1	HiperTFS2_Two-switch_Forward_012919; Rev.2.2; Copyright Power Integrations 2019	INPUT	INFO	OUTPUT	UNIT	Two-switch Forward Transformer Design Spreadsheet
2	**Hiper-TFS MAIN OUTPUT (TWO-SWITCH FORWARD STAGE)**					
3	**OUTPUT VOLTAGE AND CURRENT**					**Design Title**
4	VMAIN	5.00		5.00	V	Main output voltage
5	IMAIN	70.00		70.00	A	Main output current
6	VOUT2			0.00	V	Output2 voltage - enter zero or leave blank if none
7	IOUT2			0.00	A	Output2 current - enter zero or leave blank if none
8	**Post Regulated Output**					
9	Post Regulator	**NONE**		NONE		Select post regulator from Mag-Amp, Buck, or NONE
10	V_SOURCE	**NONE**		NONE	V	Select source of input voltage for post regulator. Enter None if Post regulator not used.
11	VOUT3			0.00	V	Enter post regulator output voltage. Enter zero or leave blank if none
12	IOUT3			0.00	A	Enter post regulator output current. Enter zero or leave blank if none
13	n_PR			1.00		Enter post regulator efficiency (Buck only)
14	**Coupled Inductor (Low Power) derived output**					
15	VOUT4			0.00	V	Output choke derived (low power) output voltage (typically -12 V)
16	IOUT4			0.00	A	Output choke derived (low power) output current
17	**System Power**					
18	POUT(Main)			350.0	W	Total output power (Main converter)
19	POUT_PEAK(Main)			350.0	W	Peak Output power (Main converter). If there is no peak power requirement enter value equal to continuous power
20	POUT(Standby)			12.3	W	Continuous output power from Standby power supply
21	POUT_PEAK(Standby)			12.3	W	Peak output power from Standby section below
22	**POUT(System Total)**			**362.3**	**W**	**Total system continuous output power**
23	POUT_PEAK(System Total)			362.3	W	Total system peak output power
24						
25						
26	**INPUT VOLTAGE AND UV/OV**					
27	CIN_MIN			310	uF	Minimum Input Capacitance to meet holdup time. To increase CMIN, increase T_HOLDUP
28	T_HOLDUP			20.0	ms	Holdup time
29	CIN_ACTUAL	**270**	Info	270	uF	The selected capacitor will not meet the specified holdup time
30	CIN_ESR			0.27	Ω	Bulk capacitor ESR
31	IRMS_CIN			1.32	A	RMS current through bulk capacitor
32	PLOSS_CIN			0.47	W	Bulk capacitor ESR losses
33	VMIN			300	V	Minimum input voltage to guarantee output regulation at full load
34	VNOM			380	V	Nominal input voltage
35	VMAX			420	V	Maximum DC input voltage
36	RR			3.92	MΩ	R pin resistor
37	RL			3.92	MΩ	Line Sense resistor value (L-pin) - goal seek (VUV OFF) for std 1% resistor series
38	**UV and OV thresholds**					
45	**Clamp Section**					
46	**Clamp Selection**	**CLAMP TO RAIL**				Select either "CLAMP TO RAIL" (default) or "CLAMP TO GND"
47	VCLAMP			150	V	Asymmetric Clamp Zener Voltage
48	VDSOP			570	V	Estimated Maximum Hiper-TFS Drain voltage (at VOVOFF_MAX)
49						
50						
51	**DUTY CYCLE VALUES (REGULATION)**					
52	DVMIN			0.58		Duty cycle at minimum DC input voltage
53	DVNOM_GOAL			0.45		Target duty cycle at nominal input voltage (VNOM)

