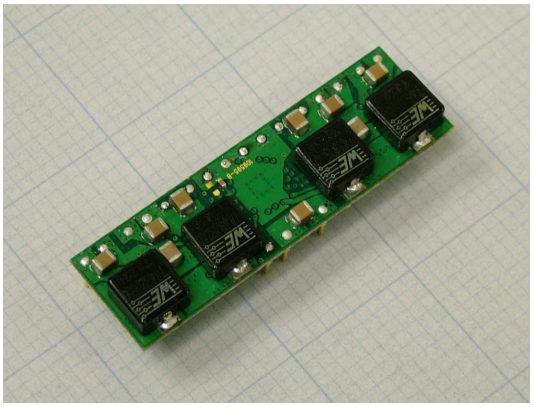
Technical Datasheet FLEX-4

Features



- Quad output non-isolated DC-DC converter
- Up to 60A total output current (2ch @ 10A + 2ch @ 20A)
- High efficiency outputs meet or beat industry standard performance - 94.5% at 5V, 10A; 89% at 1V8, 20A.
- Input voltage range: 7 – 15 Vin (5 Vin models available)
- Output voltage programmable from 0.6 – 5.1Vdc (outputs >5.1V are possible – consult factory)
- Additional LDO output: 5V or 3.3V, up to 50mA
- Independently programmable sequencing; start-up & soft-stop delay and ramp time for each output.
- Startup into pre-biased output voltage
- No minimum load required
- Small Size:
  66 mm x 20.3 mm) x 9.27 mm
  (2.60 in x 0.80 in x 0.365 in)
- Fixed-frequency operation: 300kHz typical, up to 1MHz possible (w/derated output current)
- Each channel is 90 degrees out of phase from adj. channels, minimizing input filter requirements
- Fully programmable protection features (OTP, OCP, OVP, UVLO)
- Real-time parameter monitoring & adjustments possible; V_{out}, I_{limit} & other protection features can be adjusted.
- Remote ON/OFF pin
- Two General Purpose Input-Outputs (GPIOs – 4 if I^2C communication disabled) – can be used to enable channel(s), PG signal, show any fault condition, sync clock in, or Soft Start in process.
- Weight: 0.8 oz [22.7 g]

Description

The FLEX-4 DC-DC converter is a 4 output module that provides up to 60 Amps of total output current. The converter operates over an input voltage range of 7 to 15 VDC (5 Vin models are available), and provides 4 programmable output voltages with output currents up to 20A per channel. The standard feature set includes remote On/Off, input undervoltage lockout, output overvoltage protection, overcurrent protection & over temperature shutdown with hysteresis. The high efficiency of the FLEX-4 allows operation over a wide ambient temperature range with minimal derating. Each output has programmable start-up delay and ramp time, including startup into a pre-biased output voltage. Soft-stop delay and ramp rate is also programmable for each channel. Switching frequency is 300 kHz nominal, but can be programmed for frequencies up to 1MHz (with output current/power derating.) Synchronization to an external clock is also possible. Customers can optionally communicate with the module using an external microcontroller allowing real-time parameter monitoring and adjustment capabilities. For example, output voltage can be adjusted as required on the fly while the module is operating. Voltage changes can be confirmed by reading back voltage from the on-board ADCs. Because the outputs are phased 90 degrees apart, input filtering requirements are significantly reduced versus using 4 individual DC-DC modules. Stability is assured as loop compensation can be adjusted (in the digital domain) as needed based on actual system component values. This minimizes disruptions as the Flex-4 can adapt to changes in the host system as required.

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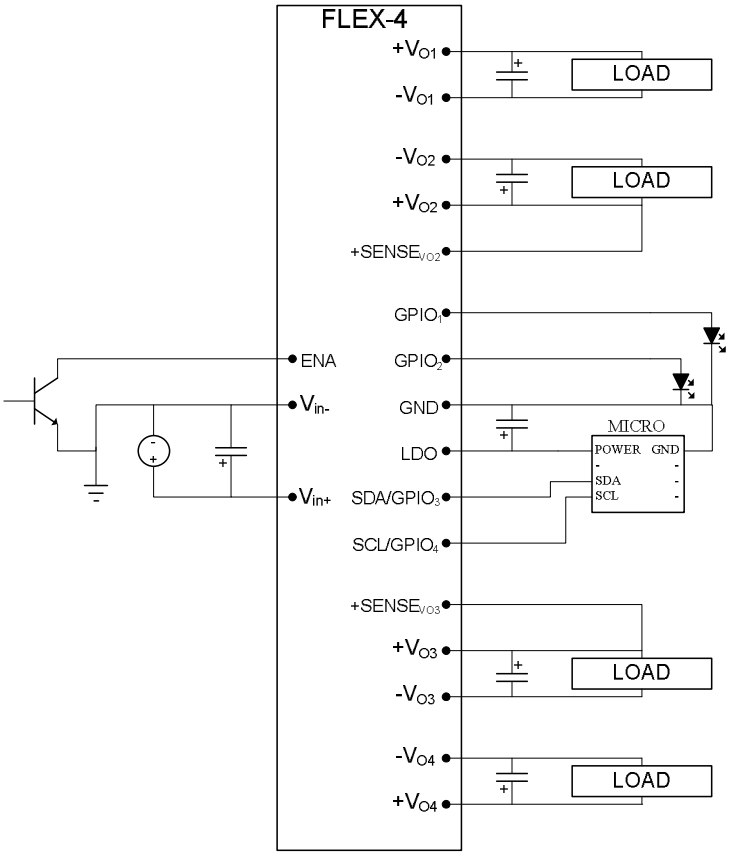
APPLICATION DIAGRAM



Note: Positive enable pin has internal pull-up, pull down w/transistor to turn supply off. Microcontroller is not required; it is an application specific enhancement.

ELECTRICAL SPECIFICATIONS 7–15Vin, 10/20Aout

Conditions: T_A = 25 °C, Airflow = 300 LFM, Vin = 12 VDC, Cin = 470 µF, standard configuration.

