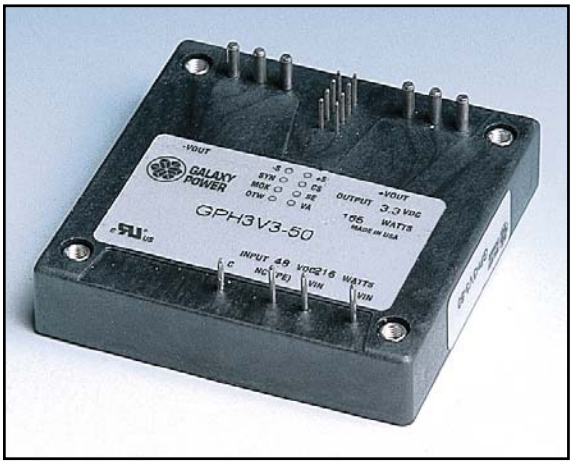
GALAXY POWER Incorporated

HERCULES SERIES

Industry's first 60A half brick DC/DC Converter
48V Input, 1.5V, 2.2V, 3.3V or 5.0V



The Hercules Series are the highest performance half brick DC/DC converters in the industry with:

- **Output Current up to 60 Amperes**
- **Parallel up to 5 units**
- **Pin Programmable Output Voltage**
- **200 Watts @ 100° Baseplate**
- **69 Watts/cu. inch**
- **2.4" x 2.4" x 0.4"**
- **Accurate Current Share**
- **Synchronizable**
- **Fixed Frequency Operation**
- **Automatic OVP tracking to Voltage Trim**
- **Output OK signal**
- **UL and CSA approved**
- **Two Year Warranty**

CONTROL FUNCTIONS

- **Remote Sense**
- **Output Enable**

PROTECTION FEATURES

- **Over Temperature Protection**
- **Over Voltage Protection**
- **Over Current Protection**

TYPICAL CHARACTERISTICS

- **Output Setpoint Accuracy: ±1.25%**
- **Load & Line Regulation: ±0.25%**
- **Noise & Ripple: 75 mVp–p**
- **Long Term Temperature Drift: ±0.5%**
- **Output Trim**

General Specifications

Operating Temperature	-20°C to +100°C baseplate	
Storage Temperature	–40°C to +100°C	
Relative Humidity	10% to 95% RH, Non–condensing	
Vibration	10–500Hz 0.75g peak	
Weight	130gm, maximum	
Material Flammability	UL94V–2	
Safety	UL 1950, CSA C22.2 No. 950 approved[1]	
MTBF	MIL–HDBK–217	500,000 hours[2]

Notes: 1. Requires one fuse located in either the plus or minus side of the 48V supply; fuse rated for 7A max for all conditions.

2. 80% load; 70°C baseplate.

Input Characteristics

Baseplate Temperatures from 0°C to +100°C.

Parameter			Test Condition	Requirement		Unit
Name	Var	Symbol		Min	Max	
Input Voltage		V_I		36	72	V
Input Low Line Power On V		V_{Ion}	Module Power On	30	35	V
Input Low Line Power Off V		V_{Ioff}	Module Shutdown	80	90	$\%V_{Ion}$
No Load Input Power		P_{IL}	$V_I=V_{Inom}$	–	2.5	W
Input Capacitor (external to the converter)			rated 80V min	250	–	µF
Input Current	1.5V	I_I	V_I = 36V, I_O = 60A, V_O = 1.5V	–	4.0	A
	2.2V	I_I	V_I = 36V, I_O = 60A, V_O = 2.2V	–	5.2	A
	3.3V	I_I	V_I = 36V, I_O = 50A, V_O = 3.3V	–	5.6	A
	5.0V	I_I	V_I = 36V, I_O = 40A, V_O = 5.0V	–	6.3	A
Inrush Transient			V_I = 48V, I_O = $I_{O\ max\ rated}$	–	1.0	A^2s
Efficiency	1.5V		$V_O = V_{O\ nom}$, $I_O = I_{O\ rated}$, $V_I=V_{Inom}$	66	–	%
	2.2V			74	–	%
	3.3V			77	–	%
	5.0V			80	–	%
Reflected Input Ripple			V_I = 48V, I_O = Io max rated, C_I = 250µF	–	2.5	A_{p-p}
Maximum Losses at Local Sense	1.5V	P_d	V_I = 48V, $V_O = V_{Onom}$ $I_O = I_{Omax\ rated}$, T_{Case}= 70°C	–	44	W
	2.2V			–	44	W
	3.3V			–	42	W
	5.0V			–	42	W

Output Characteristics

Over the complete baseplate temperatures and input voltage ranges.

