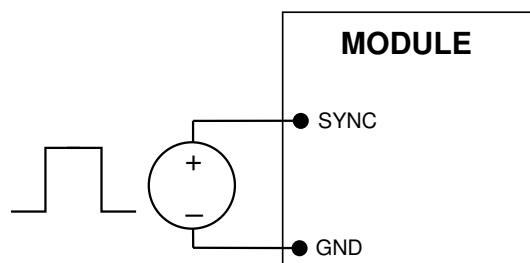


Figure 19. External source connections to synchronize switching frequency of the module.



## 26. MEASURING OUTPUT CURRENT, OUTPUT VOLTAGE AND INPUT VOLTAGE

Please see the Digital Feature Descriptions section.

## 27. DUAL LAYOUT

Identical dimensions and pin layout of Analog and Digital modules permit migration from one to the other without needing to change the layout. In both cases the trim resistor is connected between trim and signal ground. The output of the analog module cannot be trimmed down to 0.45V.

## 28. POWER GOOD

The SLDN-20D1Ax module provides a Power Good (PGOOD) signal that is implemented with an open-drain output to indicate that the output voltage is within the regulation limits of the power module. The PGOOD signal will be de-asserted to a low state if any condition such as overtemperature, overcurrent or loss of regulation occurs that would result in the output voltage going  $\pm 10\%$  outside the setpoint value. The PGOOD terminal can be connected through a pullup resistor (suggested value 100K $\Omega$ ) to a source of 5VDC or lower.

## 29. TUNABLE LOOP™

The SLDN-20D1Ax has a feature that optimizes transient response of the module called Tunable Loop™.

External capacitors are usually added to the output of the module for two reasons: to reduce output ripple and noise (see Figure 38) 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 Tunable Loop™ allows the user to externally adjust the voltage control loop to match the filter network connected to the output of the module. The Tunable Loop™ is implemented by connecting a series R-C between the VS+ and TRIM pins of the module, as shown in Fig. 20. This R-C allows the user to externally adjust the voltage loop feedback compensation of the module.

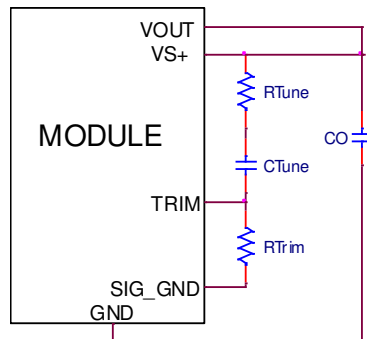


Figure 20. Circuit diagram showing connection of RTUNE and CTUNE to tune the control loop of the module.

Recommended values of RTUNE and CTUNE for different output capacitor combinations are given in Tables 2 and 3. Table 3 shows the recommended values of RTUNE and CTUNE for different values of ceramic output capacitors up to 1000uF that might be needed for an application to meet output ripple and noise requirements. Selecting RTUNE and CTUNE according to Table 3 will ensure stable operation of the module. 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 RTUNE and CTUNE in order to meet 2% output voltage deviation limits for some common output voltages in the presence of a 10A to 20A step change (50% of full load), with an input voltage of 12V.

Please contact your Bel Power technical representative to obtain more details of this feature as well as for guidelines on how to select the right value of external R-C to tune the module for best transient performance and stable operation for other output capacitance values.

Co	2x47 $\mu$ F	4x47 $\mu$ F	6x47 $\mu$ F	10x47 $\mu$ F	20x47 $\mu$ F
RTUNE	330	330	270	330	180
CTUNE	47pF	560pF	1200pF	2200pF	4700pF

Table 2.

General recommended values of of RTUNE and CTUNE for  $V_{in}=12V$  and various external ceramic capacitor combinations.

