1	Hiper_PFS-4_Boost_051319; Rev.1.2; Copyright Power Integrations 2019	INPUT	INFO	OUTPUT	UNITS	Continuous Mode Boost Converter Design Spreadsheet
2	**Enter Application Variables**					**Design Title**
3	Input Voltage Range	**High Line**		High Line		Input voltage range
4	VACMIN			185	VAC	Minimum AC input voltage. Spreadsheet simulation is performed at this voltage. To examine operation at other votlages, enter here, but enter fixed value for LPFC_ACTUAL.
5	VACMAX			265	VAC	Maximum AC input voltage
6	VBROWNIN			167	VAC	Expected Typical Brown-in Voltage per IC specifications; Line impedance not accounted for.
7	VBROWNOUT			156	VAC	Expected Typical Brown-out voltage per IC specifications; Line impedance not accounted for.
8	VO			385	VDC	Nominal load voltage
9	PO	466		466	W	Nominal Output power
10	fL			50	Hz	Line frequency
11	TA Max			40	°C	Maximum ambient temperature
12	Efficiency Estimate	0.95		0.95		Enter the efficiency estimate for the boost converter at VACMIN. Should approximately match calculated efficiency in Loss Budget section
13	VO_MIN			366	VDC	Minimum Output voltage
14	VO_RIPPLE_MAX			20	VDC	Maximum Output voltage ripple
15	T_HOLDUP	16	Warning	16	ms	Expected holdup time is smaller than specified value. Please use larger Output capacitance
16	VHOLDUP_MIN			308	VDC	Minimum Voltage Output can drop to during holdup
17	I_INRUSH			40	A	Maximum allowable inrush current
18	Forced Air Cooling	**Yes**		Yes		Enter "Yes" for Forced air cooling. Otherwise enter "No". Forced air reduces acceptable choke current density and core autopick core size
19						
20	**KP and INDUCTANCE**					
21	KP_TARGET			0.80		Target ripple to peak inductor current ratio at the peak of VACMIN. Affects inductance value
22	LPFC_TARGET (0 bias)			172	uH	PFC inductance required to hit KP_TARGET at peak of VACMIN and full load
23	LPFC_DESIRED (0 bias)			172	uH	LPFC value used for calculations. Leave blank to use LPFC_TARGET. Enter value to hold constant (also enter core selection) while changing VACMIN to examine brownout operation. Calculated inductance with rounded (integral) turns for powder core.
24	KP_ACTUAL			0.802		Actual KP calculated from LPFC_DESIRED
25	LPFC_PEAK			172	uH	Inductance at VACMIN and maximum bias current. For Ferrite, same as LPFC_DESIRED (0 bias)
26						
27	**Basic current parameters**					
28	IAC_RMS			2.65	A	AC input RMS current at VACMIN and Full Power load
29	IO_DC			1.21	A	Output average current/Average diode current
30						
31						
32	**PFS Parameters**					
33	PFS Package	**H/L**		H/L		HiperPFS package selection
34	PFS Part Number	**Auto**		PFS7636H		If examining brownout operation, over-ride autopick with desired device size
35	Operating Mode	**Full Power**		Full Power		Mode of operation of PFS. For Full Power mode enter "Full Power" otherwise enter "EFFICIENCY" to indicate efficiency mode
36	IOCP min			6.80	A	Minimum Current limit
37	IOCP typ			7.20	A	Typical current limit
38	IOCP max			7.50	A	Maximum current limit
39	IP			6.24	A	MOSFET peak current
40	IRMS			2.01	A	PFS MOSFET RMS current
41	RDSON			0.49	Ohms	Typical RDSon at 100 'C
42	FS_PK			114.4	kHz	Estimated frequency of operation at crest of input voltage (at VACMIN)
43	FS_AVG			102.8	kHz	Estimated average frequency of operation over line cycle (at VACMIN)
44	PCOND_LOSS_PFS			1.998	W	Estimated PFS conduction losses
45	PSW_LOSS_PFS			1.836	W	Estimated PFS switching losses
46	PFS_TOTAL			3.833	W	Total Estimated PFS losses
47	TJ Max			100	deg C	Maximum steady-state junction temperature
48	Rth-JS			2.80	°C/W	Maximum thermal resistance (Junction to heatsink)
49	HEATSINK Theta-CA			12.85	°C/W	Maximum thermal resistance of heatsink
50						
51						
52	**INDUCTOR DESIGN**					
53	**Basic Inductor Parameters**					
54	LPFC (0 Bias)			172	uH	Value of PFC inductor at zero current. This is the value measured with LCR meter. For powder, it will be different than LPFC.
