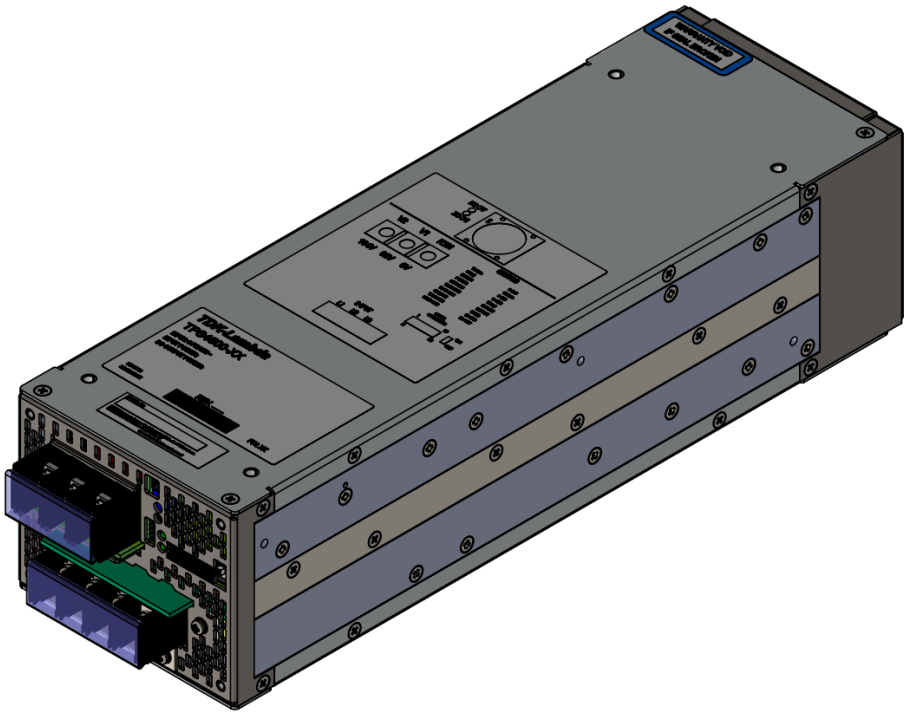
TDK·Lambda

TPS4500-DUAL SERIES POWER SUPPLY OPERATION MANUAL



GENERAL SAFETY INSTRUCTIONS

High Voltage Warning

Dangerous voltages are present within the power supply.

Critical Components

This product is not authorized for use as a critical component in nuclear control systems, life support systems or equipment for use in hazardous environments without the express written approval of the Engineering Director of TDK-Lambda Americas.

Servicing

This product is not customer serviceable.
Unit repairs shall only be carried out by TDK- Lambda Americas or their Authorized agents.

Contact: TDK-Lambda Americas
1669 Brandywine Ave., Suite A
Chula Vista, CA 91911
Tel 619-575-4400
Fax 619-575-7185

Safety Class of Protection

The unit is designed for the following parameters: Material Group IIIb, Pollution Degree 2, Overvoltage Category II, Class 1 (earthed), Indoor use. The unit is considered as fixed and rated IPX0. All outputs can provide hazardous energy (>240VA). The final equipment should provide protection to service personnel against inadvertent contact with the PSU output terminals.

Installation

This product is designed for use within other equipment which restricts access to Authorized competent personnel only. The unit covers/chassis must not be made user accessible.

The appliance may be mounted in any orientation.

The mains input connector is not acceptable for use as field wiring terminals.
The appliance must be securely mounted, and the baseplate properly bonded to the main protective earth contact before any connection to AC mains supply is made.

The ventilation openings must not be impeded – ensure a space at least 5cm between any obstruction and the ventilation openings.

BEFORE USING THE POWER SUPPLY UNIT

Be sure to read this instruction manual thoroughly before using this product. Pay attention to all cautions and warnings before using this product. Incorrect usage could lead to an electrical shock, damage to the unit or a fire hazard.

⚠ DANGER

- Never use this product in locations where flammable gas or ignitable substances are present.

⚠ WARNING

- Do not make unauthorized changes to power supply unit, otherwise you might have electric shock and void your warranty.
- Do not touch this unit and the internal components in operation or shortly after shut down. They might have high voltage or high temperature and as the unit dissipates its heat, so the surface of the unit is hot. You might receive electric shock or burn.
- When the unit is operating, keep your hands and face away from it; you might be injured by an accident.
- Do not use unit under unusual conditions such as emission of smoke or abnormal smell and sound etc. It might cause fire and electric shock. In such case, please contact us; do not repair by yourself, as it is dangerous for the user.
- Do not drop or insert anything into unit. It might cause failure and fire.
- Do not operate these units under condensation condition. It might cause fire and electric shock.

⚠CAUTION

- As a component part, compliance with the standard will be based upon installation in the final application. This product must be installed in a restricted access location, accessible to authorized competent personnel only. These AC to DC converters have reinforced insulation between the input and the output. The outputs of these products are energy hazards. The equipment has been evaluated for use in a Pollution Degree 2 environment.
- This product is designed for use within other equipment or enclosures which restrict access to authorized competent personnel only and must not be user accessible. Confirm connections to input/output terminals and signal terminals are correct as indicated in the instruction manual.
- Input voltage, Output current, Output power, ambient temperature and ambient humidity should be used within specifications, otherwise the unit will be damaged.
- For application equipment, which requires very high reliability (Nuclear related equipment, traffic control equipment, medical equipment, etc.), please provide fail safety function in the equipment.
- Do not use the product in environment with strong electromagnetic field, corrosive gas and conductive substance.
- Do not operate and store this unit at an environment where condensation occurs. In such case, waterproof treatment is necessary.
- Never operate the unit under over current or shorted conditions for 30 seconds or more and out of Input Voltage Range as specification. Insulation failure, smoking, burning or other damage might occur to the unit.
- The main outputs of this power supply unit are considered to be a hazardous energy level (240VA or more). Prevention from direct contact with output terminal is highly necessary. While installing or servicing this power supply unit, avoid dropping tools by mistake or direct contact with output terminal. This might cause an electrical shock. While repairing this power supply unit, the AC input power must be switched off and the input and output voltage should be level.
- To maintain the Low Voltage output, under fault conditions, the output must be connected to earth in the final application.
- The application circuits and their parameter are for reference only. Be sure to verify effectiveness of application circuits and their parameters before finalizing circuit design.
- Do not inject abnormal voltage to output terminal and signal terminal from the outside. The injection of reverse voltage or over voltage exceeding nominal output voltage to output terminals might cause damage to internal components.
- This information in this document is subject to change without prior notice. For actual design-in, please refer to the latest publications of data sheet, etc., for the most up-to date specifications of the unit.

CE Marking, when applied to a product or packing material for a product covered by this handbook, indicates compliance with the Low Voltage Directive and RoHS Directive.

UKCA Marking, when applied to a product or packing material for a product covered by this handbook, indicates compliance with the Electrical Equipment (Safety) Regulations and Restriction of the Use of Certain Hazardous Substances in Electrical & Electronic Equipment Regulations.

Ratings, Specifications and Features

Emissions		
AC Line Conducted Emissions	EN 55032:2015	(0.15-30 MHz) Class A
Radiated RF Emissions	EN 55032:2015	0-1000 MHz Class A *
Immunity		
Electrostatic Discharge	EN61000-4-2: 2008	+/-8 kV Air discharge +/-4 kV Contact Discharge
RF Radiated Fields	EN 61000-4-3: 2006 +A1:2008 +A2:2010	3 V/m from 80-1000 MHz; (80% AM at 1kHz)
Electrical Fast Transients	EN61000-4-4: 2004+A1:2010	Power line pulses of ± 1 kV; I/O line pulses of ± 0.5 kV
Lightning Surge	EN61000-4-5: 2005	±4kV common mode (Line to Ground) ±2kV differential mode (Line to Line)
Conducted RF Common Mode	EN61000-4-6: 2009	150 kHz - 80 MHz at 3 Vrms, 1 kHz 80% Amplitude Modulated
Power Frequency Magnetic Field	EN61000-4-8:2009	30Arms/m (Continuous Field) 300Arms/m (Short Duration)
Voltage Dips/Short Variations	EN61000-4-11:2004	5% of nom. line for .5 cycles - Criteria B 70% for 25 cycles - Criteria B 95% Dip for 5 seconds - Criteria C
Voltage Dips/Short Variations	SEMI F47-0706	50% of nom. line for 10 cycles - Criteria B 70% for 25 cycles - Criteria B 80% for 50 cycles - Criteria B
Regulatory		
RoHS	Refer to EU DECLARATION OF CONFORMITY for details	

Table 1.