Vo	5V	3.3V	2.5V	1.8V	1.2V	0.6V
Co	8x47 $\mu$ F	5x47 $\mu$ F + 1x330 $\mu$ F Polymer	2x47 $\mu$ F + 2x330 $\mu$ F Polymer	2x47 $\mu$ F + 3x330 $\mu$ F Polymer	1x47 $\mu$ F + 5x330 $\mu$ F Polymer	1x47 $\mu$ F + 11x330 $\mu$ F Polymer
RTUNE	220	220	220	220	180	180
CTUNE	1500pF	2200pF	3300pF	5600pF	10nF	47nF
$\Delta V$	100mV	64mV	49mV	36mV	24mV	12mV

Table 3.

Recommended values of RTUNE and CTUNE to obtain transient deviation of 2% of  $V_{out}$  for a 10A step load with  $V_{in}=12V$ .

**NOTE:** The capacitors used in the Tunable Loop tables are 47  $\mu$ F/3 m $\Omega$  ESR ceramic and 330  $\mu$ F/12 m $\Omega$  ESR polymer capacitors.

## 30. DIGITAL FEATURE DESCRIPTIONS

### PMBus Interface Capability

The SLDN-20D1Ax modules have a PMBus interface that supports both communication and control. The PMBus Power Management Protocol Specification can be obtained from [www.pmbus.org](http://www.pmbus.org). The modules support a subset of version 1.1 of the specification (see Table 6 for a list of the specific commands supported). Most module parameters can be programmed using PMBus and stored as defaults for later use.

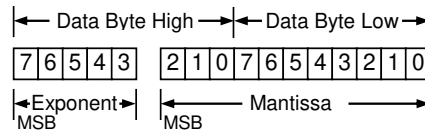
The module also supports the SMBALERT response protocol whereby the module can alert the bus master if it wants to talk. For more information on the SMBus alert response protocol, see the System Management Bus (SMBus) specification.

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 6 for which command parameters can be saved to non-volatile storage).

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### 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:



**NOTE:** The value of the number is then given by

Value = Mantissa x 2 Exponent

### PMBus Addressing

The SLDN-20D1Ax module can be addressed through the PMBus using a device address. The module has 64 possible addresses (0 to 63 in decimal) which can be set using resistors connected from the ADDR0 and ADDR1 pins to 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 specifications 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 4 (1% tolerance 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.

DIGIT	RESISTOR VALUE (K $\Omega$ )
0	10
1	15.4
2	23.7
3	36.5
4	54.9
5	84.5
6	130
7	200

Table 4.

The user must know which I2C 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](http://smbus.org).

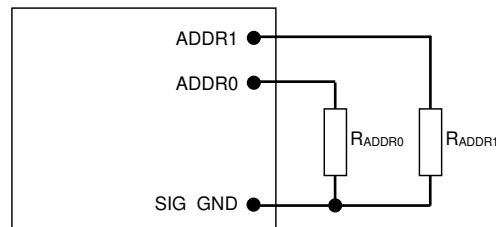


Figure 21. Circuit showing connection of resistors used to set the PMBus address of the module.

### 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/w	r
FUNCTION	PU	CMD	CPR	POL	CPA
DEFAULT VALUE	1	0	1	1	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

### PMBus Adjustable Soft Start Rise Time

The soft start rise time can be adjusted in the module via PMBus. When setting this parameter, make sure that the charging current for output capacitors can be delivered by the module in addition to any load current to avoid nuisance tripping of the overcurrent protection circuitry during startup. The TON\_RISE command sets the rise time in ms, and allows choosing soft start times between 600 $\mu$ s and 9ms, with possible values listed in Table 5. Note that the exponent is fixed at -4 (decimal) and the upper two bits of the mantissa are also fixed at 0.

RISE TIME	EXPONENT	MANTISSA
600μs	11100	00000001010
900μs	11100	00000001110
1.2ms	11100	00000010011
1.8ms	11100	00000011101
2.7ms	11100	00000101011
4.2ms	11100	00001000011
6.0ms	11100	00001100000
9.0ms	11100	00010010000

Table 5.