Absolute Maximum Ratings					
Parameter	**Conditions**	**Min**	**Typ**	**Max**	**Unit**
Input Voltage	Continuous Operation	6.5		16	VDC
Operating Ambient Temperature	w/derating	-40		85	°C
Storage Temperature		-55		125	°C
Feature Characteristics					
Parameter	**Conditions**	**Min**	**Typ**	**Max**	**Unit**
Switching Frequency			300		kHz
Remote Sense Compensation				+10	$\%V_o$
Output Over-voltage Protection	Latching		120	133	$\%V_o$
Over-temperature Shutdown[1]	Auto-restart (w/ hysteresis)		135	165	°C
Over-temperature Restart[1]			115		°C
Peak Backdrive Output Current during startup into prebiased output	Sinking current from external voltage source equal to V_{OUT} – 0.6V and connected to the output via 1Ω resistor. C_{OUT}=220µF, Aluminum		0	20	mA
Backdrive Output Current in OFF state	Converter disabled		0	5	mA
Output Startup Delay[2]		0	0	16	ms
Output Rise Time[2]	Rise time per Vout_set	0	2	20	ms/V
Output Enable ON/OFF Converter ON Converter OFF	Module has internal pull-up	 2.4 -0.5		 5 0.8	 VDC VDC
Output Voltage Overshoot @ Startup			0	1	$\%V_o$

ELECTRICAL SPECIFICATIONS (continued) 7–15Vin, 10/20Aout

Conditions: T_A = 25 °C, Airflow = 300 LFM, Vin = 12 VDC, Cin = 470 µF, standard configuration.

Input Characteristics					
Parameter	**Conditions**	**Min**	**Typ**	**Max**	**Unit**
Operating Input Voltage Range		7	12	15	VDC
Input Under-Voltage Lock-out Turn-on Threshold Turn-off Threshold		 6.8 6.3	 7 6.5	 7.2 6.7	VDC
Input Voltage Transient	100ms			20	VDC
Maximum Input Current - Continuous Operation	Limits potential output power			18	A
Maximum Input Current – Short-term battery dropout	V_{IN} = 7V_{DC}; P_{out} = 125W			21	A
Input Standby Current	Converter Disabled		10		mA
Input No-Load Current	All 4 Channels Enabled		200	250	mA
Input Reflected Ripple Current	5Hz to 50MHz			50	mA_{PK-PK}
Inrush Current	All	-	-	1	A^2/s

Output Characteristics					
Parameter	**Conditions**	**Min**	**Typ**	**Max**	**Unit**
Output Voltage Set Point	Sense pins connected to output pins for Ch 2&3	-	±1	±2	%
Output Voltage Set Point Range[3]		0.6		5.1	VDC
Output Current - Channels 1 & 4		0		10	A
Output Current - Channels 2 & 3		0		20	A
Output Power - Channels 1 & 4		0		50	W
Output Power - Channels 2 & 3		0		40	W
Output Current Limit Inception[4]		-	200	-	% I_{o_nom}
Peak Short-Circuit Current	10mΩ Short			300	% I_{o_max}
Auto-Restart Period	(overcurrent SD)		200		ms
Output Ripple and Noise 20 MHz bandwidth	0.6V ≤ V_o ≤ 2.5V		25	50	mV_{PK-PK}
	2.6V ≤ V_o ≤ 5.1V		35	70	mV_{PK-PK}
Output Regulation Line: Load: Overall Output Regulation:	 Over line, load & temp.		 0.1 0.3	 0.3 0.6 ±2	 %Vo %Vo %Vo

ELECTRICAL SPECIFICATIONS (continued) 7–15Vin, 10/20Aout

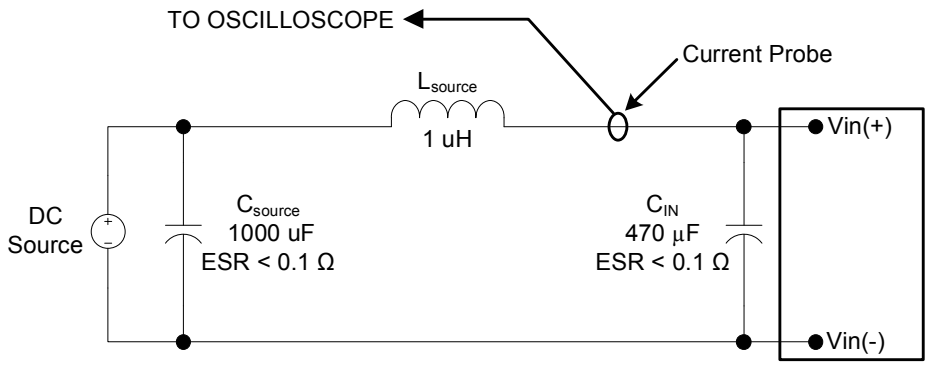
Conditions: T_A = 25 °C, Airflow = 300 LFM, Vin = 12 VDC, Cin = 470 µF, standard configuration.

Combined Efficiency (5V, 3V3 @ 10A; 1V8, 1V0 @ 20A)					
Parameter	**Conditions**	**Min**	**Typ**	**Max**	**Unit**
100% Load			90		%
50% Load			92		%
10% Load			83		%
Individual Channel Efficiency (other channels disabled)					
Vin = $12V_{DC}$, T_A = 25ºC Io = 20A @ ≤ $2.5V_o$ Io = 10A @ $2.6V_o$ ≤ $5.1V_o$	$V_o = 0.6V_{DC}$		78		%
	$V_o = 0.9V_{DC}$		83		%
	$V_o = 1.2V_{DC}$		86		%
	$V_o = 1.8V_{DC}$		89		%
	$V_o = 2.5V_{DC}$		90.8		%
	$V_o = 3.3V_{DC}$		92.5		%
	$V_o = 5.0V_{DC}$		94.5		%
Dynamic Response[5]					
Parameter	**Conditions**	**Min**	**Typ**	**Max**	**Unit**
Load Change 25%-75%-25% of Iout Max, di/dt = 0.2 A/µs	Co = .1 µF ceramic + 10 µF tantalum	-	±180	-	mV
Settling Time to 1% of Vout			50		µs
Load Change 25%-75%-25% of Iout Max, di/dt = 2.5 A/µs	Co = .1 µF ceramic + 470 µF tantalum	-	±180	-	mV
Settling Time to 1% of Vout			50		µs

Notes:

1) OTP (over-temperature protection) shutdown and restart settings are programmable
2) Startup delay and rise time are programmable for each channel
3) Output voltages greater than 5.1V are possible – consult factory.
4) Overcurrent limit is fully programmable based on customer requirements.
5) Typical performance - loop response can be optimized to customer's system – consult factory.