Parameter			Test Condition		Requirement			Unit
Name	Var	Symbol			Min	Typ	Max	
Output Voltage (nominal)	1.5V	V_{Onom}			–	1.5	–	V_{nom}
	2.2V	V_{Onom}			–	2.2	–	V_{nom}
	3.3V	V_{Onom}			–	3.3	–	V_{nom}
	5.0V	V_{Onom}			–	5.0	–	V_{nom}
Rated Output Current	1.5V	I_O	$V_O = V_{Onom}$		0	–	60/40	A
	2.2V	I_O	$V_O = V_{Onom}$		0	–	60/40	A
	3.3V	I_O	$V_O = V_{Onom}$		0	–	50/40	A
	5.0V	I_O	$V_O = V_{Onom}$		0	–	40/30	A
Initial Output Voltage Tolerance (with remote sense)			Vadj = open, T_C = +25°C $V_I = V_{Inom}$, $I_O = I_{Orated}/2$		-1.25	–	1.25	$\%V_{Onom}$
Noise and Ripple			20MHz$_{P-P}$ bandwidth, V_I=36-72V, I_O = 0 amps to 100%				75	mV_{P-P}
Static Load and Line Regulation			V_I=36-72V, I_O = 0.2 amps to 100%		–	–	±0.25	$\%V_{Onom}$
Long Term Temperature Drift					-0.5	_	0.5	%V
Voltage Programming Slope	1.5V		V_{IN} = 48V $V_O = V_{Onom}$ $I_O = I_{Orated}/2$	V_{adj} = 0.5V to 1.5V	–	0.30 ± 0.014	–	mV/mV
	2.2V				–	0.44 ± 0.02	–	mV/mV
	3.3V				–	0.66 ± 0.03	–	mV/mV
	5.0V				–	1.0 ± 0.04	–	mV/mV
V_{adj} Initial Tolerance				V_{adj} = 1.0V			±1.25	$\%V_{Onom}$
Resistance Programming Tolerance				R_{adj} = 500Ω	-11.7		-8.3	$\%V_{Onom}$
				R_{adj} = 1500Ω	+8.3		+11.7	$\%V_{Onom}$
Total Remote Sense Compensation (round trip)	1.5V 2.2V		$V_I = V_{Imin}$, $I_O = I_{Omax\ rated}$		–		100	mV
	3.3V 5V				–		500	mV
Output Overvoltage Protection (Latching)					110		127	$\%V_O$ prog.
Output Voltage Protection Response Time		T_{OVP}	$V_O = V_{Onom}$, $I_O = I_{Orated}$		–		30	µs

Note: Overvoltage Protection must function over full programming range. Also, reference for OVP Threshold must be a redundant or equivalent reference.

Output Characteristics (continued)

Over the complete baseplate temperatures and input voltage ranges.