*With appropriate installation

Maximum Ratings			
	Units	TPS4500-92/184	
Outputs	-	V1[9]	V2[9]
Output Voltage Range (Adjust via Trim Potentiometer)	V	57 - 99	114 -198
Output Voltage Range (Adjust via Analog Signal Voltage)	V	56 – 96.5	112 – 193
Output Voltage Range (Adjust via Digital Signal)	V	30 – 96.5	60 -193
Total Maximum Output Power (Po=P1+P2) Shared@ 50°C[1,2]	W	4600	
V1 Maximum Output Current (Power) with P2=0W @ 50°C[1,2]	A(W)	50(4600)	0
V2 Maximum Output Current (Power) with P1=0W @ 50°C[1,2]	A(W)	0	25(4600)
Total Maximum Output Power (Po=P1+P2) Shared@ 60°C[1,2]	W	3680	
V1 Maximum Output Current (Power) with P2=0W @ 60°C[1,2]	A(W)	40(3680)	0
V2 Maximum Output Current (Power) with P1=0W @ 60°C[1,2]	A(W)	0	20(3680)
Total Maximum Output Power (Po=P1+P2) Shared@ 70°C[1,2]	W	2530	
V1 Maximum Output Current (Power) with P2=0W @ 70°C[1,2]	A(W)	27.50(2530)	0
V2 Maximum Output Current (Power) with P1=0W @ 70°C[1,2]	A(W)	0	12.77(2530)
Maximum O/P Power with Dropped Phase[3] and Po=P1+P2 Shared (400VAC)[1]	W	2250	
V1 Maximum Output Current (Power) with Drop Phase[3] & P2=0W(400VAC)[1]	A(W)	24.45(2250)	0
V2 Maximum Output Current (Power) with Drop Phase[3] &P1=0W(400VAC)[1]	A(W)	0	12.22(2250)
Maximum O/P Power with Dropped Phase[3] and Po=P1+P2 Shared (480VAC)[1]	W	2925	
V1 Maximum Output Current (Power) with Drop Phase[3] & P2=0W(480VAC)[1]	A(W)	31.79(2925)	0
V2 Maximum Output Current (Power) with Drop Phase[3] &P1=0W(480VAC)[1]	A(W)	0	15.89(2925)
Minimum Current	A	Not needed	
Operating Temperature[4]	°C	100% rated Power -10°C to 50°C Derated Power: 50°C to 60°C: -2%/ºC and 60°C to 70°C: -2.5%/ºC	
Start-up Temperature[4]	°C	-40°C to +70°C	

Table 2.

[1] Output adjustment at nominal set point 92V&184V for TPS4500-92/184.

[2] Output current and power, as measured at output terminals, must be less than or equal to quoted maximum values for a given ambient temperature.

[3] Dropped phase condition operation is considered an abnormal operation condition. It is not recommended to operate the unit in this mode permanently. Unit is able to handle the specified output power during dropped phase temporarily.

[4] Operation at -40°C may require 10min warm up at 80% load to meet regulation and output ripple. Not all parameters are guaranteed at -40°C operation.

Input Specifications		
	Units	TPS4500-92/184
Input Voltage	VAC	400/480 (50/60Hz) Three Phase Delta
Input Current (RMS) Per Phase 400-480VAC input	A	9.0
Inrush Current (Peak, at cold start) Per Phase, 400-480VAC input *	A	<25
Power Factor (at rated output power) Per Phase @400/480VAC input	-	0.92 typical
Input EMI Conducted Emissions	-	FCC Class A, CISPR 22 Class A
Efficiency (at rated output power) @400/480VAC input	%	93 typical
Input Protection	-	10A 600V Fast Acting Fuse – Present on each phase (3 total) Internal – Not user accessible

Table 3.

*Excluding initial spike charging EMI capacitors lasting <2mS

Output Performance Specifications			
	Units	TPS4500-92/184	
Outputs		V1	V2
Max Voltage Line Regulation, SW (V1/V2 REG.) Position V1[5]	%	Less than 0.25%	Less than 0.5%
Max Voltage Line Regulation, SW (V1/V2 REG.) Position V2[5]	%	Less than 0.5%	Less than 0.25%
Max Voltage Load Regulation, SW (V1/V2 REG.) Position V1[5]	%	Less than 0.5%	Less than 3%
Max Voltage Load Regulation, SW (V1/V2 REG.) Position V2[5]	%	Less than 3%	Less than 0.5%
Total Regulation[5], SW (V1/V2 REG.) Position V1[5]	%	Less than 1.75%	Less than 3%
Total Regulation[5], SW (V1/V2 REG.) Position V2[5]	%	Less than 3%	Less than 1.75%
Warm up Drift, SW (V1/V2 REG.) Position V1[5]	%	Less than 0.25%	Less than 0.50%
Warm up Drift, SW (V1/V2 REG.) Position V2[5]	%	Less than 0.50%	Less than 0.25%
Temperature Stability	-	0.05% of rated outputs V1/V2 for 8hrs after 30min warm-up. Constant line, load & temp.	
Temperature Coefficient	ppm/°C	200ppm/C	
Ripple/Noise P-P(20MHz), JEITA RC-9131C/250V[6,7]	mVp-p	<2% of V1	<2% of V2
Output Ripple (20MHz), JEITA RC-9131C/250V[6,7]	mVrms	<1% of V1	<1% of V2
Negative Remote Sense Compensation	V	0.25V	

Table 4.

[5]The switch **V1/V2REG** is settable by user to Select the Regulated Output. It is not recommended to change this switch position with voltage on Vout.

[6] Total Regulation at -40°C may require 10min warm up at 80% load to meet regulation and output ripple.

[7]See Ripple and Noise Notes for Details on JEITA RC-9131C/250V method and Scope BW should be 20MHz; All Three Phases present.

Protective Functions		
	Units	TPS4500-92/184
Over Current Protection (OCP) TYPE	-	CONSTANT CURRENT
Over Current Protection (OCP) KNEE POINT[8]	-	Adjustable 70% to >100% of maximum rated current.
SHORT CIRCUIT PROTECTION	-	CONSTANT CURRENT 50%-120% of Maximum rated current. Self-recovery
OVP TYPE	-	Tracking, Inverter shut-down, manual reset by AC input recycles or by remote On/Off control.
OVP RANGE	-	110%-120% of V1&V2 (Tracking V1&V2 Adjustments)
OVP RESET TIME	s	Manual Reset by cycling AC Input or Remote On/Off Or self-recovers after 1-5minutes after remove OVP conditions
FAN FAIL	-	Blocked fan and fan failure detection. Manual reset by input cycling or remote control via the PMBus Interface.
OTP	-	Yes. Standard: Non-Latch type (automatic reset)

Table 5.

[8]Adjust Over Current Protection and Total Output Power Limit with Trim Potentiometer I_{LIMIT}ADJ

Operating Modes	
Series Operation	Yes. External Bypass Diodes are required. Unit with lowest OCP set-point will govern.
Parallel Operation	Current share single wire (Terminal 1 on Signal Connector) Connect outputs with same voltage and current rated. 20% accuracy of max Iout up to 8 units. Power derated 10% of rated. -External O-Ring Diodes are required for redundant operation.

Table 6.

Regulation Switch and Trim Potentiometers Adjustments (See Figure 1.)	
SW(V1/V2REG.)[10]	Position V1: V1 Regulated Output, and V2 Unregulated Output Position V2: V2 Regulated Output, and V1 Unregulated Output
V_{OUT}(ADJ)[11] Trim Pot.	Adjust Fully **CW** for Maximum V1&V2 Output Voltage. Adjust Fully **CCW** for Minimum V1&V2 Output Voltage. Output voltage range is specified in Table 2.
I_{LIMIT}(ADJ)[12] Trim Pot.	Adjust Fully **CW** for Maximum Current/Power Limit. Adjust Fully **CCW** for Minimum Current/Power Limit. Range is specified in Table 5.

Table 7.

[9] Where V1 and V2 are non-isolated stacked outputs with common Return (RTN).
[10]The switch V1/V2REG is settable by user to Select the Regulated Output. It is not recommended to change this switch position while there is voltage on Vout.
[11]The Trim Pot (V_{OUT})ADJ adjusts both outputs at same time, the ratio of voltages are V2=2*V1 or V1=0.5*V2.
[12]The Trim pot (I_{LIMIT})ADJ adjust Current/Power Limit. The ratio of currents is I1=2*I2 or I2=0.5*I1 and the total power is Po=V1*I1+V2*I2

Front and Read Panel Dual Bicolor Indicators (See Figure 1.)	
DC OK	LED: Illuminate Green color when outputs V1&V2 >90% of set voltage, LED: Turn-Off when outputs V1&V2 dropping <90% of set voltage, Standby/Disable, OCP, OTW, LED: Illuminate RED color when OVP trip.
AC ON	LED: Illuminate Green color when AC is present. LED: Blinking RED/GRN colors when phase dropped (Applicable for 400/480 with 30% Load or greater).

Table 8.

Remote Control Features	
Negative Remote Voltage Sensing Signal Only (-SNS)	Negative Sense. Used for remote sense connection. Return for certain analog signals (see Table 12).
Remote On/Off Control	On/Off control: Selectable Enable or Inhibit via front panel switch. Switch in the ON position: Unit powers up if PSON left open; Unit in standby mode if PSON shorted to -SNS. Switch in the OFF position: Unit in standby mode if PSON left open; Unit powers up if PSON shorted to -SNS. PSON High / Low thresholds: 3.0V / 0.6V 12V Maximum allowable. -5V Minimum allowable. Signal applied between terminals 14 (PSON) and 18 (-SNS) on Signal Connector.
Remote Analog Voltage Programming	Provides remote adjustment of the output voltages via a DC voltage applied between terminals 3 (VADJ) and 18 (-SNS) on Signal Connector. 0V = V1/V2 max, 5V = V1/V2 min. Adjustments of greater than 1V/Sec can cause Fault conditions. Adjustment range changes with adjustment of V_{out} Adj trim pot.
Remote Analog Overcurrent Limit Programming	Provides remote adjustment of the Overcurrent limit via a DC voltage applied between terminals 10 (IADJ) and 18 (-SNS) on Signal Connector. 0V = I1/I2 max, 5V = I1/I2 min Adjustment range changes with adjustment of I_{LIMIT} Adj trim pot.