55	LP_TOL			10.0	%	Tolerance of PFC Inductor Value (ferrite only)
56	IL_RMS			2.99	A	Inductor RMS current (calculated at VACMIN and Full Power Load)
57	**Material and Dimensions**					
58	Core Type	**Ferrite**		Ferrite		Enter "Sendust", "Iron Powder" or "Ferrite"
59	Core Material	**Auto**		PC44/PC95		Select from 60u, 75u, 90u or 125 u for Sendust cores. Fixed at PC44/PC95 for Ferrite cores. Fixed at -52 material for Pow Iron cores.
60	Core Geometry	**Auto**		PQ		Toroid only for Sendust and Powdered Iron; EE or PQ for Ferrite cores.
61	Core	**PQ32/20**		PQ32/20		Core part number

62	Ae			170.00	mm^2	Core cross sectional area
63	Le			55.50	mm	Core mean path length
64	AL			6530.00	nH/t^2	Core AL value
65	Ve			9.44	cm^3	Core volume
66	HT (EE/PQ/EQ/RM/POT) / ID (toroid)			5.12	mm	Core height/Height of window; ID if toroid
67	MLT			67.1	mm	Mean length per turn
68	BW			8.98	mm	Bobbin width
69	LG			0.47	mm	Gap length (Ferrite cores only)
70	**Flux and MMF calculations**					
71	BP_TARGET (ferrite only)			3900	Gauss	Target flux density at worst case: IOCP and maximum tolerance inductance (ferrite only) - drives turns and gap
72	B_OCP (or BP)			3793	Gauss	Target flux density at worst case: IOCP and maximum tolerance inductance (ferrite only) - drives turns and gap
73	B_MAX			2867	Gauss	Peak flux density at AC peak, VACMIN and Full Power Load, nominal inductance,minimum IOCP
74	μ_TARGET (powder only)			N/A	%	target μ at peak current divided by μ at zero current, at VACMIN, full load (powder only) - drives auto core selection
75	μ_MAX (powder only)			N/A	%	actual μ at peak current divided by μ at zero current, at VACMIN, full load (powder only)
76	μ_OCP (powder only)			N/A	%	μ at IOCPtyp divided by μ at zero current
77	I_TEST			7.2	A	Current at which B_TEST and H_TEST are calculated, for checking flux at a current other than IOCP or IP; if blank IOCP_typ is used.