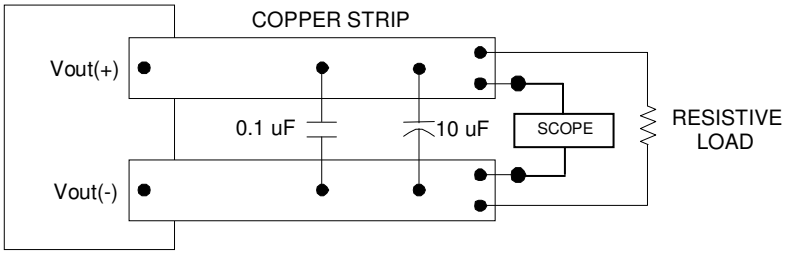
INPUT REFLECTED RIPPLE TEST SETUP:



Note: Measure input reflected-ripple current with a simulated source inductance (L_{source}) of 1 uH. Capacitor C_{source} offsets possible source impedance.

Figure 1. Input Reflected-ripple Current Test Setup.

OUTPUT RIPPLE TEST SETUP:



Note: Use a 0.1µF X7R ceramic capacitor and a 10µF @ 25V tantalum capacitor. Scope measurement should be made using a BNC socket. Position the load 3 in. [76mm] from module.

Figure 2. Peak-to-Peak Output Noise Measurement Test Setup.

CHARACTERISTIC CURVES:

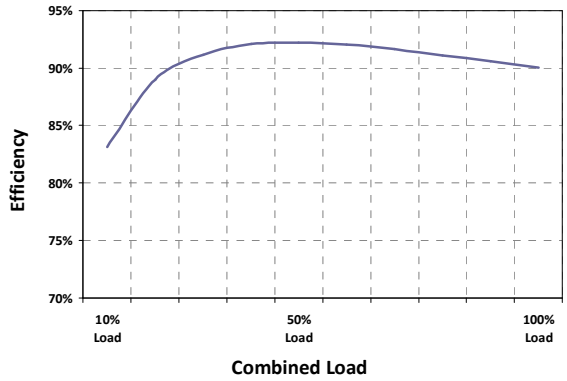


Figure 3. Efficiency vs Total Combined Load, 12Vin, 25°C ambient, 300LFM airflow, 5 & 3V3 @ 10A max, 1V8 & 1.0V @ 20A max.

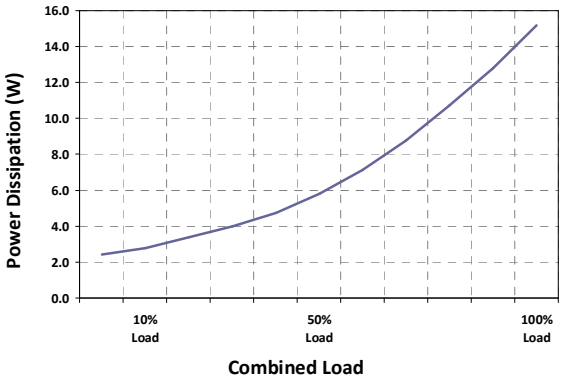


Figure 4. Power Dissipation vs. Load Current, 12Vin, 25°C ambient, 300LFM airflow, 5 & 3V3 @ 10A max, 1V8 & 1.0V @ 20A max.

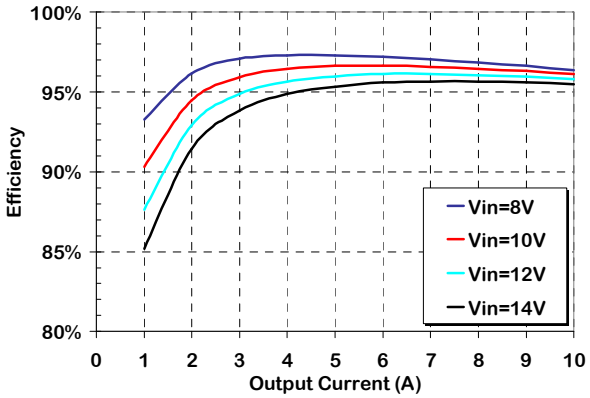


Figure 5. Efficiency vs Load Current, V_{out} = 5V 300lfm airflow, 25°C ambient.

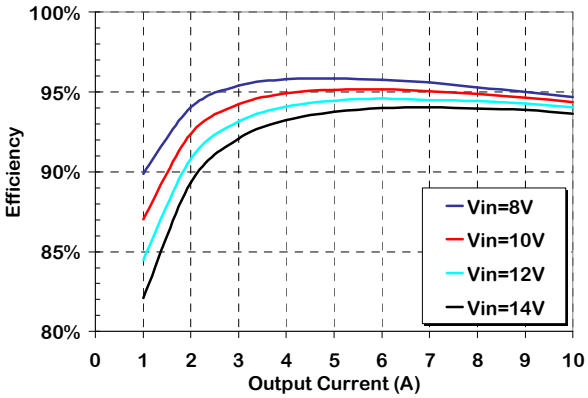


Figure 6. Efficiency vs Load Current, V_{out} = 3.3V 300lfm airflow, 25°C ambient.

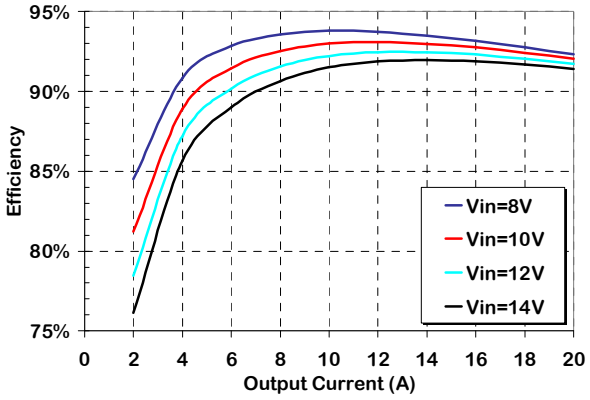


Figure 7. Efficiency vs Load Current, V_{out} = 2.5V 300lfm airflow, 25°C ambient.