54	DVNOM			0.45		Duty cycle at nominal DC input voltage
55	DVMAX			0.41		Duty cycle at maximum DC input voltage
56	DOVOFF MIN			0.37		Duty cycle at over-voltage DC input voltage (DOVOFF_MIN)
57	**Maximum Duty Cycle values**					
58	DMAX_UVOFF_MIN			0.65		Max duty cycle clamp at VUVOFF_MIN
59	DMAX_VMIN			0.60		Max duty clamp cycle at VMIN
60	DMAX_VNOM			0.56		Max duty clamp cycle at VNOM
61	DMAX_VMAX			0.51		Max duty clamp cycle at VMAX
62	DMAX_OVOFFMIN			0.46		Max duty clamp cycle at VOVOFF_MAX
63						
64						
65	**DEVICE VARIABLES**					
66	**Device**	**Auto**		TFS7708		Selected HiperTFS device
67	Select Frequency mode	**66**		66	kHz	Select Frequency mode.
68	ILIMIT_MIN			4.61	A	Device current limit (Minimum)
69	ILIMIT_TYP			4.96	A	Device current limit (Typical)
70	ILIMIT_MAX			5.31	A	Device current limit (Maximum)
71	fSMIN			62,000	Hz	Device switching frequency (Minimum)
72	fS			66,000	Hz	Device switching frequency (Typical)
73	fSMAX			70,000	Hz	Device switching frequency (Maximum)
74	KI	1.0		1.0		Select Current limit factor (KI=1.0 for default ILIMIT, or select KI=0.9 or KI=0.7)
75	R(FB)			232	kΩ	Feedback (FB) pin resistor
76	ILIMIT SELECT			4.61	A	Selected current limit
77	RDS(ON)			2.37	Ω	Sum of Rds(on) of high and low-side MOSFETs at 100°C
78	VDS			4.97	V	HiperTFS full-load average on-state Drain to Source Voltage (sum for both MOSFETs)
79	**Main MOSFET losses**					
90						
91	**MAIN TRANSFORMER**					
92	**Transformer core selection**					
93	**Core Type**	**ETD39**		ETD39		Selected core type
94	AE			1.25	cm^2	Core effective cross sectional area
95	LE			9.21	cm	Core Effective Path Length
96	AL			3150	nH/T^2	Ungapped Core Effective Inductance
97	BW			25.70	mm	Bobbin Physical Winding Width
98	B_HT			6.90	mm	Height of bobbin (to calculate fit)
99	B_WA			1.77	cm^2	Bobbin Winding area
100	M			4.50	mm	Bobbin safety margin tape width (2 * M = Total Margin)
101						
102	**Primary Inductance**					
103	LMAG_MAX			40.21	mH	Max LMAG to hit min zero-load resonant frequency, calculated from C_PRI. Do not exceed.
104	LMAG			10.19	mH	Estimated magnetizing inductance of transformer; may be lower than LMAG_MAX due to minimum gap size of 0.05 mm. Enter actual value.
105	GAP			0.00	mm	gap calculatedfrom LMAG
106	FRES_SYS			119	kHz	Estimated total XFMR + system resonant frequency
107	C_SYS			175	pF	Estimated total XFMR + Sys parasitic cap reflected to primary, calc'd from LMAG and FRES
108	**Diode Vf Selection**					
114	**Turns**					
115	NMAIN			2	turns	Main rounded turns
116	NS2			N/A	turns	2nd output number of turns
117	VOUT2 ACTUAL			0.0	V	Approximate Output2 voltage with NS2 = 0 turns (AC stacked secondary). VDMAIN and VDOUT2 affect this.