Parameter			Test Condition	Requirement			Unit
Name	Var	Symbol		Min	Typ	Max	
Current Limit (nominal)	1.5V	I_{Olim}	V_O = 90% V_{Onom}, V_I = 48V	61		72	A
	2.2V	I_{Olim}		61		72	A
	3.3V	I_{Olim}		46		54	A
	5.0V	I_{Olim}		37		42	A
Short Circuit Current	1.5V		V_O = 0.2 to 0.4V, V_I = 72V	–	–	80/55	A
	2.2V			–	–	80/55	A
	3.3V			–	–	70/55	A
	5.0V			–	–	55/45	A
Transient Response [1, 2]	1.5V		I_{step} =15A, di/dt=10A/µsec C_O = 35-470µf caps	–	–	3	%V_{Onom}
	2.2V		I_{step} =28A, di/dt=28A/µsec C_O = 35-470µf caps	–	–	3	%V_{Onom}
	3.3V		I_{step} =12A, di/dt=10A/µsec C_O = 10-470µf caps	–	–	3	%V_{Onom}
	5.0V		I_{step} =10A, di/dt=10A/µsec C_O = 5-470µf caps	–	–	3	%V_{Onom}
Settling Time to ±1%				–	–	600	µs
Turn On Time (to 90% final value)		t_{on}	I_O = 5A, V_I= V_{Imin} to V_{Imax} C_{in} = 250µf, 80V C_{out} = 10,000µf tantalum & 0.47µf Ceramic	10	–	75	ms
Rise Time (10% to 90%)		T_{rise}	V_I= V_{Imin} to V_{Imax} I_O= I_{Omin} to I_{Omax} Capacitors as in Turn On Time	10	–	20	ms
Turn Off Time (to 10% initial value)		t_{off}	I_O = 5A, V_{Imin} to V_{Imax} C_{in} = 250µf, 80V Co = 330µf tantalum & 0.47µf Ceramic	–	–	2.0	ms
External Load Capacitance			ESR@17,000µf = 2mΩ	1,500		18,800	µf
Current Sharing (Secondary Side)		Ishare	Vin = 48V, Vo = Vonom I = 10% Iop to Iop	—		±5	%I_{Omax}
Synchronization	Fanout			1		5	units
Over Temperature Shutdown (Latching)		$T_{BASEPLATE}$		–	–	125	°C
Isolation Resistance (1500V_{DC}) Input-Output				10			MΩ

Notes: 1. Transient response is for a positive or a negative current step within the range of 5% of Imax to Imax.

2. Transient response is measured with the specified number of 470µF tantalum external load capacitors with a maximum ESR of 55mΩ each.

Control Signal Characteristics

Parameter Name	Symbol	Test Condition	Requirement Min	Requirement Max	Unit
Enable_L Function Control Voltage (Secondary Side)	V_{ENABLE}	Enable_L asserted	0	0.8	V
		Enable_L de-asserted	4.5	5.5	V
		Source Current (V_{ENABLE} = 0.8V)	–	-1.0	mA
Enable Function Control Resistance (Secondary Side)	R_{ENABLE}	Enable_L asserted	–	100	Ω
		Enable_L de-asserted	200K	–	Ω
		Source Current (R_{ENABLE} = 100Ω)	–	-1.0	mA
OTW–L Overtemperature Warning	I_{SINK}	OTW_L asserted, V_S = 5V, R_L = 50Ω	8	20	mA
	$I_{LEAKAGE}$	OTW_L de-asserted, V_S = 15V	–	10	µA
	V_L	OTW_L asserted, V_S = 5V, R_L =5K	–	0.2	V
	T_{OTW-L} Time delay	V_I = 48V, V_O = rated V_O, I_O= Rated I_{Omax}, Fan-off early warning time before converter shuts down due to thermal overload	500	–	ms
MODOK_L	$I_{LEAKAGE}$	MODOK_L de-asserted, V_S = 15V	–	10	µA
	I_{SINK}	MODOK_L asserted, V_S = 5V, R_L = 50Ω	8	20	mA
	V_L	MODOK_L asserted, V_S = 5V, R_L = 5K	–	0.2	V

Maximum Output Load Current (I_{OP}) vs Number of Converters

No. of Converters	1.5V & 2.2V	3.3V	5.0V
1	60A	50A	40A
2	117A	87.75A	58.5A
3	174A	130.5A	87.0A
4	231A	173.25A	115.5A
5	288A	216A	144A

Thermal Characteristics (Θ_{CA})

Air Velocity (m/s)	Thermal Resistance (Baseplate to Ambient) °C/W	
	0.9" Heatsink	1.4" Heatsink
0.5	3.0	2.1
1.0	1.9	1.3
1.5	1.6	1.1
2.0	1.4	1.0
2.5	1.3	0.9

Signal Characteristics: Per table on page 5.