Table 9.

PMBus Features	
Output Voltage Monitoring	Output voltage monitoring, V1 only via the PMBus, V2 can be calculated with Equation: V2=2*V1. Accuracy of the voltage reading is +/-2% of full scale
Output Current and Power Monitoring	Output total Current/Power monitoring (percentage, %) via the PMBus. Measurement range is 20% to 100% of rated Current/Power. Accuracy of the current-power reading is +/-10% of full scale. The reported value of Current/Power depends on the load applied to each output, see below the three criteria of PMBus reads. 1) When I1>0A and I2=0A The PMBus will report Power Po(%) and Current I1(%) 2) When I1=0A and I2>0A The PMBus will report Power Po(%) and Current I2(%) 3) When I1>0A and I2>0A The report PMBus will report the total shared Power Po (%).
Remote On/Off Control	Supply ON/OFF control via the PMBus
Internal Temperature Monitoring	Internal Temperature monitoring via PMBus: Measurement range +30 ~ +100ºC (above 100C the monitor reads ≥180ºC during OTP)
Remote Digital Voltage Programming	Provides remote adjustment of both output voltage V1&V2 via the PMBus interface. Adjustments of greater than 1V/Sec can cause Fault conditions. Setting is not stored after AC source power cycling.
Remote Digital Overcurrent Limit Programming	Provides remote adjustment of the Current/Power limit via the PMBus interface. Setting is not stored after AC source power cycling.

Table 10.

Input, Output and Signal Connections	
Input	Heavy Duty terminal block with M4 screws for L1, L2, L3 and Grounding terminal included on terminal block.
DC Outputs	Heavy Duty terminal block with M4 screws for V1, V2 and RTN.
Signal Connector	20 pin signal connector. See Table 12 for pin configuration. Recommended mating connector: JST P/N: PHDR-20VS Recommended receptacle contacts: JST P/N: SPHD-001T-P0.5
Address Pin / PMBus Voltage Selector Pin	10 pin connector. Rows 1-4 used for PMBus address selection. Row 5 used to select PMBus Voltage Selection. Open = 5V; Short = 3.3V Recommended shunt jumper: Samtec P/N: 2SN-BK-G
I2C Connector	4 Pin connector: See Table 1 for pin configuration. Recommended mating connector: MOLEX P/N: 51110-0460 Recommended receptacle contacts: MOLEX P/N: 50394-8051

Table 11.

Signal Connector (See Figure 1.)		
Name	Terminal Location	Description
ISHARE	1	Current share single wire. Internally connected to Terminal 4
IOUT	2	Current/Power monitor signal. 0V = Pout min; 5V = Pout max Terminal 8 or 18 used for Return. "Iout" is total power P1+P2 in the circuit.
VADJ	3	Analog Remote Voltage Programming Terminal via applied DC voltage. 0V = V1max/V2 max; 5V = V1min/V2 min. Terminal 8 or 18 used for Return.
ISHARE	4	Current share single wire. Internally connected to Terminal 1
OTW 1	5	Over Temperature Warning Signal Isolated. Open collector. Non-Polarized, 60V peak, Max. sink current: 5mA$_{DC}$. 2Ω ON resistance, Isolated Terminal 7 used for Return.
ENA+	6	ENABLE Positive connection for remote ON/OFF.
OTW 2 (RTN)	7	Return for Over Temperature warning Terminal 5
-SNS	8	Negative Sense. Return for certain analog signals (as defined in this table.) Internally connected to Terminal 18.
PH OK 1	9	Phase OK signal Isolated. Open collector. Max. sink current: 5mA. Off (open) when OK, ON (closed) when input phase missing. (Applicable for 400/480 with 30% Load or greater). Open collector. Non-Polarized, 60V peak, Max. sink current: 5mA$_{DC}$. 2Ω ON resistance, Isolated
IADJ	10	Analog remote adjustment of the Current/Power limit via an applied DC voltage. 0V = I1max/I2 max and Pomax, 5V = I1min/I2 min and Pomin.; Terminal 8 or 18 used for Return.
PH OK 2	11	Return for Phase OK signal Terminal 9
PSON	12	Remote On/Off control. See Remote Control Features section for additional details. Terminal 8 or 18 used for Return.
AC OK 2	13	AC OK signal Return for Terminal 15
PSON	14	Remote On/Off control. See Remote Control Features section for additional details. Terminal 8 or 18 used for Return.
AC OK 1	15	AC OK signal Isolated. On when Vin>340Vac AND unit enabled. Turns off 5mS before DC FAIL at nominal Vout, 80% of rated load. Open collector. Non-Polarized, 60V peak, Max. sink current: 5mA$_{DC}$. 2Ω ON resistance, Isolated
ENA-	16	ENABLE Negative connection for Remote ON/OFF.
DC OK 1	17	DC OK signal Isolated. Conducts when Vout is greater than 90% of the set output voltage (Tracking) Open collector. Non-Polarized, 60V peak, Max. sink current: 5mA$_{DC}$. 2Ω ON resistance, Isolated
-SNS	18	Negative Sense. Return for certain analog signals (as defined in this table.) Internally connected to Terminal 8.
DC OK 2	19	DC OK signal Return for Terminal 17
+12V	20	Auxiliary Power Supply: 11.2-12.5V, 0-0.3A. Less than 200mVp-p ripple and noise. Signal non-isolated.

Table 12.

PMBus Connections		
Name	Terminal Location	Description
SMB ALERT	4	Interrupt Line for I2C
SMB GND	3	Return for I2C
SCL	2	Clock Line for I2C
SDA	1	Data Line for I2C

Table 13.

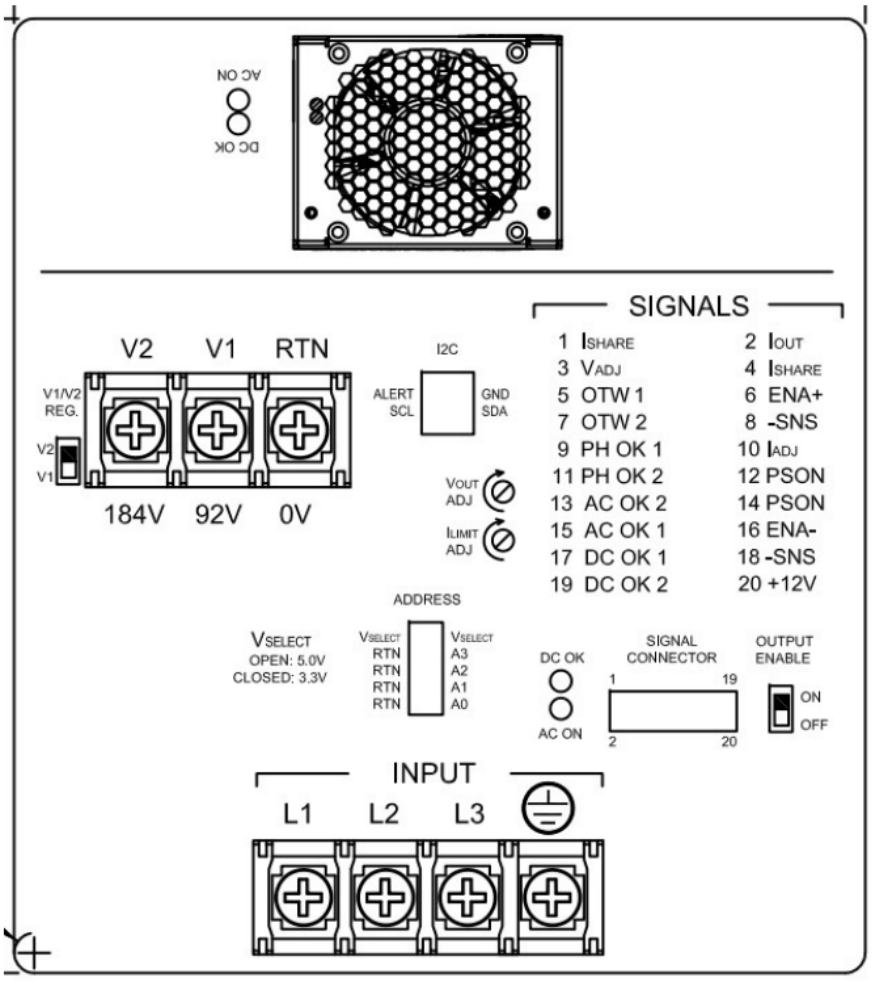


Figure 1: Pin assignments.

CAUTION:

VERIFY THE A.C POWER SOURCE IS OFF BEFORE MAKING CONNECTIONS.
HAZARDOUS VOLTAGE AND CURRENT MAY BE PRESENT.