78	B_TEST			3641	Gauss	Flux density at I_TEST and maximum tolerance inductance
79	μ_TEST (powder only)			N/A	%	μ at IOCP divided by μ at zero current, at IOCPtyp
80	**Wire**					
81	TURNS			22		Inductor turns. To adjust turns, change BP_TARGET (ferrite) or μ_TARGET (powder)
82	ILRMS			2.99	A	Inductor RMS current
83	Wire type	**Litz**		Litz		Select between "Litz" or "Magnet" for double coated magnet wire
84	AWG	40	Info	40	AWG	Selected wire has increased losses due to skin and proximity effects. Consider using multiple strands of thinner wires, Litz wire, or decreasing the number of layers
85	Filar			154		Inductor wire number of parallel strands. Leave blank to auto-calc for Litz
86	OD (per strand)			0.079	mm	Outer diameter of single strand of wire
87	OD bundle (Litz only)			1.37	mm	Will be different than OD if Litz
88	DCR			0.044	ohm	Choke DC Resistance
89	P AC Resistance Ratio			1.60		Ratio of total copper loss, including HF AC, to the DC component of the loss
90	J		Info	3.99	A/mm^2	Current density is low. If copper loss is low, you can use thinner wire or fewer strands
91	FIT			90	%	Percentage fill of winding window for EE/PQ core. Full window approx. 90%
92	Layers			3.53		Estimated layers in winding
93	**Loss calculations**					
94	BAC-p-p			2298	Gauss	Core AC peak-peak flux excursion at VACMIN, peak of sine wave
95	LPFC_CORE_LOSS			0.843	W	Estimated Inductor core Loss
96	LPFC_COPPER_LOSS			0.631	W	Estimated Inductor copper losses
97	LPFC_TOTAL_LOSS			1.473	W	Total estimated Inductor Losses
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99						
100	**External PFC Diode**					
101	PFC Diode Part Number	**Auto**		LXA08T600		PFC Diode Part Number
102	Type / Part Number			Qspeed		PFC Diode Type / Part Number
103	Manufacturer			PI		Diode Manufacturer
104	VRRM			600.0	V	Diode rated reverse voltage
105	IF			8.00	A	Diode rated forward current
106	Qrr			82.0	nC	Qrr at High Temperature
107	VF			2.10	V	Diode rated forward voltage drop
108	PCOND_DIODE			2.697	W	Estimated Diode conduction losses
109	PSW_DIODE			0.245	W	Estimated Diode switching losses
110	P_DIODE			2.942	W	Total estimated Diode losses
111	TJ Max			100.0	deg C	Maximum steady-state operating temperature
112	Rth-JS			1.50	degC/W	Maximum thermal resistance (Junction to heatsink)
113	HEATSINK Theta-CA			18.39	degC/W	Maximum thermal resistance of heatsink
114	IFSM			60.0	A	Non-repetitive peak surge current rating. Consider larger size diode if inrush or thermal limited.
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116						
117	**Output Capacitor**					
118	COUT	**270**		270	uF	Minimum value of Output capacitance
119	VO_RIPPLE_EXPECTED			15.0	V	Expected ripple voltage on Output with selected Output capacitor
120	T_HOLDUP_EXPECTED			15.5	ms	Expected holdup time with selected Output capacitor
121	ESR_LF			0.55	ohms	Low Frequency Capacitor ESR
122	ESR_HF			0.25	ohms	High Frequency Capacitor ESR
123	IC_RMS_LF			0.88	A	Low Frequency Capacitor RMS current
124	IC_RMS_HF			1.58	A	High Frequency Capacitor RMS current
125	CO_LF_LOSS			0.425	W	Estimated Low Frequency ESR loss in Output capacitor
126	CO_HF_LOSS			0.622	W	Estimated High frequency ESR loss in Output capacitor
127	Total CO LOSS			1.047	W	Total estimated losses in Output Capacitor