118	NP			58	turns	Primary rounded turns. NMAIN and DVNOM_GOAL affect this.

119	HI SIDE BIAS WINDING (optional)	**No**		No		Can be used to eliminate pulse skipping at light load 132 kHz when zero transformer gap; better efficiency than adding gap
120	VBIAS				V	DC bias voltage from main transformer optional aux winding
121	NBIAS				turns	VBias rounded turns
122	VBIAS_ACTUAL				V	Vbias not used
123	**Flux calculations**					
124	BM_MAX			2200	Gauss	Peak positive flux density at nominal switching frequency
125	BM PK-PK			3333	Gauss	Peak-peak flux density at nominal conditions. Used to calculate core losses
126	BP_MAX			2953	Gauss	Max transient positive flux density at Vmax (limited by DVMAX clamp)
127	BP PK-PK			4474	Gauss	Max transient peak-peak flux density at Vmax (limited by DVMAX clamp)
128						
129						
130	**TRANSFORMER LOSSES AND FIT ESTIMATE**					
131	**Core loss**					
132	Core material	**PC95**		PC95		Core material
133	core_loss_multiplier			23.97		Core Loss multiplier
134	f_coeff			1.56		Core Loss Frequency co-efficient
135	BAC_coeff			2.89		Core Loss AC flux density co-efficient
136	specific core loss			92	mW/cc	Core loss per unit volume
137	core volume			11.50	cm^3	Volume of core
138	core loss			1.06	W	Core loss
139	**Primary Winding Fit and losses**					
140	L			3	layers	Transformer primary layers (split primary recommended)
141	OD_PRI			0.63	mm	Primary winding diameter
142	FILAR_PRI			1	strands	Number of parallel strands of wire (primary)
143	MLT_PRI			6.90	cm	Mean length per turn
144	DCR_PRI			282	mΩ	DC resistance of primary winding
145	PCOND_PRI			0.79	W	Conduction loss in primary winding
146	FILL_PRI			10	%	Fill factor (primary only)
147	**Secondary Winding 1 (lower winding when AC stacked)**					
148	**VOUT**			5.0	V	Specified voltage for this winding
149	NS1			2.0	turns	Number of turns
150	IRMS_SEC1			59.3	A	RMS current through winding
151	Foil/Wire	**FOIL**		FOIL	foil/wire	Select FOIL or WIRE for winding
152	OD/Thickness			0.13	mm	Wire diameter or Foil thickness
153	FILAR_SEC1			N/A	strands	Number of parallel strands (wire selection only)
154	SEC1_WIDTH			18.00	mm	Foil Width (Applicable if FOIL winding used)
155	SEC1_MLT			6.90	cm	Mean length per turn
156	DCR_SEC1			1.36	mΩ	DC resistance of secondary winding
157	PCOND_SEC1			4.77	W	Conduction loss in secondary winding
158	FILL_SEC1			3	%	Fill factor (secondary 1 only)
159	**Secondary Winding 2 (upper winding when AC stacked)**					
160	**VOUT**			0.0	V	Specified voltage for this winding
161	NS2			0.0	turns	Number of turns
162	IRMS_SEC2			0.0	A	RMS current through winding
163	Foil/Wire	**FOIL**		FOIL	foil/wire	Select FOIL or WIRE for winding
164	OD/Thickness			0.13	mm	Wire diameter or Foil thickness
165	FILAR_SEC2			N/A	strands	Number of parallel strands (wire selection only)
166	SEC2_WIDTH			18.00	mm	Foil Width (Applicable if FOIL winding used)
167	SEC2_MLT			6.90	cm	Mean length per turn
168	DCR_SEC2			0.00	mΩ	DC resistance of secondary winding
169	PCOND_SEC2			0.00	W	Conduction loss in secondary winding
170	FILL_SEC2			0	%	Fill factor (secondary 1 only)
171	**Fill Factor and losses of main transformer**					
172	FILL_TOTAL			13	%	Total transformer fill factor
173	TOTAL_CU_LOSS			5.56	W	Total copper losses in transformer
174	TOTAL_CORE_LOSS			1.06	W	Total core losses in transformer

175	TOTAL_TRF_LOSS			6.62	W	Total losses in transformer
176						
177						
178	**CURRENT WAVESHAPE PARAMETERS**					
179	IP			3.29	A	Peak primary current at Full Load, VNOM
180	IP_PEAK			3.29	A	Peak primary current at Peak Load and VNOM
181	IPRMS(NOM)			1.67	A	Primary RMS current at Full Load, VNOM
182	IMAG			0.25	A	Peak magnetizing current at VMIN
183						
184						
185	**OUTPUT INDUCTOR**					
186	KDI_ACTUAL		Warning	0.52		!!! Warning. KDI_ACTUAL too high. Increase NMAIN_INDUCTOR
187	**Turns**					
188	POWDER TURNS MULTIPLIER			3.00		Powder only. Multiplier factor between main number of turns in transformer and inductor (default value = 3 for 66kHz or 4 for 132kHz).