Local Sense Dual Output Setup

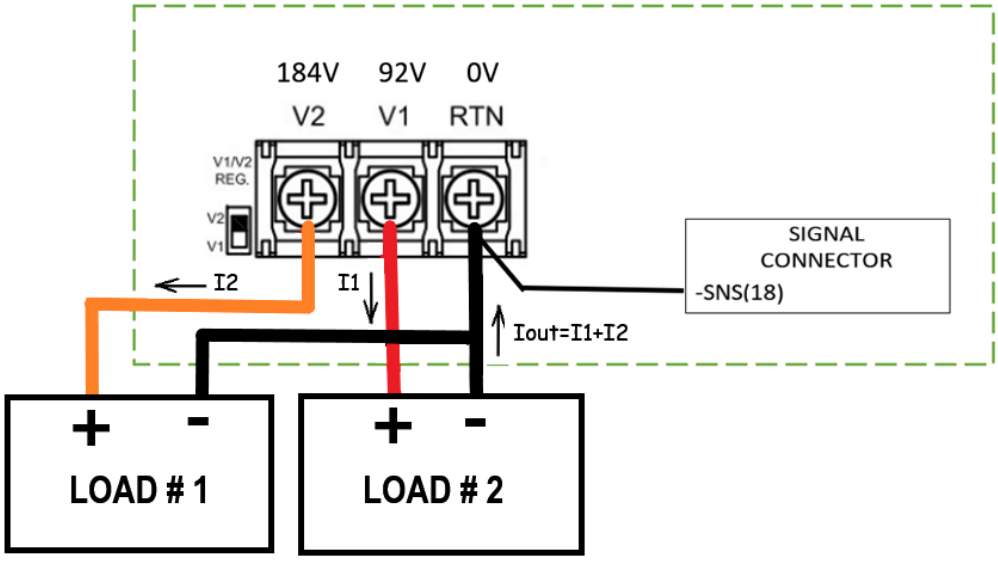


Figure 2: Typical Local Sense (-SNS) Connection.

2.A. The switch **V1/V2REG** is settable by user (with outputs discharged) to Select the Regulated Output. Either load is optional.

2.B. * Suitable Decoupling Capacitors (0.1uF/250V or higher) may be required at loads.

2.C. Caution: Verify unit doesn't exceed the Maximum power rating, (Pomax ≤4600W) reduce the total load if necessary.

2.D. Minimum and Maximum

Po(W)		V1(Vdc)		I1(A)		V2(Vdc)		I2(A)		OCP(%)	
Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
0	4600	57	99	0	50	114	198	0	25	70	>100

2.E. Examples with Different Conditions of Voltages, Currents and Power.

N	**Examples:** TPS4500-92/184 (Optional)
0	V1=92V, I1=50A; V2=184V, I2=25A ;No Valid Loads Combination; Po>Pomax
1	V1=92V, I1=50A; V2=184V, I2=0A ; Pomax=4600W; OCPmax(I1)=52.5A
2	V1=92V, I1= 0A; V2=184V, I2=25A ; Pomax=4600W; OCPmax(I2)=26.3A
3	V1=92V, I1=25A; V2=184V, I2=12.5A; Pomax=4600W; OCPmax(I1)=52.5A

Remote Sense Dual Output Setup

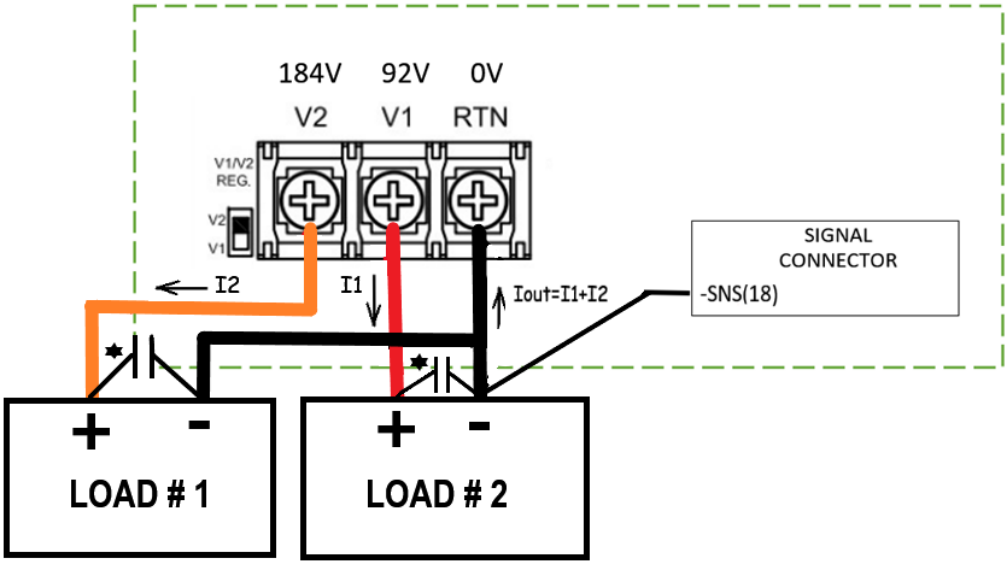


Figure 3: Typical Remote Sense (-SNS) Connection

3.A. The switch **V1/V2REG** is settable by user (with outputs discharged) to Select the Regulated Output. Either load is optional.

3.B. * Suitable Decoupling Capacitors (0.1uF/250V or higher) may be required at loads.

3.C. Caution: Verify unit doesn't exceed the Maximum power rating, (Pomax ≤4600W) reduce the total load if necessary.

3.D. Minimum and Maximum

Po(W)		V1(Vdc)		I1(A)		V2(Vdc)		I2(A)		OCP (%)	
Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
0	4600	57	99	0	50	114	198	0	25	70	>100

3.E. Examples with Different Conditions of Voltages, Currents and Power.

N	**Examples:** TPS4500-92/184 (Optional)
0	V1=92V, I1=50A; V2=184V, I2=25A ; Po>Pomax: Invalid load combination
1	V1=92V, I1=50A; V2=184V, I2=0A ; Pomax=4600W; OCPmax(I1) =52.5A
2	V1=92V, I1= 0A; V2=184V, I2=25A ; Pomax=4600W; OCPmax(I2)=26.3A
3	V1=92V, I1=25A; V2=184V, I2=12.5A; Pomax=4600W; OCPmax(I1)=52.5A