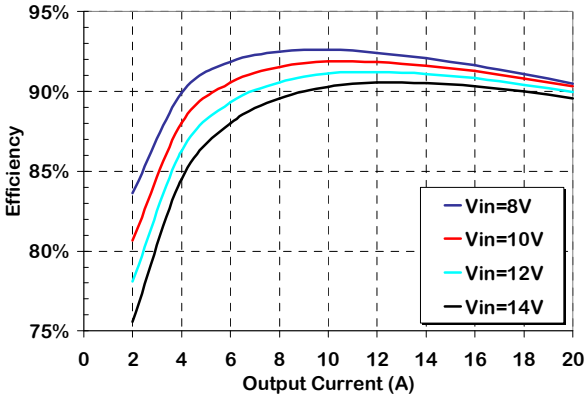


Figure 8. Efficiency vs Load Current, V_{out} = 1.8V 300lfm airflow, 25°C ambient.

CHARACTERISTIC CURVES (continued):

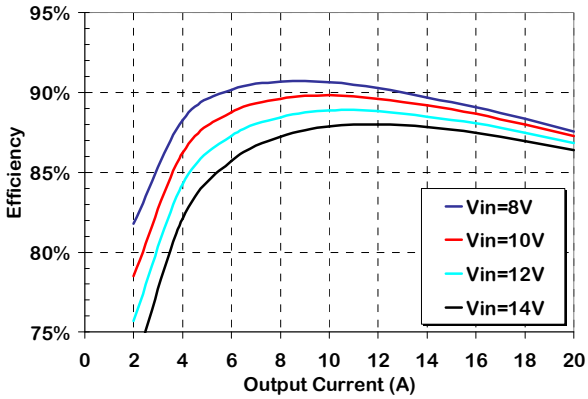


Figure 9. Efficiency vs Load Current, V_{out} = 1.2V
300lfm airflow, 25℃ ambient.

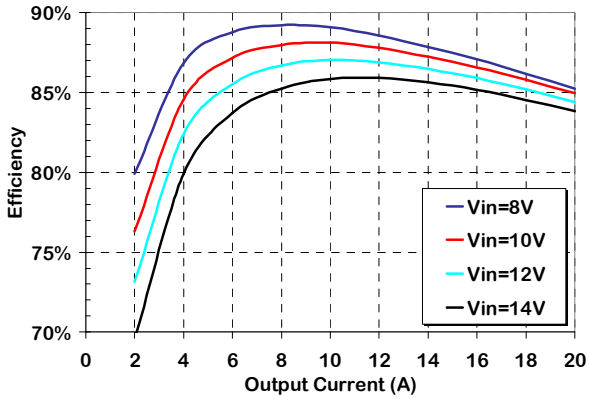
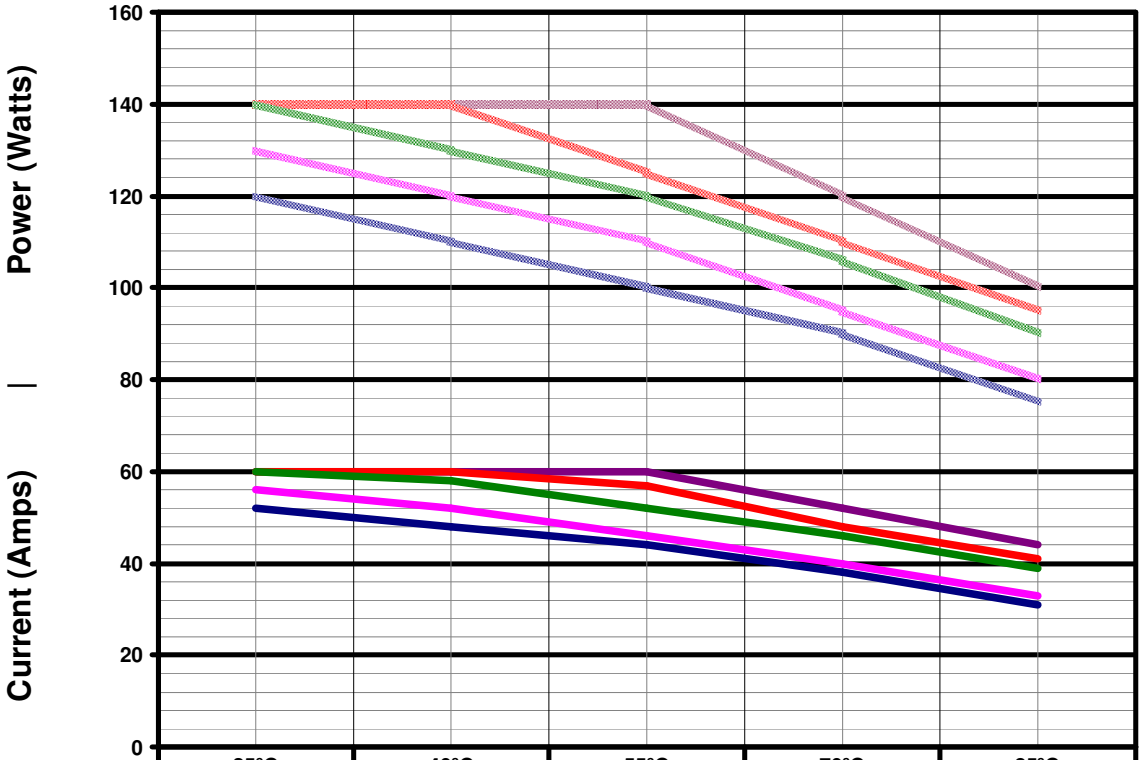


Figure 10. Efficiency vs Load Current, V_{out} = 0.9V
300lfm airflow, 25℃ ambient.