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129						
130	**Input Bridge (BR1) and Fuse (F1)**					
131	I^2t Rating			18.96	A^2*s	Minimum I^2t rating for fuse
132	Fuse Current rating			3.81	A	Minimum Current rating of fuse
133	VF			0.90	V	Input bridge Diode forward Diode drop
134	IAVG			2.37	A	Input average current at VBROWNOUT.
135	PIV_INPUT BRIDGE			375	V	Peak inverse voltage of input bridge
136	PCOND_LOSS_BRIDGE			4.297	W	Estimated Bridge Diode conduction loss
137	CIN			0.82	uF	Input capacitor. Use metallized polypropylene or film foil type with high ripple current rating
138	CIN_DF			0.001		Input Capacitor Dissipation Factor (tan Delta)
139	CIN_PLOSS			0.021	W	Input Capacitor Loss
140	RT1			9.37	ohms	Input Thermistor value
141	D_Precharge			1N5407		Recommended precharge Diode
142						
143						
144	**PFS4 small signal components**					
145	C_REF			1.0	uF	REF pin capacitor value
146	RV1			4.0	MOhms	Line sense resistor 1
147	RV2			6.0	MOhms	Line sense resistor 2
148	RV3			6.0	MOhms	Typical value of the lower resistor connected to the V-PIN. Use 1% resistor only!
149	RV4			161.6	kOhms	Description pending, could be modified based on feedback chain R1-R4
150	C_V			0.495	nF	V pin decoupling capacitor (RV4 and C_V should have a time constant of 80us) Pick the closest available capacitance.
151	C_VCC			1.0	uF	Supply decoupling capacitor
152	C_C			100	nF	Feedback C pin decoupling capacitor
153	Power good Vo lower threshold VPG(L)			333	V	Vo lower threshold voltage at which power good signal will trigger
154	PGT set resistor			333.0	kohm	Power good threshold setting resistor
155						
156						
157	**Feedback Components**					
158	RFB_1			4.00	Mohms	Feedback network, first high voltage divider resistor
159	RFB_2			6.00	Mohms	Feedback network, second high voltage divider resistor
160	RFB_3			6.00	Mohms	Feedback network, third high voltage divider resistor
161	RFB_4			161.6	kohms	Feedback network, lower divider resistor
162	CFB_1			0.495	nF	Feedback network, loop speedup capacitor. (R4 and C1 should have a time constant of 80us) Pick the closest available capacitance.
163	RFB_5			22.1	kohms	Feedback network: zero setting resistor
164	CFB_2			1000	nF	Feedback component- noise suppression capacitor
165						
166						
167	**Loss Budget (Estimated at VACMIN)**					
168	PFS Losses			3.833	W	Total estimated losses in PFS
169	Boost diode Losses			2.942	W	Total estimated losses in Output Diode
170	Input Bridge losses			4.297	W	Total estimated losses in input bridge module
171	Input Capacitor Losses			0.021	W	Total estimated losses in input capacitor
172	Inductor losses			1.473	W	Total estimated losses in PFC choke
173	Output Capacitor Loss			1.047	W	Total estimated losses in Output capacitor
174	EMI choke copper loss			0.703	W	Total estimated losses in EMI choke copper
175	Total losses			14.316	W	Overall loss estimate
176	Efficiency			0.97		Estimated efficiency at VACMIN, full load.
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178						
179	**CAPZero component selection recommendation**					
180	CAPZero Device			CAP200DG		(Optional) Recommended CAPZero device to discharge X-Capacitor with time constant of 1 second
181	Total Series Resistance (Rcapzero1+Rcapzero2)			0.730	MOhms	Maximum Total Series resistor value to discharge X-Capacitors
182						
183						
184	**EMI filter components recommendation**					
185	CX2			470	nF	X capacitor after differencial mode choke and before bridge, ratio with Po
186	LDM_calc			197	uH	Estimated minimum differential inductance to avoid <10kHz resonance in input current
187	CX1			470	nF	X capacitor before common mode choke, ratio with Po
188	LCM			10.0	mH	typical common mode choke value
189	LCM_leakage			30	uH	estimated leakage inductance of CM choke, typical from 30~60uH
190	CY1 (and CY2)			220	pF	typical Y capacitance for common mode noise suppression
191	LDM_Actual			167	uH	cal_LDM minus LCM_leakage, utilizing CM leakage inductance as DM choke.
192	DCR_LCM			0.070	Ohms	Total DCR of CM choke for estimating copper loss
193	DCR_LDM			0.030	Ohms	Total DCR of DM choke(or CM #2) for estimating copper loss
194						
195	**Note: CX2 can be placed between CM chock and DM choke depending on EMI design requirement.**					
196						