Parallel Operation Setup

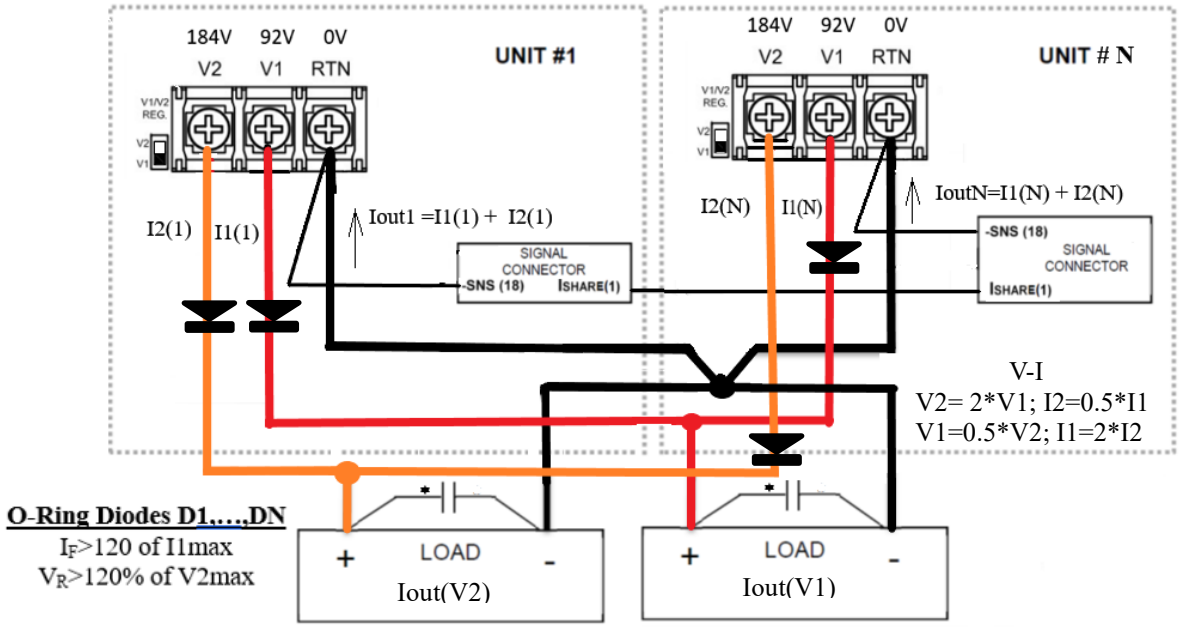


Figure 8a: Outputs V1&V2 Parallel Operation (Local -SNS Sensing),

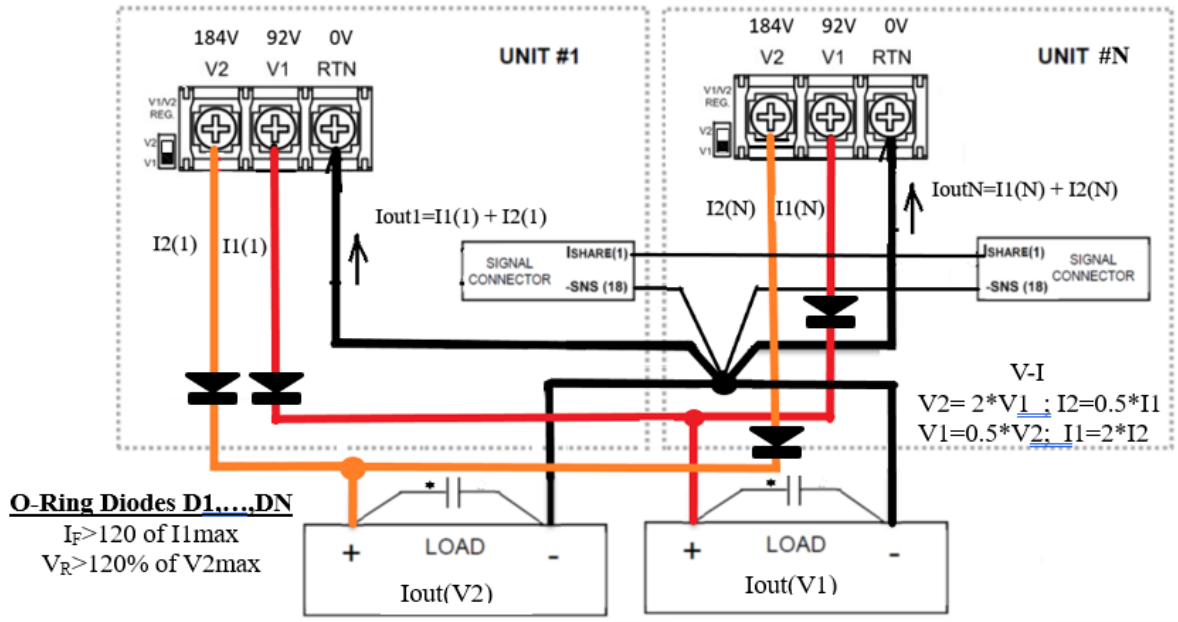


Figure 8b: Outputs V1& V2 Parallel Operation (Remote -SNS Sensing).

8.1 The switch **V1/V2REG** is settable by user (with outputs discharged) to Select the Regulated Output. Either load is optional. Diodes D1…Dn are optional.

8.2 For optimal performance, power supplies should have their Regulated Output voltage set to within 1% of each other.

8.3 * Suitable Decoupling Capacitors (0.1uF/250V or higher) may be required at loads.

8.4 Caution: Verify each unit Not exceed the Maximum power rate (Pomax ≤4600W) reduce the total load it is necessary.

8.5 Minimum and Maximum

Parallel	Po(W)		V1(Vdc)		I1(A)		V2(Vdc)		I2(A)		OCP (%)	
N	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
≤8	0	4600	57	99	0	50	114	198	0	25	70	>100

8.6 Examples with Different Conditions of Voltages, Currents and Power.

Steps	**Example 1: 5 units in parallel, V1 loaded, V2 unloaded (or load doesn't exist)**
1	V1=92V, I1max=50A; V2=184V, I2=0A; Pomax=4600W; OCPmax(I1) =52.5A;
2	N=5: Number of Units connected in Parallel.
3	Po(derated)=N*Po*(100%-10%) =5*4600W*(90%) =20700W. 10% Derated total power of 5 units connected in Parallel.
4	Iout(V1) =Po(derated)/V1=20700W/92V=225A. Iout(V2) =0A Total Current allowable (from V1 outputs only) with 5 units connected in Parallel.
5	Iout1=Iout2…=Iout5=[Iout(V1) +Iout(V2)]/N=[225A+0A]/5=225A/5=45A. Approx Total current load per Unit in Parallel.

Steps	**Example 2: 3 units in parallel, V1 and V2 both loaded at half power.**
1	V1=92V, P1=50%Pomax; V2=184V, P2=50%Pomax; Pomax=4600W; OCPmax (Po)=4830W
2	N=3: Number of Units connected in Parallel.
3	Po(derated)=N*Po*(100%-10%) =3*4600W*(90%) =12420W. 10% Derated total power of 3 units connected in Parallel.
4	Iout(V1) =50%*Po(derated)/V1=50%*12420W/92V=67.5A. Total Current loading V1 outputs. Iout(V2) =50%*Po(derated)/V2=50%*12420W/184V=33.75A. Total Current loading V2 outputs.
5	Pout1=Pout2=Pout3=[Pout(V1) +Pout(V2)]/N=[6210W+6210W]/3=4140W Approx Total Power load per Unit in Parallel.

Steps	**Example 3:** 6 units in parallel, Vout trimmed down.
1	V1=60V, I1max=50A; V2=120V, I2=0A; Po(65%Pomax) =V1*I1=60V*50A=3000W; OCPmax(I1) =52.5A
2	N=6: Number of Units connected in Parallel.
3	Po(derated)=N*Po*(100%-10%) =6*3000W*(90%) =16200W. 10% Derated total power of 6 units connected in Parallel.
4	Iout(V1) =Po(derated)/V1=16200W/60V=270A. Iout(V2) =0A Total Current loading V1 outputs (combined) with 6 units connected in Parallel.
5	Iout1=Iout2…=Iout6=[Iout(V1) +Iout(V2)]/N=[270A+0A]/6=270A/6=45A Approx Total current load per Unit in Parallel.

Steps	**Example 4:** 7 units in parallel, Vout adjusted up. V1 unloaded (or load doesn't exist), V2 max loaded.
1	V1=97.5V, I1=0A; V2=195V, I2(92%I2max) =23A; Pomax=4600W; OCPmax(I2) =26.25A
2	N=7: Number of Units connected in Parallel.
3	Po(derated)=N*Po*(100%-10%) =7*4600W*(90%) =28980W. 10% Derated total power of 7 units connected in Parallel.
4	Iout(V1) =0A Iout(V2) =Po(derated)/V2=28980W/195V=148.6A. Total Current available from V2 outputs (combined) with 7 units connected in Parallel.
5	Iout1=Iout2…=Iout7=[Iout(V1) +Iout(V2)/N=[0A+148.6A]/7=148.6A/7=21.23A. Approx Total current load per Unit in Parallel.

Series Operation Setup

CAUTION: DO NOT CONNECT THE NEGATIVE SENSE WIRES IN PARALLEL DURING SERIES OPERATION – THIS MAY RESULT IN DAMAGE TO THE POWER SUPPLY.

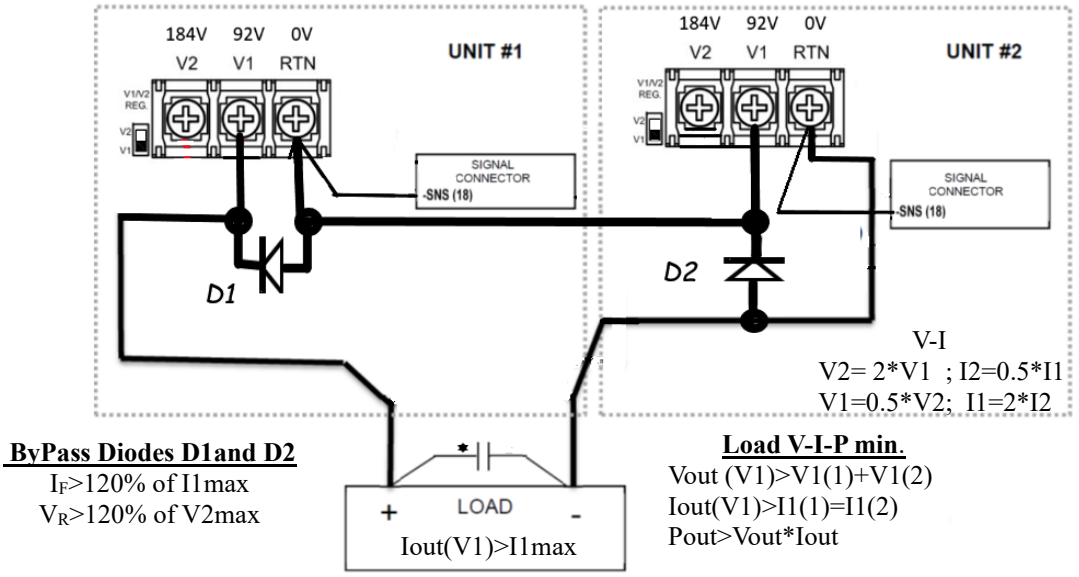


Figure 10: Output V1 in Series Operation (Local -SNS Sensing)

-The switch V1/V2REG is settable by user (with outputs discharged) to Select the Regulated Output.
-*Suitable Decoupling Capacitor (0.1uF/500V or higher for two unit in series) may be required at load.
-**Note:** External Bypass diodes are recommended that are rated to exceed the max current and voltage rating.