Flex-4 Output Power/Current Derating vs. Ambient Temperature & Airflow Rate



	25ºC	40ºC	55ºC	70ºC	85ºC
400 LFM Pout Tot	140	140	140	120	100
300 LFM Pout Tot	140	140	125	110	95
200 LFM Pout Tot	140	130	120	106	90
100 LFM Pout Tot	130	120	110	95	80
N/C ~30LFM Pout Tot	120	110	100	90	75
400 LFM Iout Tot	60	60	60	52	44
300 LFM Iout Tot	60	60	57	48	41
200 LFM Iout Tot	60	58	52	46	39
100 LFM Iout Tot	56	52	46	40	33
N/C ~30LFM Iout Tot	52	48	44	38	31

Figure 11. Output Power/Current Derating vs Ambient Temperature & Airflow; converter mounted vertically with air flowing perpendicular to long side of module, Vin = 9.5 – 12.5 V. Derate output current/power by 3% for each Volt above 12.5V or below 9.5V. $T_{hotspot}$ = 120ºC max.

Total combined current (if running maximum derated current) must be split equally between Channels 1&2 and Channels 3&4. Total combined power must be split within 5% per “side”. E.g., 120W total power = 60W power per side (Ch1&2/Ch3&4); power may be split 63W max for Ch1&2 & 57W max for Ch3&4.

Channels 1&4 are 10A or 50W max, 2&3 are 20A or 40W maximum. Below 54A combined output current (27A/side), 20A channels are derated by 1A ea per 2A combined below 54A. E.g., 48A total combined current = 17A max on the 20A channels (Ch 2&3; 54 – 48 = 6, 6/2 = 3A reduction in rated current per 20A channel.) 1 additional amp per 20A channel is possible if total power on that "side" is reduced by 10W. E.g., 55C & 100LFM airflow gives 46 total amps or 110W max. power. Max current for 20A channels will be 16A & power per side is 55W. If max power is reduced to 45W on one side, the 20A max channel can supply up to 17A on that side.

While the above is somewhat complicated, it should be noted that all effort was made to demonstrate the maximum capabilities of the module (the definition of a derating curve.) Highly imbalanced loading is no problem at all so long as maximum current and power levels are observed for each channel/channel pair (see how channel pairs appear in the IR thermal image below.) Please contact the factory for questions about specific applications.

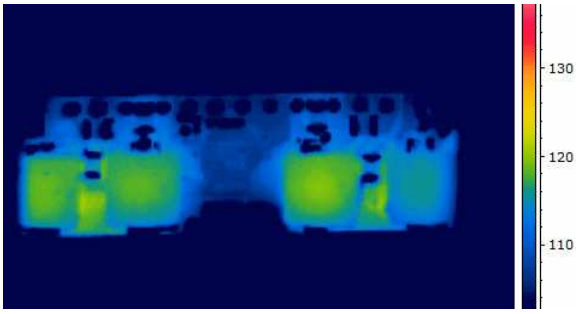


Figure 12. Thermal Image of Flex-4; 52A combined output current, Vin = 12V, 55ºC Ambient, 200lfm airflow, $T_{hotspot}$ = 120ºC

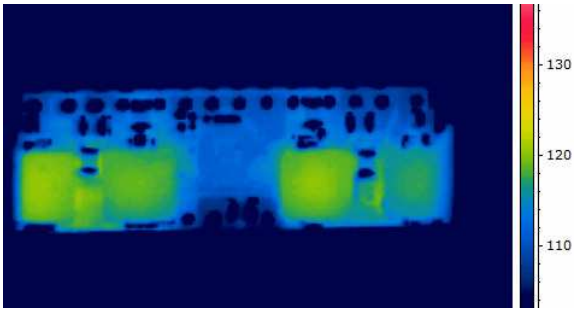


Figure 13. Thermal Image of Flex-4; 39A combined output current, Vin = 12V, 85ºC Ambient, 200lfm airflow, $T_{hotspot}$ = 120ºC

Application Design Considerations

Cooling Considerations

- It is preferable that the Flex-4 have an unobstructed flow of air across it for best thermal performance. Thermal testing was performed with a single 0.4" (10mm) diameter electrolytic capacitor within 0.5" (12.5mm) of the input pins (approximately centered in length dimension at input pins.) Since the major heat dissipating components are on either side away from the center of the Flex-4, this does not create much of an issue. Components taller than ~ 2mm in front of the heat dissipating areas (yellow/green area in thermal image above) can deflect airflow and possibly create hotspots.

- Airflow should flow perpendicular to the long side of the Flex-4. Airflow running parallel to the long side will heat as it crosses the module and the channels downstream will see higher air temperatures, thus they will run hotter. The derating curves in this datasheet apply to airflow perpendicular to the module. If airflow parallel to the long side of the converter is unavoidable, current/power must be derated 15% from the values in the derating table above.

- Peak temperatures are to be measured at the center of the 4 inductors and are not to exceed 120ºC. This is the ultimate in-system verification of module derating performance.

SMT Version Layout Considerations

- Copper traces with sufficient cross-section must be provided for all high-current outputs & input pins. SMT pads tied to internal power/ground planes must have multiple vias around each SMT pad to couple expected current loads from module pins into internal traces/planes. One 0.024" (0.6mm) diameter via for each 4A of expected source or load current must be provided as close to Flex-4 termination as possible, preferably in the direction of current flow from SMT pad to load. Vias must be at least 0.024" (0.6 mm) away from the SMT pad to prevent solder from flowing into the vias.

- SMT pads on the host card are to be 0.110" (2.79mm) diameter. Solder paste screen opening should be 0.105" diameter and the screen should be 0.006" (0.15 mm) thick (other thicknesses are possible; 0.006" provides a good compromise between solder volume and coplanarity compensation.)

CHARACTERISTIC WAVEFORMS:

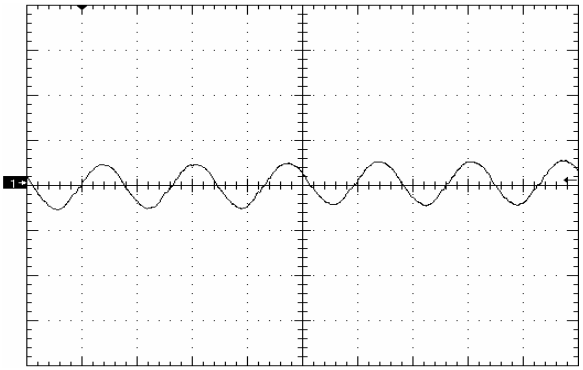


Figure 15. Output Voltage Ripple – 5V, 10A out (50mV/div),time scale – 2uS/div.