Input Signals:

Enable_L: This input signal is used to enable the output of the converter when activated (active Low). The signal is referenced to the output side (–Sense). Enable_L does not require an external pull-up resistor. If an external pull-up is used it should be tied to +5V. To minimize start-up problems it is recommended that Enable_L be driven from an open-drain configured FET.

Voltage Adjust: The output voltage of the converter shall be adjustable as specified in the table on page 3. The voltage adjust pin sources 1 mA current. The adjustment shall be done using an external voltage source or a resistor connected between the Voltage Adjust pin and the – Sense pin. See below for output voltage adjustment application information.

Current Share: When two or more converters are connected in parallel, their current share pins must be connected together to allow proper load sharing.

Sync: When two or more converters from the same manufacturer are connected in parallel, their sync pins may be connected together to synchronize their operating frequencies. When two or more converters from different manufacturers are connected in parallel their sync pins must NOT be connected together.

Output Signals:

MODOK_L: MODOK_L shall be asserted to indicate that the output voltage is in regulation. When two or more converters are operating in parallel a failed converter may or may not de-assert its MODOK_L signal.

OTW_L: OTW_L shall be asserted to indicate that the converter temperature is too high and that the converter is about to shut down. OTW_L will be asserted a minimum of 500 msec before the converter shuts down due to an overtemperature condition. The output of this signal is the open drain of a FET. The output is current limited to 8-15 mA and may be used to drive an external LED directly.

Output Voltage Adjustment:

Voltage Programming: A voltage may be applied between the Voltage Adjust pin (pin 5) and the – Sense pin (pin 1) to adjust the output voltage up or down from the nominal output voltage by a maximum of ±10%.

The trim voltage for the GPH1V5-40 and GPH1V5-60 is:

$$V_{TRIM} = \frac{(V_O - 1.5)}{0.30} + 1.0V$$

For the GPH2V2-40 and GPH2V2-60 the output voltage may be trimmed to +15% , - 10%. The trim voltage for these two units is:

$$V_{TRIM} = \frac{(V_O - 2.2)}{0.44} + 1.0V$$

The trim voltage for the GPH3V3-40 and GPH3V3-60 is:

$$V_{TRIM} = \frac{(V_O - 3.3)}{0.66} + 1.0V$$

The trim voltage for the GPH5V0-30 and GPH5V0-40 is:

$$V_{TRIM} = \frac{(V_O - 5.0)}{1.0} + 1.0V$$

Resistor Programming: A resistor may be connected between the Voltage Adjust pin (pin 5) and the – SENSE pin (pin 1) to adjust the output voltage up or down from the nominal output voltage by a maximum of +/- 10 %. The GPH2V2-40, -60 may be adjusted +15 %, -10 %. The value of the trim resistor is for a single converter or for multiple paralleled converters with separate trim resistors on each of their Voltage Adjust pins.

Although not recommended, the Voltage Adjust pins for N paralleled converters may be tied together. In this case the value of the trim resistor will be R_{TRIM}/N.

For the GPH1V5-40 and GPH1V5-60, the trim resistor value in Kohms for these two units is:

$$R_{TRIM} = \frac{(V_O - 1.5)}{0.30} + 1.0K\Omega$$

The resistor value in Kohms for the GPH2V2-40 and GPH2V2-60 is:

$$R_{TRIM} = \frac{(V_O - 2.2)}{0.44} + 1.0K\Omega$$

The resistor value in Kohms for the GPH3V3-40 and GPH3V3-60 is:

$$R_{TRIM} = \frac{(V_O - 3.3)}{0.66} + 1.0K\Omega$$

The resistor value in Kohms for the GPH5V0-30 and GPH5V0-40 is:

$$R_{TRIM} = \frac{(V_O - 5.0)}{1.0} + 1.0K\Omega$$

Thermal Considerations:

Thermal considerations are an important factor in the reliable operation of the converter. The maximum operating baseplate temperature is 100°C. The maximum recommended operating baseplate temperature is 90°C. The baseplate temperature is a function of the losses within the converter, the converter ambient temperature, and airflow across the heat sink.

The reference baseplate temperature is measured at the center coordinates of the baseplate.