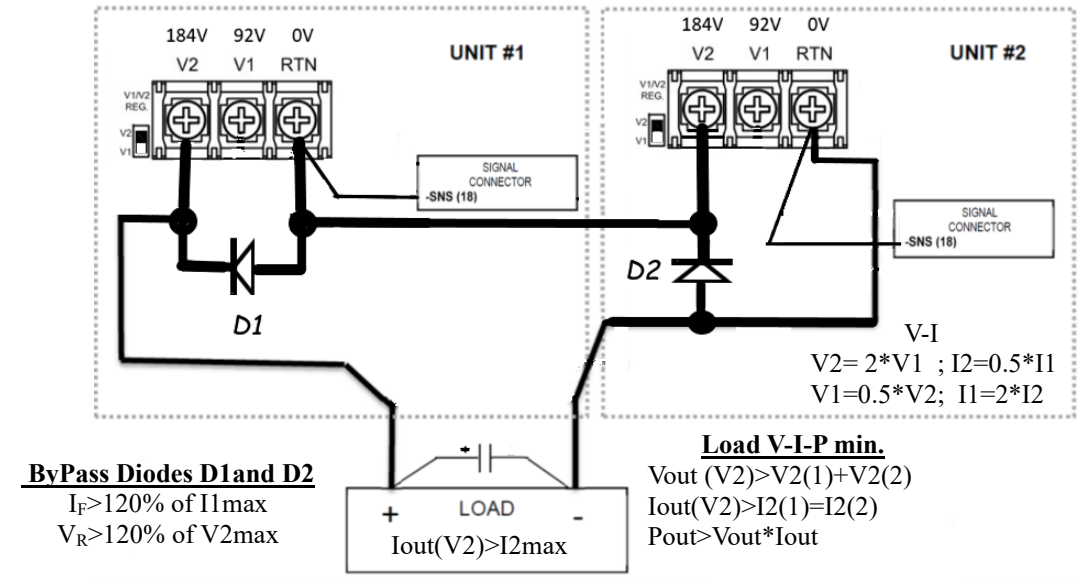


Figure 11: Output V2 in Series Operation (Local -SNS Sensing)

-The switch V1/V2REG is settable by user (with outputs discharged) to Select the Regulated Output.
-*Suitable Decoupling Capacitor (0.1uF/500V or higher for two units in series) may be required at load.
-**Note:** External Bypass diodes are recommended that are rated to exceed the max current and voltage rating

Ripple and Noise Notes (Optional)

Ripple and Noise is measured according to the description below in accordance with JEITA RC-9131C/250V (Sections 7.16, 7.17 and 7.18).

The measurement connection is shown in Fig. 3-1.

Caution use 10X probe between Scope and filters and 250V Capacitors for high voltages measurement.

C1 (0.1µF/250V Ceramic Capacitor), C2 (47uF/250V Aluminum Electrolytic Capacitor) must be connected in parallel at 30cm from the output terminals, along the load cable. Attach a maximum 1.5m 50Ω coaxial cable from the ceramic capacitor electrodes to a filter attachment installed on the oscilloscope. The filter attachment consists of C3 (4700pF/250V film capacitor) in series with R (50Ω resistor). Use 10X probe and 20MHz bandwidth oscilloscope or equivalent.

In general, output ripple voltage and output spike noise voltage can be reduced by increasing external capacitance.

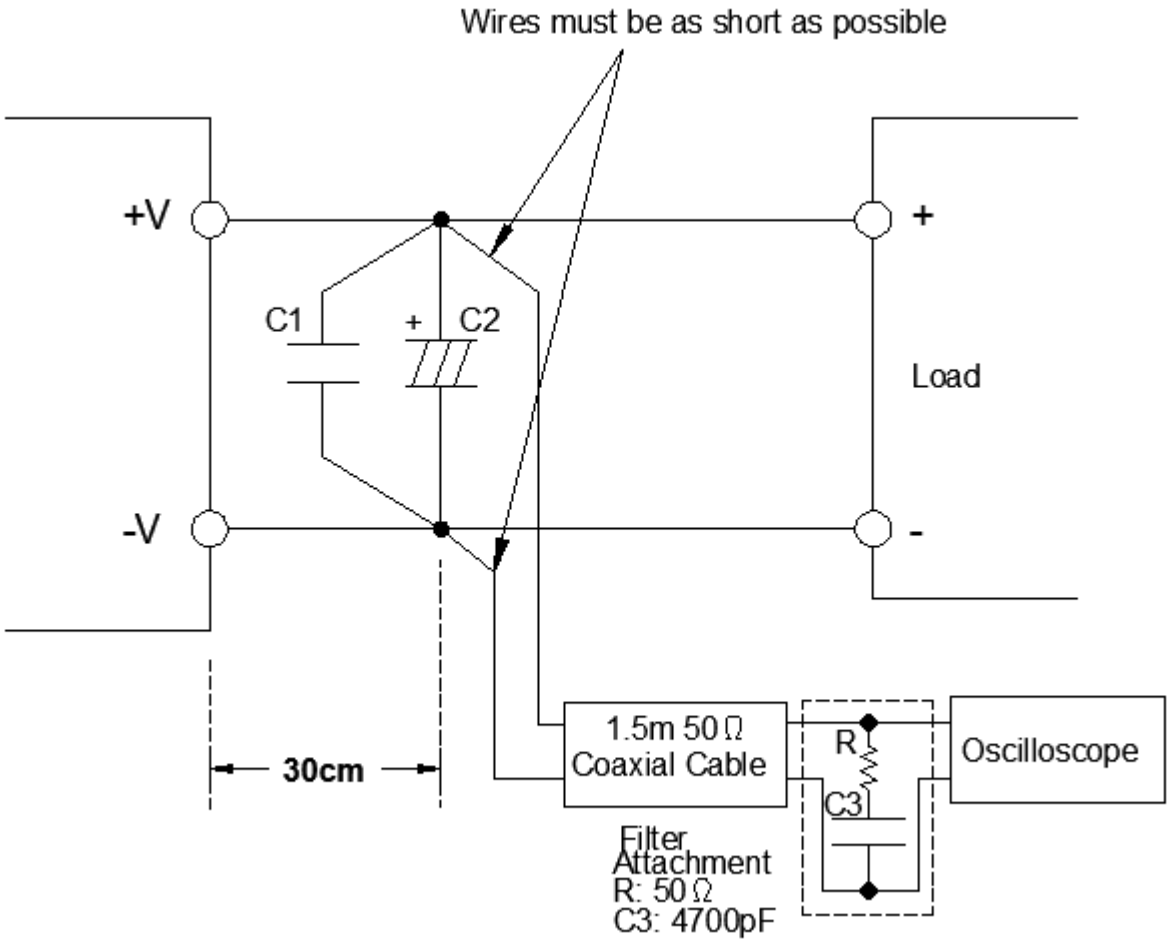
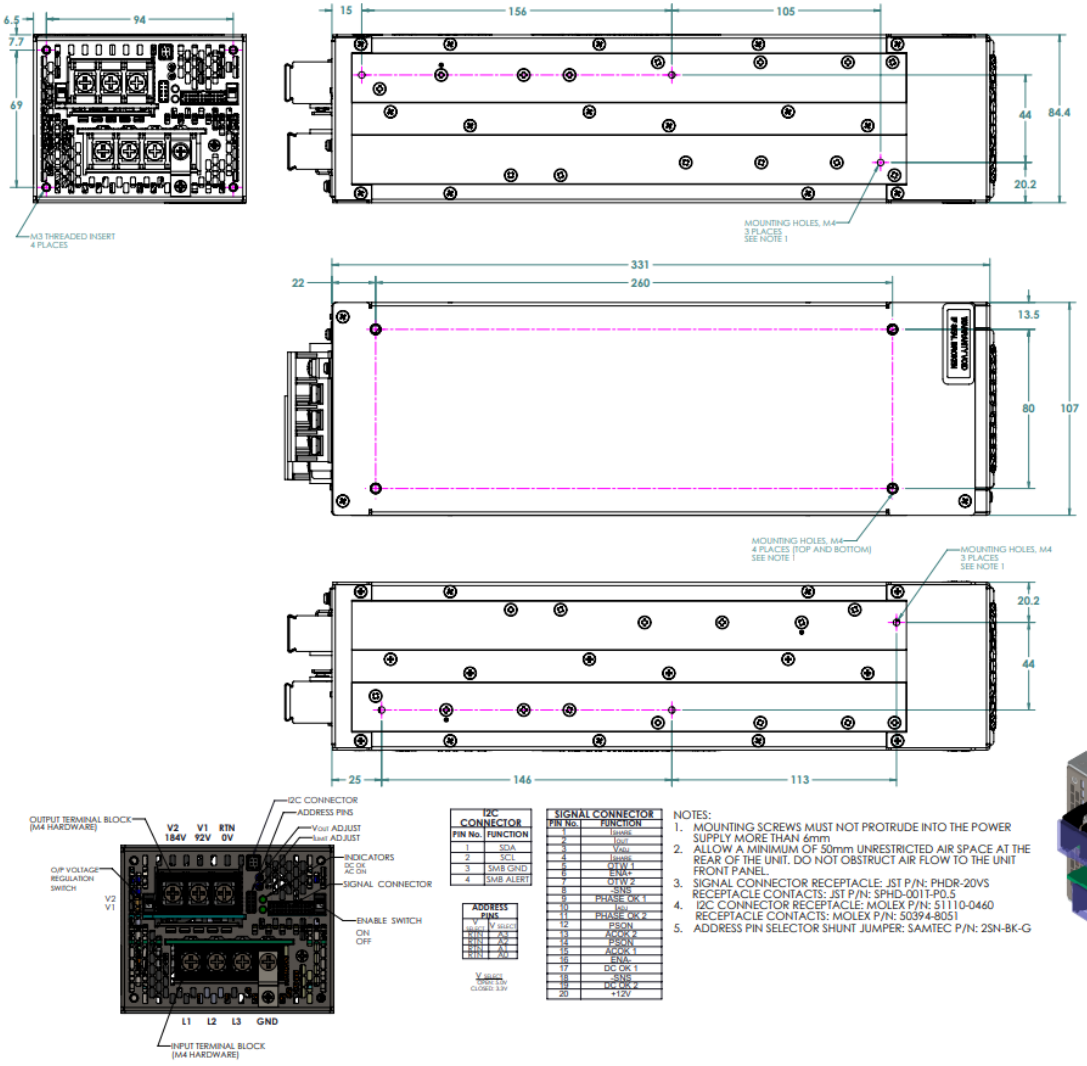