### Output Voltage Adjustment Using the PMBus

The VOUT\_SCALE\_LOOP parameter is important for a number of PMBus commands related to output voltage trimming, margining, over/under voltage protection and the PGOOD thresholds. The output voltage of the module is set as the combination of the voltage divider formed by RTrim and a 20kΩ upper divider resistor inside the module, and the internal reference voltage of the module. The reference voltage VREF is nominally set at 600mV, and the output regulation voltage is then given by

$$V_{OUT} = \left[ \frac{20000 + RTrim}{RTrim} \right] \times V_{REF}$$

Hence the module output voltage is dependent on the value of RTrim which is connected external to the module. The information on the output voltage divider ratio is conveyed to the module through the VOUT\_SCALE\_LOOP parameter which is calculated as follows:

$$VOUT\_SCALE\_LOOP = \frac{RTrim}{20000 + RTrim}$$

The VOUT\_SCALE\_LOOP parameter is specified using the “Linear” format and two bytes. The upper five bits [7:3] of the high byte are used to set the exponent which is fixed at –9 (decimal). The remaining three bits of the high byte [2:0] and the eight bits of the lower byte are used for the mantissa. The default value of the mantissa is 00100000000 corresponding to 256 (decimal), corresponding to a divider ratio of 0.5. The maximum value of the mantissa is 512 corresponding to a divider ratio of 1. Note that the resolution of the VOUT\_SCALE\_LOOP command is 0.2%.

When PMBus commands are used to trim or margin the output voltage, the value of VREF is what is changed inside the module, which in turn changes the regulated output voltage of the module.

The nominal output voltage of the module can be adjusted with a minimum step size of 0.4% over a ±25% range from nominal using the VOUT\_TRIM command over the PMBus. The VOUT\_TRIM command is used to apply a fixed offset voltage to the output voltage command value using the “Linear” mode with the exponent fixed at –10 (decimal). The value of the offset voltage is given by

$$V_{OUT(offset)} = VOUT\_TRIM \times 2^{-10}$$

This offset voltage is added to the voltage set through the divider ratio and nominal VREF to produce the trimmed output voltage. The valid range in two's complement for this command is –4000h to 3FFFh. The high order two bits of the high byte must both be either 0 or 1. If a value outside of the ±25% adjustment range is given with this command, the module will set its output voltage to the nominal value (as if VOUT\_TRIM had been set to 0), assert SMBALRT#, set the CML bit in STATUS\_BYTE and the invalid data bit in STATUS\_CML.



### Output Voltage Margining Using the PMBus

The module can also have its output voltage margined via PMBus commands. The command VOUT\_MARGIN\_HIGH sets the margin high voltage, while the command VOUT\_MARGIN\_LOW sets the margin low voltage. Both the VOUT\_MARGIN\_HIGH and VOUT\_MARGIN\_LOW commands use the “Linear” mode with the exponent fixed at –10 (decimal). Two bytes are used for the mantissa with the upper bit [7] of the high byte fixed at 0. The actual margined output voltage is a combination of the VOUT\_MARGIN\_HIGH or VOUT\_MARGIN\_LOW and the VOUT\_TRIM values as shown below.

$$V_{OUT(MH)} = (VOUT\_MARGIN\_HIGH + VOUT\_TRIM) \times 2^{-10}$$

$$V_{OUT(ML)} = (VOUT\_MARGIN\_LOW + VOUT\_TRIM) \times 2^{-10}$$

Note that the sum of the margin and trim voltages cannot be outside the  $\pm 25\%$  window around the nominal output voltage. The data associated with VOUT\_MARGIN\_HIGH and VOUT\_MARGIN\_LOW can be stored to non-volatile memory using the STORE\_DEFAULT\_ALL command.