The baseplate temperature can be approximated by the following equation:

$$T_{BASEPLATE} = P_{OUTPUT} * \frac{1 - \eta}{\eta} * R_{BASEPLATE\text{-}AMBIENT} + T_{AMBIENT}$$

Where:

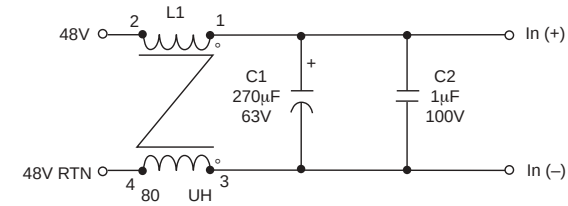
$T_{BASEPLATE}$ is the temperature of the baseplate.

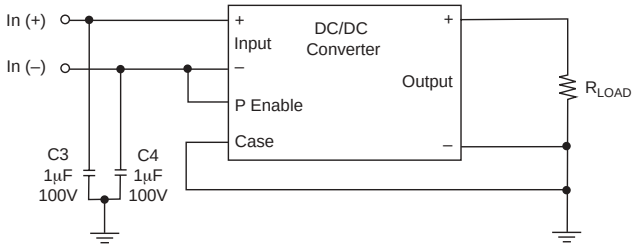
$T_{AMBIENT}$ is the local ambient temperature around the converter

η is the efficiency of the converter (see table on page 2)

$R_{BASEPLATE\text{-}AMBIENT}$ is the thermal resistance from the baseplate to the ambient environment. This is a function of the heat sink and air velocity. See table on page 5 for thermal resistance characteristics.

Recommended Input Filter, Fuse and Case Connections: A fuse is required in series with the plus or minus side of the 48V input to meet safety requirements. The following input filter circuit is recommended for all applications. The fuse should be inserted between the capacitors and the plus or minus input of the converter. The case should be connected to the output return.





L1	Common Mode Inductor
C1	270µF, 63V Aluminum Electrolytic Capacitor
C2-C4	1µF, 100V Ceramic capacitor

Paralleling Converters: Two to five converters can be paralleled as long as the following conditions are met. When all of the converters are from the same manufacturer the current share pins must be connected together and the sync pins may be connected together if desired.

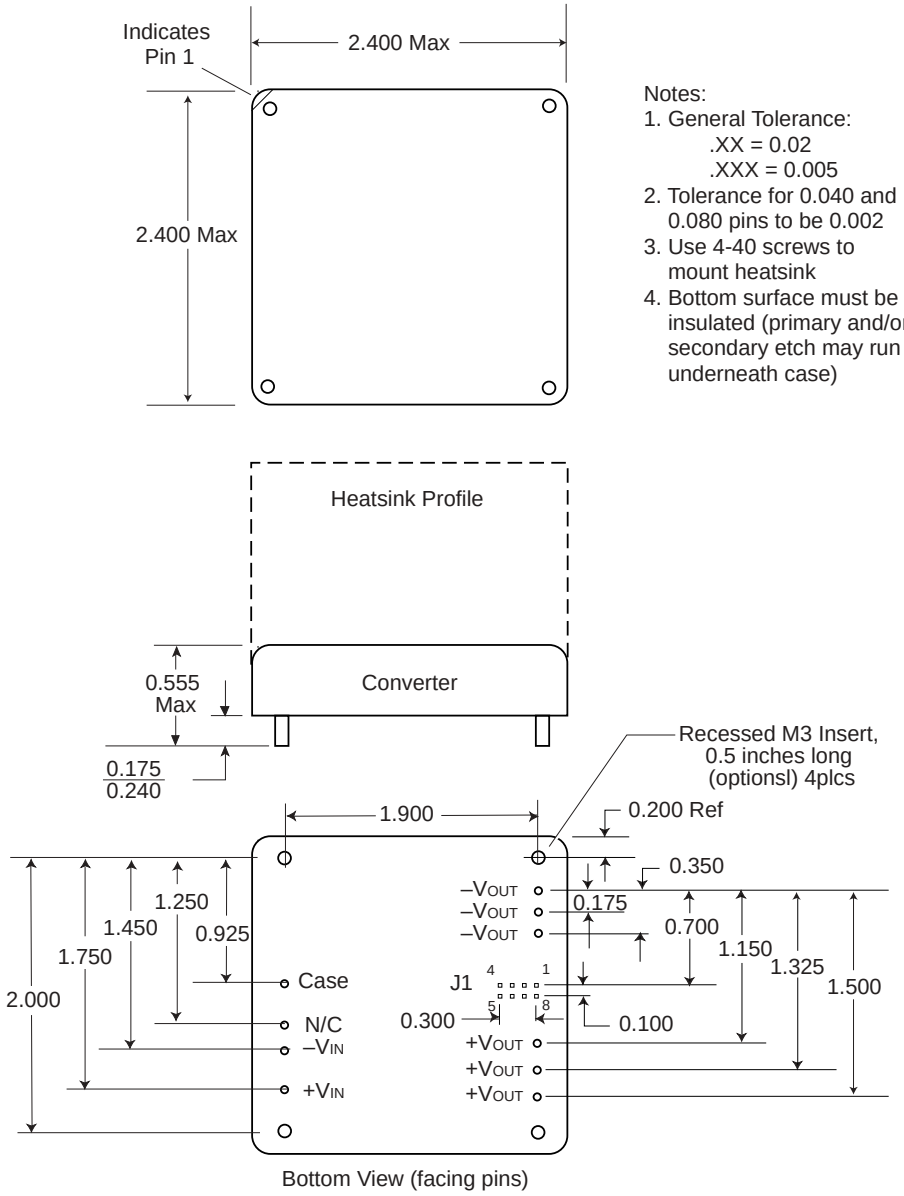
When converters from different manufacturers are paralleled, the current share pins must be connected together and the sync pins must NOT be connected together.