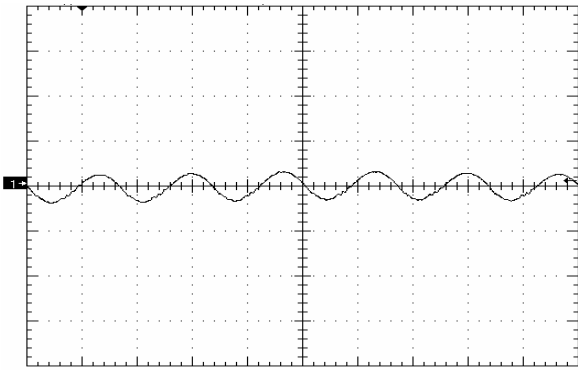


Figure 16. Output Voltage Ripple – 3V3, 10A out (50mV/div),time scale – 2uS/div.

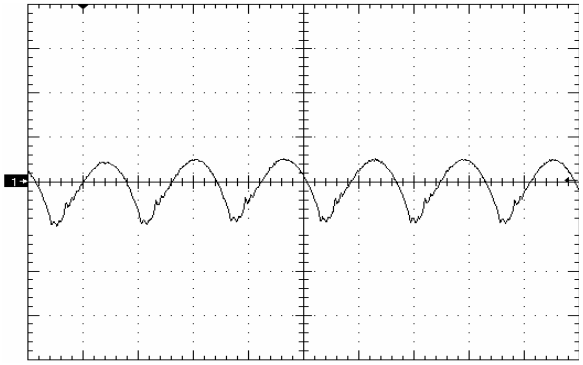


Figure 17. Output Voltage Ripple – 1.8V, 20A out (20mV/div),time scale – 2uS/div.

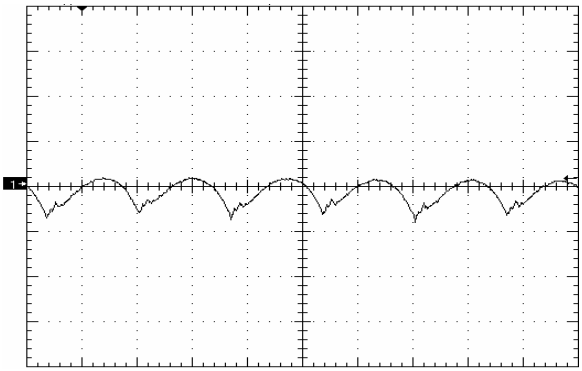


Figure 18. Output Voltage Ripple – 1.0V, 20A out (20mV/div),time scale – 2uS/div.

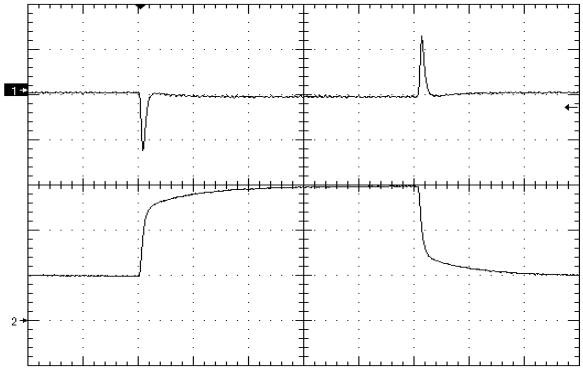


Figure 19. Load Transient Response 1V8 output, di/dt=0.2A/uS, 25% - 75% - 25% of full load, (100mV/div, 5A/div, time scale: 100uS/div.)

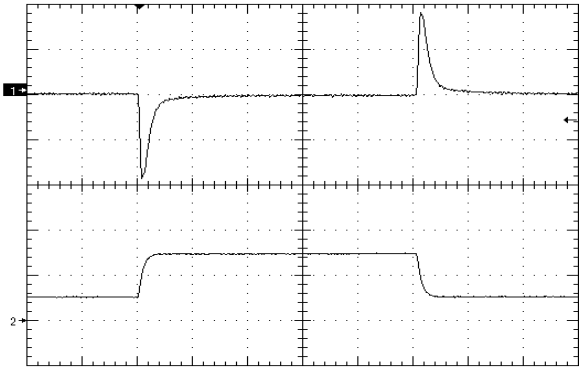


Figure 20. Load Transient Response 3V3 output di/dt=0.2A/uS, 25% - 75% - 25% of full load, (100mV/div, 5A/div, time scale: 100uS/div.)

CHARACTERISTIC WAVEFORMS (continued):

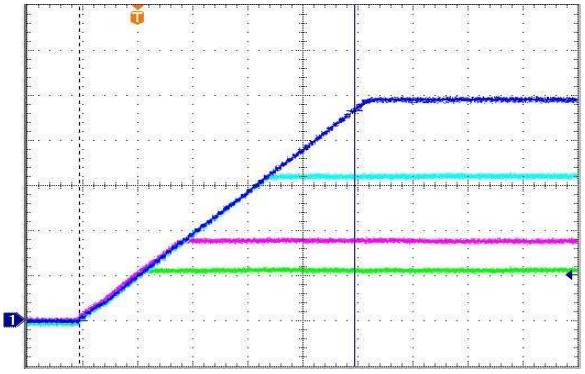


Figure 21. Simultaneous Startup (1V/div, 2ms/div). Outputs = 5V, 3V3, 1V8 & 1V2.

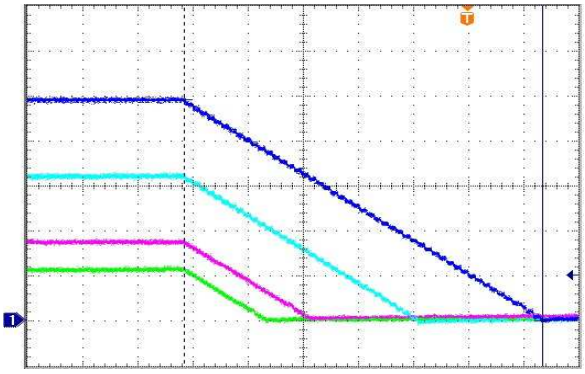


Figure 22. Simultaneous Shutdown (1V/div, 2ms/div). Outputs = 5V, 3V3, 1V8 & 1V2.