The module is commanded to go to the margined high or low voltages using the OPERATION command. Bits [5:2] are used to enable margining as follows:

00XX :	Margin Off
0101 :	Margin Low (Ignore Fault)
0110 :	Margin Low (Act on Fault)
1001 :	Margin High (Ignore Fault)
1010 :	Margin High (Act on Fault)

### PMBus Adjustable Overcurrent Warning

The SLDN-20D1Ax 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 exponent is fixed at –1 (decimal). The upper five bits of the mantissa are fixed at 0 while the lower six bits are programmable with a default value of 24A. The resolution of this warning limit is 500mA. 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 SLDN-20D1Ax module can provide information related to temperature of the module through the STATUS\_TEMPERATURE command. The command returns information about whether the pre-set over temperature fault threshold and/or the warning threshold have been exceeded.

### PMBus Adjustable Output Over and Under Voltage Protection

The SLDN-20D1Ax 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 from four possible values: 108%, 110%, 112% or 115% of the commanded output voltage. The command VOUT\_UV\_FAULT\_LIMIT sets the threshold that causes an output under voltage fault and can also be selected from four possible values: 92%, 90%, 88% or 85%. The default values are 112% and 88% of

commanded output voltage. Both commands use two data bytes formatted as two's complement binary integers. The "Linear" mode is used with the exponent fixed to -10 (decimal) and the effective over or under voltage trip points given by:

$$V_{OUT(OV\_REQ)} = (VOUT\_OV\_FAULT\_LIMIT) \times 2^{-10}$$

$$V_{OUT(UV\_REQ)} = (VOUT\_UV\_FAULT\_LIMIT) \times 2^{-10}$$

Values within the supported range for over and undervoltage detection thresholds will be set to the nearest fixed percentage. Note that the correct value for VOUT\_SCALE\_LOOP must be set in the module for the correct over or under voltage trip points to be calculated.

In addition to adjustable output voltage protection, the 12A Digital module can also be programmed for the response to the fault. The VOUT\_OV\_FAULT\_RESPONSE and VOUT\_UV\_FAULT\_RESPONSE commands specify the response to the fault. Both these commands use a single data byte with the possible options as shown below.

1. Continue operation without interruption (Bits [7:6] = 00, Bits [5:3] = xxx).
2. Continue for four switching cycles and then shut down if the fault is still present, followed by no restart or continuous restart (Bits [7:6] = 01, Bits [5:3] = 000 means no restart, Bits [5:3] = 111 means continuous restart).
3. Immediate shut down followed by no restart or continuous restart (Bits [7:6] = 10, Bits [5:3] = 000 means no restart, Bits [5:3] = 111 means continuous restart).
4. Module output is disabled when the fault is present and the output is enabled when the fault no longer exists (Bits [7:6] = 11, Bits [5:3] = xxx).

Note that separate response choices are possible for output over voltage or under voltage faults.

### PMBus Adjustable Input Undervoltage Lockout

The SLDN-20D1Ax 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 2.75V, and 3V to 14V in 0.5V steps. For the VIN\_OFF command, possible values are 2.5V to 14V in 0.5V steps. If other values are entered for either command, they will be mapped to the closest of the allowed values.

Both the VIN\_ON and VIN\_OFF commands use the "Linear" format with two data bytes. The upper five bits represent the exponent (fixed at -2) and the remaining 11 bits represent the mantissa. For the mantissa, the four most significant bits are fixed at 0.

### Power Good

The SLDN-20D1Ax module provides a Power Good (PGOOD) signal that is implemented with an open-drain output to indicate that the output voltage is within the regulation limits of the power module. The PGOOD signal will be de-asserted to a low state if any condition such as overtemperature, overcurrent or loss of regulation occurs that would result in the output voltage going outside the specified thresholds. The PGOOD thresholds are user selectable via the PMBus (the default values are as shown in the Feature Specifications Section). Each threshold is set up symmetrically above and below the nominal value. The POWER\_GOOD\_ON command sets the output voltage level above which PGOOD is asserted (lower threshold). For example, with a 1.2V nominal output voltage, the POWER\_GOOD\_ON threshold can set the lower threshold to 1.14 or 1.1V. Doing this will automatically set the upper thresholds to 1.26 or 1.3V.