The maximum output current for paralleled configurations is shown in the table on page 5.

When a converter fails in a parallel configuration it may or may not deassert its MODOK_L signal.

It should also be noted that current for the control circuit in the converter flows through the – SENSE lead. For this reason it is important to keep the impedance between the – SENSE pins on the converters in a parallel configuration low. The best approach is to connect the – SENSE pins together with as large of an etch as possible (250 milliohms maximum recommended) and then run a single set of sense leads to the remote sense point at the load.

PACKAGE DETAIL



Notes:
1. General Tolerance:
   .XX = 0.02
   .XXX = 0.005
2. Tolerance for 0.040 and 0.080 pins to be 0.002
3. Use 4-40 screws to mount heatsink
4. Bottom surface must be insulated (primary and/or secondary etch may run underneath case)

Pin Assignments

Power Pins	
Designation	**Pin Config.**
+Vout	.080 round
–Vout	.080 round
Case	.040 round
N/C	.040 round
–Vin	.040 round
+Vin	.040 round

Signal Pins (25 mils sq.)	
Pin	**Designation**
1	-Sense
2	SYNC
3	MODOK_L
4	OTW_L
5	Voltage Adjust
6	Enable_L
7	Current Share
8	+ Sense

Galaxy Power Inc. warrants to the original purchaser that the products conform to this data sheet and are free from material and workmanship defects for a period of two (2) years from the date of manufacture, if this product is used within specified conditions. Galaxy Power Inc. reserves the right to make changes to the product(s) or information contained herein without notice. No liability is assumed as a result of their use or application. No rights under any patent accompany the sale of any such products or information. For additional details on this limited warranty consult the factory.

ORDERING INFORMATION

Model Number	Output Voltage	Max Current	Efficiency (Typ)
GPH5V0-40	5.0V	40 A	85%
GPH5V0-30	5.0V	30 A	86%
GPH3V3-50	3.3V	50 A	81%
GPH3V3-40	3.3V	40 A	82%

Model Number	Output Voltage	Max Current	Efficiency (Typ)
GPH2V2-60	2.2V	60 A	74%
GPH2V2-40	2.2V	40 A	75%
GPH1V5-60	1.5V	60 A	67%
GPH1V5-40	1.5V	40 A	68%

** Heatsinks required: available on request. See table on page 5.*

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