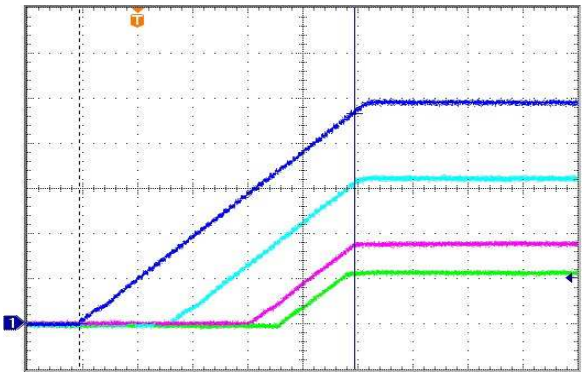


Figure 23. Sequential Startup (1V/div, 2ms/div). Note 4 outputs reaching regulation simultaneously. Outputs = 5V, 3V3, 1V8 & 1V2.

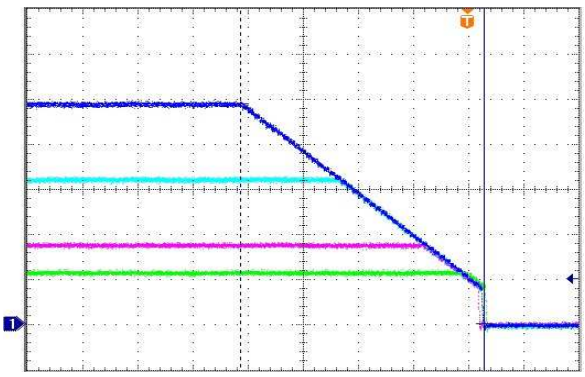
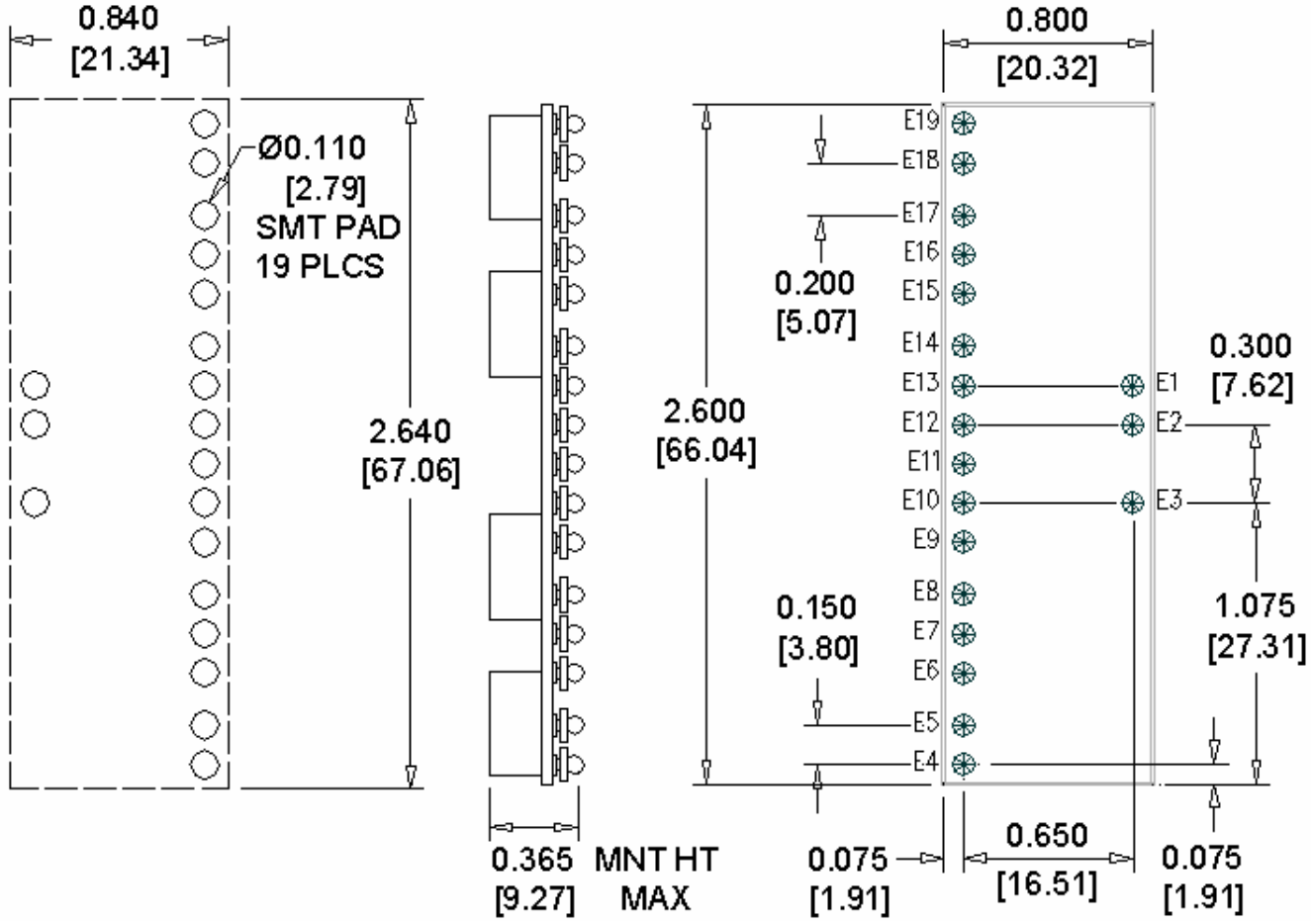


Figure 24. Sequential Shutdown (1V/div, 2ms/div). Note Vout shutdown threshold setting of 0.8V (soft-stop ceases at 0.8V & load then pulls outputs to 0V.) Outputs = 5V, 3V3, 1V8 & 1V2.