The POWER\_GOOD\_OFF command sets the level below which the PGOOD command is de-asserted. This command also sets two thresholds symmetrically placed around the nominal output voltage. Normally, the POWER\_GOOD\_ON threshold is set higher than the POWER\_GOOD\_OFF threshold.

Both POWER\_GOOD\_ON and POWER\_GOOD\_OFF commands use the "Linear" format with the exponent fixed at -10 (decimal). The two thresholds are given by

$$V_{OUT(PGOOD\_ON)} = (POWER\_GOOD\_ON) \times 2^{-10}$$

$$V_{OUT(PGOOD\_OFF)} = (POWER\_GOOD\_OFF) \times 2^{-10}$$

Both commands use two data bytes with bit [7] of the high byte fixed at 0, while the remaining bits are r/w and used to set the mantissa using two's complement representation. Both commands also use the `VOUT_SCALE_LOOP` parameter so it must be set correctly. The default value of `POWER_GOOD_ON` is set at 1.1035V and that of the `POWER_GOOD_OFF` is set at 1.08V. The values associated with these commands can be stored in non-volatile memory using the `STORE_DEFAULT_ALL` command.

The PGOOD terminal can be connected through a pullup resistor (suggested value 100KΩ) to a source of 5VDC or lower.

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

The SLDN-20D1Ax module is capable of measuring key module parameters such as output current and voltage and input voltage and providing this information through the PMBus interface. Roughly every 200μs, the module makes 16 measurements each of output current, voltage and input voltage. Average values of each of these measurements are then calculated and placed in the appropriate registers. These values in the registers can then be read using the PMBus interface.

### Measuring Output Current Using the PMBus

The module measures current by using the inductor winding resistance as a current sense element. The inductor winding resistance is then the current gain factor used to scale the measured voltage into a current reading. This gain factor is the argument of the `IOUT_CAL_GAIN` command, and consists of two bytes in the linear data format. The exponent uses the upper five bits [7:3] of the high data byte in two's complement format and is fixed at -15 (decimal). The remaining 11 bits in two's complement binary format represent the mantissa. 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 argument for this command consists of two bytes composed of a 5-bit exponent (fixed at -4d) and a 11-bit mantissa. This command has a resolution of 62.5mA and a range of -4000mA to +3937.5mA.

The `READ_IOUT` command provides module average output current information. This command only supports positive or 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. The exponent uses the upper five bits [7:3] of the high data byte in two's complement format and is fixed at -4 (decimal). The remaining 11 bits in two's complement binary format represent the mantissa with the 11th bit fixed at 0 since only positive numbers are considered valid.

Note that the current reading provided by the module is not corrected for temperature. The temperature corrected current reading for module temperature  $T_{Module}$  can be estimated using the following equation

$$I_{OUT,CORR} = \frac{I_{READ\_OUT}}{1 + [(T_{IND} - 30) \times 0.00393]}$$

where  $I_{OUT\_CORR}$  is the temperature corrected value of the current measurement,  $I_{READ\_OUT}$  is the module current measurement value,  $T_{IND}$  is the temperature of the inductor winding on the module. Since it may be difficult to measure  $T_{IND}$ , it may be approximated by an estimate of the module temperature.

### Measuring Output Voltage Using the PMBus

The SLDN-20D1Ax module can provide output voltage information using the `READ_VOUT` command. The command returns two bytes of data all representing the mantissa while the exponent is fixed at -10 (decimal).