Figure 12: Output Ripple Voltage (including Spike Noise) Measurement Method

Mechanical Drawing

Overall dimensions for the TPS4500-Dual Series are shown below:



PMBus Interface

The TPS4500-DUAL has Power Management Bus (PMBus) hardware.

The PMBUS interface in the TPS4500-Dual includes:

- Monitoring the Output Voltage V1 (+/- 2% of Full Scale).
- Monitoring the Output Current and Output Power (+/- 10% of Full Scale) (from 20% to 100% total Load).
- Monitoring the internal Temperature (works on +30°C to 100° C range. Above 100°C the OTP activates and the monitor reads >180°C).
- Programming the Output Voltage V1 (+/- 2% of Full Scale).
- Programming the Current and Output Power Limit.
- Programming the Supply ON/OFF state.
- Reading and Clearing Faults.
- Reading the Manufacturing Related Data (Model Name, Serial No, Manufacturing Date, etc).

ATTENTION:
The PMBus supports:

- 100 KHz Operation.
- Block Read Protocol.
- Group Command Protocol.
- Direct Command Format for Monitoring and Programming
- Functions. See Version 1.1 of PMBus Specifications.

ADDRESSING (A3, A2, A1, A0 inputs)
To communicate with the TPS4500-DUAL, the master must first address the slave devices via a slave address byte. The slave address byte consists of seven address bits and a direction bit that indicates the intent to execute a read or write operation.

The TPS4500-DUAL features four variable address lines that allow up to 16 Supplies to be connected on a single bus.

PMBus uses 7 bit addressing. There is constant part of address and variable part of address:
Constant part of address consists of 3 Most Significant Bits **A6**, **A5**, and **A4** and always equals **010**.
Variable part of address consists of 4 Least Significant bits: **A3**, **A2**, **A1**, and **A0**.
Values of these four bits have to be assigned by hardware connections of 4 pins of the TPS4500-DUAL address connector.
The Address lines (**A3**, **A2**, **A1**, and **A0**) are internally pulled up by resistors to +5V.
The Address lines can be left open for ‹1› address or connected for ‹0› address.
There are 16 possible addresses: from **0100000** to **0101111**.
Factory default Address is 5Eh.
In case more than one TPS4500-DUAL is connected to PMBus, each unit must be set to its own unique address. Duplicate addressing is not allowed.

A6	A5	A4	A3	A2	A1	A0	R/W Byte	Hex Address
0	1	0	0	0	0	0	x	40h
0	1	0	0	0	0	1	x	42h
0	1	0	0	0	1	0	x	44h
0	1	0	0	0	1	1	x	46h
0	1	0	0	1	0	0	x	48h
0	1	0	0	1	0	1	x	4Ah
0	1	0	0	1	1	0	x	4Ch
0	1	0	0	1	1	1	x	4Eh
0	1	0	1	0	0	0	x	50h
0	1	0	1	0	0	1	x	52h
0	1	0	1	0	1	0	x	54h
0	1	0	1	0	1	1	x	56h
0	1	0	1	1	0	0	x	58h
0	1	0	1	1	0	1	x	5Ah
0	1	0	1	1	1	0	x	5Ch
0	1	0	1	1	1	1	x	5Eh

Table 14.

SERIAL CLOCK
This line is clocked by the Controller which controls the PMBUS. It is connected to +5.0V (referenced to “SMB_GND”) via a 5.0kΩ pull-up resistor.

SERIAL DATA
This is a Bi-Directional line which is connected to +5.0V (referenced to "SMB_GND") via a 5.0kΩ pull up resistor.

ALERT
ALERT is used to indicate to the HOST about any Faults/Error/Warning Conditions.
This line is connected to +5.0V (referenced to "SMB_GND") via a 2.49kΩ pull up resistor.
This Signal is HIGH to indicate that no fault/error/warning is present. If some fault/error/warning occurs, the signal will go LOW.
The Host system must poll multiple supplies after receiving ALERT to retrieve fault/error/warning information.
Note: The TPS4500-DUAL does not respond to Alert Response Address.

PMBus™ COMMAND SET

OPERATION (ON/OFF)

If the Power Supply is turned OFF with the "OPERATION OFF" command, the Supply can be turned ON with the "OPERATION ON" command.

Command code	Type	Data sent
01h	R/W Byte	00h=OFF
01h	R/W Byte	80h=ON

Table 15.

After applying AC power to the unit, the default control mode is the "*Local Mode*".
In this Mode the Front Panel Output Enable Switch will control the output state.

To turn ON or OFF the Unit in "*Remote Mode*" (I2C) you need to do the follow:
Set Operation Mode to "*Remote Mode*".
Then issue "*Operation ON*" to turn ON or "*Operation OFF*" to turn OFF the unit.

Once you enter "*Remote Mode*" the Front Panel Output Enable Switch has no longer control of the Output until you change over to "*Local Mode*".

Attention: If the unit is ON and you issue "*Operation OFF*" followed by "*Operation ON*" command within 3.0 Sec, the Unit will remain in the OFF state for 3.0 Sec from the time you issue the "*Operation OFF*" command.
Also, in Local Mode the Front Panel Output Enable Switch will behave in the same way. If the unit was enabled and you disable it follow by Enable within 3.0 Sec, the Unit will remain in the OFF state for 3.0 Sec from the time you disabled the unit.

When you switch from "*Local Mode*" to "*Remote Mode*" for first time after applying AC power the default Operation State will be "*Operation ON*".
However, if you try to change Operation State before you change Operation Mode to "*Remote Mode*" the unit will respond with error and will ignore the command.
If you need the Unit OFF when you enter "*Remote Mode*" you need to issue "*Operation OFF*" command right after entering "*Remote Mode"*.

OPERATION MODE

This command is used to set the way you Enable/Disable the output of the Unit. Setting the Operation Mode to "*Remote Mode*" allow you to control the output using the "OPERATION ON/OFF" command via the I2C. In the "*Local Mode*" you have the option to use the Front Panel Output Enable Switch or the "PSON" pin on the Signals connector.

Command code	Type	Data sent
D8h	R/W Byte	00h=Remote
D8h	R/W Byte	80h=Local

Table 16.

PROGRAMMING MODE

This command is used to set the way you adjust the output of the Unit. Setting the Programming Mode to "*Remote"* allows you to program the output voltage and current limit using the I2C commands.
In the "*Local"* you have the option to use the Front Panel V_{out} ADJ trim pot or the V_{adj} pin on the Signals connector to adjust the output voltage and I_{Limit} ADJ trim pot or the I_{adj} pin on the Signals connector to adjust the current limit point.

Command code	Type	Data sent
D2h	R/W Byte	00h=Remote
D2h	R/W Byte	80h=Local

Table 17.

CLEAR_FAULTS

This command is used to clear any fault bits that have been set in the "STATUS REGISTER".
If the CLEAR_FAULTS command is not sent after any fault occurs, the "STATUS REGISTER" will not be cleared.
ALERT signal will remain Low until a CLEAR_FAULTS command is sent.
If a Fault or Warning is still present after CLEAR_FAULTS is sent, "STATUS REGISTER" will be updated and the ALERT signal will be Low again.

Command code	Type	#Data bytes
03h	Send Byte	0

Table 18.

COMMANDS TO READ INVENTORY DETAILS

The commands below will retrieve the inventory data stored in the units EEPROM.

Command Name	Command code	Type	#Data bytes
PMBUS_REVISION	98h	Read Byte	1
MFR_ID	99h	Read Block	10
MFR_MODEL	9Ah	Read Block	14
MFR_REVISION	9Bh	Read Block	11
MFR_LOCATION	9Ch	Read Block	3
MFR_DATE	9Dh	Read Block	8
MFR_SERIAL	9Eh	Read Block	20

Table 19.

All details except for ‹PMBUS_REVISION› are stored in ASCII format.

READ_STATUS

This Command is used to read the status of the Power Supply. The Status information is stored in a special register called the "STATUS REGISTER".

The PMBus reads 15 different types of Faults or Warnings.

Command Used	Type	#Data bytes
D0h	Read Word	2

Table 20.