MECHANICAL OUTLINE & PCB FOOTPRINT – SMT version

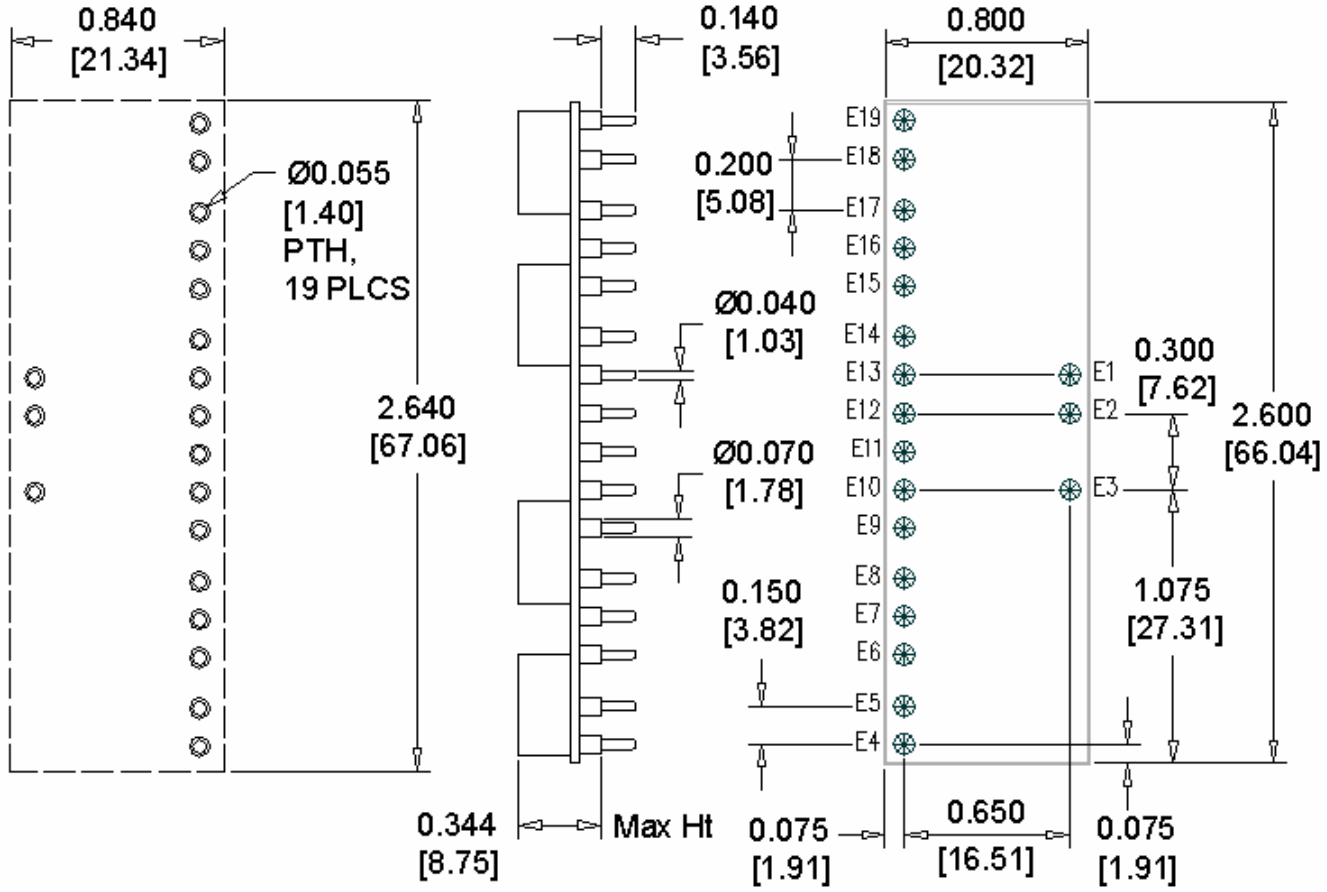


PC Board Layout | Side View | Bottom (Pin Side) View

MODULE PIN ASSIGNMENT

PIN #	DESIGNATION	PIN #	DESIGNATION
1	On/Off	11	LDO_OUT (5V or 3V3)
2	V_{IN} (-)	12	Common
3	V_{IN} (+)	13	GPIO_2
4	V_{OUT} (+) Ch 4	14	GPIO_1
5	V_{OUT} (-) Ch 4	15	Sense (+) Ch 2
6	V_{OUT} (-) Ch 3	16	V_{OUT} (+) Ch 2
7	V_{OUT} (+) Ch 3	17	V_{OUT} (-) Ch 2
8	Sense (+) Ch 3	18	V_{OUT} (-) Ch 1
9	SCL (GPIO_4)	19	V_{OUT} (+) Ch 1
10	SDA (GPIO_3)		

MECHANICAL OUTLINE & PCB FOOTPRINT – Through-hole version



PC Board Layout | Side View | Bottom (Pin Side) View

MODULE PIN ASSIGNMENT

PIN #	DESIGNATION	PIN #	DESIGNATION
1	On/Off	11	LDO_OUT (5V or 3V3)
2	V_{IN} (-)	12	Common
3	V_{IN} (+)	13	GPIO_2
4	V_{OUT} (+) Ch 4	14	GPIO_1
5	V_{OUT} (-) Ch 4	15	Sense (+) Ch 2
6	V_{OUT} (-) Ch 3	16	V_{OUT} (+) Ch 2
7	V_{OUT} (+) Ch 3	17	V_{OUT} (-) Ch 2
8	Sense (+) Ch 3	18	V_{OUT} (-) Ch 1
9	SCL (GPIO_4)	19	V_{OUT} (+) Ch 1
10	SDA (GPIO_3)		

Ordering Information:			
Product Identifier	**Customer Options**	**Mount**	**Comment**
Flex-4	-0000	S	Standard Configuration* – Surface Mount
Flex-4	-0000	T	Standard Configuration* – Through Hole
Flex-4	-XXXX	S or T	Customer Specific Options

* Standard Configuration: Ch1 = 5V @ 10A, Ch2 = 1.2V @ 20A, Ch3 = 1V8 @ 20A, Ch4 = 3V3 @ 10A; All parameters match "typical" values in electrical specifications table.