During manufacture of the module, offset and gain correction values are written into the non-volatile memory of the module. The command VOUT\_CAL\_OFFSET can be used to read and/or write the offset (two bytes consisting of a 16-bit mantissa in two's complement format) while the exponent is always fixed at -10 (decimal). The allowed range for this offset correction is -125 to 124mV. The command VOUT\_CAL\_GAIN can be used to read and/or write the gain correction - two bytes consisting of a five-bit exponent (fixed at -8) and a 11-bit mantissa. The range of this correction factor is -0.125 to +0.121, with a resolution of 0.004. The corrected output voltage reading is then given by:

$$V_{OUT}(Final) = [V_{OUT}(Initial) \times (1 + VOUT\_CAL\_GAIN)] + VOUT\_CAL\_OFFSET$$

### Measuring Input Voltage Using the PMBus

The SLDN-20D1Ax module can provide output voltage information using the READ\_VIN command. The command returns two bytes of data in the linear format. The upper five bits [7:3] of the high data form the two's complement representation of the mantissa which is fixed at -5 (decimal). The remaining 11 bits are used for two's complement representation of the mantissa, with the 11th bit fixed at zero since only positive numbers are valid.

During module manufacture, offset and gain correction values are written into the non-volatile memory of the module. The command VIN\_CAL\_OFFSET can be used to read and/or write the offset - two bytes consisting of a five-bit exponent (fixed at -5) and a 11-bit mantissa in two's complement format. The allowed range for this offset correction is -2 to 1.968V, and the resolution is 32mV. The command VIN\_CAL\_GAIN can be used to read and/or write the gain correction - two bytes consisting of a five-bit exponent (fixed at -8) and a 11-bit mantissa. The range of this correction factor is -0.125 to +0.121, with a resolution of 0.004. The corrected output voltage reading is then given by:

$$V_{IN}(Final) = [V_{IN}(Initial) \times (1 + VIN\_CAL\_GAIN)] + VIN\_CAL\_OFFSET$$

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

The SLDN-20D1Ax module supports a number of status information commands implemented in PMBus. However, not all features are supported in these commands. 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

Table 6.

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

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

Table 7. LOW 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

Table 8. HIGH BYTE

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	X	0
5	X	0
4	VOUT UV Fault	0
3	X	0
2	X	0
1	X	0
0	X	0

Table 9.



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

Table 10.

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

Table 11.

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 Command	0
5	Packet Error Check Failed	0
4	X	0
3	X	0
2	X	0
1	Other Communication Fault	0
0	X	0

Table 12.

MFR\_VIN\_MIN : Returns minimum input voltage as two data bytes of information in Linear format (upper five bits are exponent – fixed at -2, and lower 11 bits are mantissa in two's complement format – fixed at 12)

MFR\_VOUT\_MIN : Returns minimum output voltage as two data bytes of information in Linear format (upper five bits are exponent – fixed at -10, and lower 11 bits are mantissa in two's complement format – fixed at 614)

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 (000010 corresponds to the SLDN-20D1Ax series of module), while bits [7:3] indicate the revision number of the module.

BIT POSITION	FLAG	DEFAULT VALUE
7:2	Module Name	000110
1:0	Reserved	10

Table 13. LOW BYTE

BIT POSITION	FLAG	DEFAULT VALUE
7:3	Module Revision Number	None
2:0	Reserved	000

Table 14. HIGH BYTE

### Summary of Supported PMBus Commands

Please refer to the PMBus 1.1 specification for more details of these commands.