Fault or Warning is indicated by "1" –ONE- . No fault or Warning is indicated by "0" –ZERO-.

For Example: If DCOK Fault occurs, READ STATUS will return 01h. ALERT will go "LOW"

Faults	Type	Bit # in Status Register	Meaning	Main output behavior
Low Byte				
DCOK	FAULT	0	Output Voltage < 85~95% of Set Vout	Output ON or OFF
		1		
OVP	FAULT	2	Output Voltage > 1.15xVset	Output OFF
OTP	FAULT	3	Internal temperature higher than safe limit	Output OFF
OTW	WARNING	4	Internal temperature ~ 10°C below OTP limit.	Output ON
FANOK	WARNING	5	Fan is rotating slow	Output OFF
ACOK	FAULT	6	Input Voltage <250Vac	Output OFF
PHOK	WARNING	7	One Input Phase Low or Out	Output ON
High Byte				
$V1_{max}$ Limit	WARNING	0	$Vo_{prog.}$ greater than Vo_{max} Limit	Output ON
IDR	WARNING	1	Invalid Data Byte Received	Output ON
IPM	WARNING	2	Invalid Programming Mode	Output ON
IOM	WARNING	3	Invalid Operating Mode	Output ON
I2C_BE	WARNING	4	Buss Error	Output ON
ICPDR	WARNING	5	Invalid Current Prog. Data Received	Output ON
IVPDR	WARNING	6	Invalid Voltage Prog. Data Received	Output ON
ICR	WARNING	7	Invalid Command Received	Output ON

Table 21.

PROGRAMMING AND MONITORING FUNCTIONS

For Monitoring and Programming functions use the following equation

Programming Equation: $\mathbf{Y = (mX + b)* 10^{R}}$ Monitoring Equation: $\mathbf{X = (Y*10^{-R} - b)/m}$

Where:
Y is the digital value sent or received from the supply.
X is the actual value (V, A(%),W(%), °C)
m, b, R - coefficients that are explained in **Table 22**.

Voltage	Physical value	Physical	Min.	Max.	m	b	R
92/184	Voltage Programming (V1)	V	25	100	4097	-01556	**-2**
	Voltage monitoring (V1)	V	25	100	0827	003573	**-2**
	Current-Power Programming	A	20%	98%	0447	-06672	**-1**
	Current-Power monitoring	A	20%	98%	0937	-12276	**-2**
	Temperature monitoring	°C	30	100	16	6050	-1

Table 22.

Note 1: The most up-to-date **m, b, R** coefficients can be recovered from the **EEPROM**. Coefficients are stored in **ASCII** Format.

Note 2: The unit only programming and monitoring V_1. For V_2 output the value is calculate using the ratio equation $V_2=2*V_1$.

Note 3. Important the Current and Power for Programming and Monitoring are using the same commands.

Command name	Command code	Type	#Data bytes
MFR_VOLTAGE_MON_COEFF	D3h	Read Block	18
MFR_VOLTAGE PROG_COEFF	D4h	Read Block	18
MFR_CURRENT_MON _COEFF	D5h	Read Block	18
MFR_CURRENT_PROG _COEFF	D6h	Read Block	18
MFR_TEMP_MON_COEFF	D7h	Read Block	18

Table 23.

MONITORING THE OUTPUT VOLTAGE (READ_V1)

The accuracy of the voltage reading is +/-2%
Voltage can be calculated using the "Direct data Format".
Refer to **Table 22** for the Coefficients for calculating the Output Voltage.

Command code	Type	#Data bytes
8Bh	Read Word	2

Table 24.

Example:
$V_{1\ nom}$=92V, $V_{2\ nom}$=184V
Hex read back = 032Ah.
Converted to Decimal = 810.
Using the required coefficients the Output Voltage V_1= ((810*10^(-(-2)) -3573)/827 = 93.623V.
Read the Actual Output Voltages on the Output Terminal connector (V_1= 93.832V and V_2=2*93.832=187.664V).

MONITORING THE OUTPUT CURRENT and Output POWER (READ_IOUT)

The accuracy of the Current-Power reading is +/-10% (from 20% to 100% total load)
The read back output current can be calculated using the "Direct data Format".
Refer to **Table 22** for the Coefficients for calculating the Output Current and Power in percentages.

Command Used	Type	#Data bytes
8Ch	Read Word	2

Table 25.

When only one output is used to provide output load:
Examples:
V_1=92V, I_1=50A;
V_2=184V, I_2=0A; Total P_o=4600W
Hex read back = 0321h.
Converted to Decimal =801.
Using the required coefficients the output current I_o%= ((801*10^(-(-2)) -(-12276)))/937 = 98.58% of 50A or 49.29A

V_1=92V, I_1=0A;
V_2=184V, I_2=12.5A; Total P_o=2300W
Hex read back = 0152h.
Converted to Decimal =338.
Using the required coefficients the output current I_o% = ((338*10^(-(-2)) -(-12276)))/937 = 49.17% of 25A or 12.29A

When both outputs are used to provide output load:
Examples:
V_1=92V, I_1=25A;
V_2=184V, I_2=12.5A; Total P_o=4600W
Hex read back = 0321h.
Converted to Decimal =801.
Using the required coefficients the total output power P_o% = ((801*10^(-(-2))-(-12276)))/937 = 98.58% of 4600W or 4534.68W

V_1=92V, I_1=5A;
V_2=184V, I_2=2.5A; Total P_o=960W
Hex read back = 0042h.
Converted to Decimal =66.
Using the required coefficients the total output power P_o%= ((66*10^(-(-2)) -(-12276)))/937 = 20.14% of 4600W or 926.44W

MONITORING THE SUPPLY TEMPERATURE (READ TEMPERATURE)

The accuracy of the Temperature reading is +/-3 ºC.
The read back supply temperature can be calculated using the "Direct data Format".
Please refer to **Table 22** for the Coefficients for calculating the Supply Temperature.

Command Used	Type	#Data bytes
8Dh	Read Word	2

Table 26.

Example:
Hex read back = 02ECh;
Converted to Decimal = 748;
Using the required coefficients the Supply Internal Temperature = ((748*10^(-(-1)) -6050))/16 = 89.375˚C.

PROGRAMMING THE OUTPUT VOLTAGE (VOUT COMMAND)

The accuracy of the Output Voltage Programming is +/-2%
The output Voltage can be programmed using the "Direct data Format".
Please refer to **Table 22** for the Coefficients to be used for calculating the Voltage Programming.

Command Used	Type	#Data bytes
21h	R/W Word	2

Table 27.

Example:
To program the Output Voltage V_1 to 50.37V, send ((4097*50.37) +(-1556) *10^(-2) = 2048 (DEC).
Converted to Hex = 0800h.
Note: Output Voltage V_2 will always be set to 2 * V_1. In our example V_2=100.74v

PROGRAMMING THE OUTPUT CURRENT and POWER LIMIT (IOUT COMMAND)

The output Current Limit and Power Limit can be programmed using the "Direct data Format".
Please refer to **Table 22** for the Coefficients to be used for calculating the Voltage Programming.

Command Used	Type	#Data bytes
D1h	R/W Word	2

Table 28.

Example:
V_1=92V, I_1=36.1A (72.2%)
V_2=184V, I_2=0A P_o=3321W (72.2%)
To program the Output Current Limit to I_1=72.2%, send ((447*72.2) +(-6672)) *10^(-1) = 2560 (DEC)
Converted to Hex = 0A00h.

V_1=92V, I_1=0A
V_2=184V, I_2=25.5A (102%) P_o=4692W (102%)
To program the Output Current Limit to I_2=102%, send ((447*102) +(-6672)) *10^(-1) = 3892 (DEC)
Converted to Hex = 0F34h.

V_1=92V, I_1=21.73A
V_2=184V, I_2=10.87A P_o=4000W (86.96%)
To program the Output Power Limit to Po=86.96%, send ((447*86.96) +(-6672)) *10^(-1) = 3220 (DEC)
Converted to Hex = 0C94h.

PROGRAMMING THE MAXIMUM ALLOWABLE OUTPUT VOLTAGE (VOUT_MAX_COMMAND)

The VOUT_MAX command sets an upper limit on the output voltage the unit can command regardless of any other commands or combinations. The intent of this command is to provide a safeguard against a user accidentally setting the output voltage to a possibly destructive level rather than to be the primary output overprotection.
If an attempt is made to program the output voltage higher than the limit set by this command, the unit will set the output voltage to VOUT MAX, the "*IVPDR*" (Invalid Voltage Prog. Data Received) bit will be set in the STATUS_BYTE and will notify the host.
The accuracy of the $V_{1\ max}$ Programming is +/-2%
The VOUT_MAX can be programmed using the "Direct Data Format".
Please refer to **Table 22** for the Coefficients to be used for calculating the $V_{1\ max}$ Programming.

Command Used	Type	#Data bytes
24h	R/W Word	2

Table 29.

Example:
$V_{1\ max}$ Programming:
To program the $V_{1\ max}$ to 97V, send ((4097*97)-1556) *10^(-2) = 3958 (DEC), Converted to Hex = 0F76h.

Note: $V_{2\ max}$ will be always 2 * $V_{1\ max}$