Hex Code	Command	Brief Description	Non-Volatile Memory Storage																																													
01	OPERATION	Turn Module on or off. Also used to margin the output voltage <table><tr><th>Format</th><th colspan="8">Unsigned Binary</th></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>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>X</td><td>X</td></tr></table>	Format	Unsigned Binary								Bit Position	7	6	5	4	3	2	1	0	Access	r/w	r	r/w	r/w	r/w	r/w	r	r	Function	On	X	Margin				X	X	Default Value	0	0	0	0	0	0	X	X	
Format	Unsigned Binary																																															
Bit Position	7	6	5	4	3	2	1	0																																								
Access	r/w	r	r/w	r/w	r/w	r/w	r	r																																								
Function	On	X	Margin				X	X																																								
Default Value	0	0	0	0	0	0	X	X																																								
02	ON_OFF_CONFIG	Configures the ON/OFF functionality as a combination of analog ON/OFF pin and PMBus commands <table><tr><th>Format</th><th colspan="8">Unsigned Binary</th></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/w</td><td>r</td></tr><tr><th>Function</th><td>X</td><td>X</td><td>X</td><td>pw</td><td>cmd</td><td>cpr</td><td>pol</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>1</td><td>1</td></tr></table>	Format	Unsigned Binary								Bit Position	7	6	5	4	3	2	1	0	Access	r	r	r	r/w	r/w	r/w	r/w	r	Function	X	X	X	pw	cmd	cpr	pol	cpa	Default Value	0	0	0	1	0	1	1	1	YES
Format	Unsigned Binary																																															
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Access	r	r	r	r/w	r/w	r/w	r/w	r																																								
Function	X	X	X	pw	cmd	cpr	pol	cpa																																								
Default Value	0	0	0	1	0	1	1	1																																								
03	CLEAR_FAULTS	Clear any fault bits that may have been set, also releases the SMBALERT# signal if the device has been asserting it.																																														
10	WRITE_PROTECT	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><th colspan="8">Unsigned Binary</th></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> <p>Bit5: 0 – Enables all writes as permitted in bit6 or bit7 1 – Disables all writes except the WRITE_PROTECT, OPERATION and ON_OFF_CONFIG (bit 6 and bit7 must be 0) Bit 6: 0 – Enables all writes as permitted in bit5 or bit7 1 – Disables all writes except for the WRITE_PROTECT and OPERATION commands (bit5 and bit7 must be 0) Bit7: 0 – Enables all writes as permitted in bit5 or bit6 1 – Disables all writes except for the WRITE_PROTECT command (bit5 and bit6 must be 0)</p>	Format	Unsigned Binary								Bit Position	7	6	5	4	3	2	1	0	Access	r/w	r/w	r/w	x	x	x	x	x	Function	bit7	bit6	bit5	X	X	X	X	X	Default Value	0	0	0	X	X	X	X	X	YES
Format	Unsigned Binary																																															
Bit Position	7	6	5	4	3	2	1	0																																								
Access	r/w	r/w	r/w	x	x	x	x	x																																								
Function	bit7	bit6	bit5	X	X	X	X	X																																								
Default Value	0	0	0	X	X	X	X	X																																								
11	STORE_DEFAULT_ALL	Copies all current register settings in the module into non-volatile memory (EEPROM) on the module. Takes about 50ms for the command to execute.																																														
12	RESTORE_DEFAULT_ALL	Restores all current register settings in the module from values in the module non-volatile memory (EEPROM)																																														
13	STORE_DEFAULT_CODE	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>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>w</td><td>w</td><td>w</td><td>w</td><td>w</td><td>w</td><td>w</td><td>w</td></tr><tr><th>Function</th><td colspan="8">Command code</td></tr></table>	Bit Position	7	6	5	4	3	2	1	0	Access	w	w	w	w	w	w	w	w	Function	Command code																										
Bit Position	7	6	5	4	3	2	1	0																																								
Access	w	w	w	w	w	w	w	w																																								
Function	Command code																																															
14	RESTORE_DEFAULT_CODE	Restores the current register setting in the module whose command code matches the value in the data byte from the value in the module non-volatile memory (EEPROM) <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>w</td><td>w</td><td>w</td><td>w</td><td>w</td><td>w</td><td>w</td><td>w</td></tr><tr><th>Function</th><td colspan="8">Command code</td></tr></table>	Bit Position	7	6	5	4	3	2	1	0	Access	w	w	w	w	w	w	w	w	Function	Command code																										
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Access	w	w	w	w	w	w	w	w																																								
Function	Command code																																															
20	VOUT_MODE	The module has MODE set to Linear and Exponent set to -10. 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="4">Mode</td><td colspan="4">Exponent</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>1</td><td>0</td></tr></table>	Bit Position	7	6	5	4	3	2	1	0	Access	r	r	r	r	r	r	r	r	Function	Mode				Exponent				Default Value	0	0	0	1	0	1	1	0										
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