189	NMAIN_INDUCTOR			6.0	turns	Main output inductor number of turns - affected by powder turns multiplier or ferrite Target BM
190	NOUT2_INDUCTOR				turns	Output 2 inductor number of turns
191	NOUT4_INDUCTOR			N/A	turns	Output 4 number of turns (low power)
192	**Inductance and flux**					
193	LMAIN_ACTUAL			1.4	uH	Estimated inductance of main output at full load
194	LOUT_2			0.0	uH	Estimated inductance of auxiliary output at full load
195	BM_IND			2502	gauss	DC component of flux density
196	BAC_IND			683	gauss	AC component of flux density
197						
198	**Core Selection**					
199	**Core Type**	**Auto**		Kool Mu 125u		Select core type
200	**Core**	**Auto**		77324(O.D)=36.7		Output choke core size - verify on bench
201	AE			67.80	mm^2	Core Effective Cross Sectional Area
202	LE			89.80	mm	Core Effective Path Length
203	AL			117	nH/T^2	Ungapped Core Effective Inductance
204	BW			67.54	mm	Bobbin Physical Winding Width
205	VE			6088	mm^3	Volume of core
206	**Powder cores (Sendust and Powdered Iron) Cores**					
207	MUR			125		Relative permeability of material at 0 bias
208	H			50.35	AT/cm	Magnetic field strength
209	MUR_RATIO			0.32		Ratio of permeability at full load divided by initial permeability
210	LMAIN_0bias			4.2	uH	Estimated inductance of main output with 0 DC bias
211						
212	**Ferrite Cores**					
213	LG			N/A	mm	Gap length of inductor cores
214	Target BM			N/A	Gauss	Target maximum flux density
215						
216	**Choke wires**					
217	Total number of layers			0.69	layers	Total number of layers for chosen toroid
218	IRMS_MAIN			70.07	A	RMS current through main inductor windings
219	IRMS_AUX			0.00	A	RMS current through aux winding
220	AWG_MAIN			13	AWG	Main inductor winding wire gauge
221	OD_MAIN			1.90	mm	Main winding wire gauge outer diameter
222	FILAR_MAIN	4		4	strands	Number of parallel strands for main output
223	RDC_MAIN			0.43	mΩ	Resistance of wire for main inductor winding
224	AC Resistance Ratio (Main)			2.44		Ratio of total resistance (AC + DC) to the DC resistance (using Dowell curves)
225	CMA_MAIN			296	CMA	Cir mils per amp for main inductor winding
226	J_MAIN			24.65	A/mm^2	Current density in main inductor winding

227	AWG_AUX			0	AWG	Aux winding wire gauge
228	OD_AUX			N/A	mm	Auxiliary winding wire gauge outer diameter
229	FILAR_AUX			2	strands	Number of parallel strands for aux output
230	RDC_AUX			0.00	mΩ	Resistance of wire for aux inductor winding
231	AC Resistance Ratio (Aux)			0.00		Ratio of total resistance (AC + DC) to the DC resistance (using Dowell curves)
232	CMA_AUX		Info	0	CMA	!!! Info. Low CMA may cause overheating. Verify acceptable temperature rise
233	J_AUX			0.00	A/mm^2	Current density in auxiliary winding
234						
235	**Choke Losses**					
236	PCOPPER_MAIN			2.14	W	Copper loss in main inductor winding
237	PCOPPER_AUX			0.00	W	Copper loss in aux inductor windings
238	PCORE			1.29	W	Total core loss
239	PTOTAL_IND			3.42	W	Total losses in output choke
240						
241						
242	**SECONDARY OUTPUT DIODE PARAMETERS**					
243	**Main Output**					
244	ISFWDRMS			59.35	A	Full load forward diode RMS current at nominal input voltage
245	ISCATCHRMS			65.29	A	Freewheeling diode RMS current at nominal input voltage
246	IDAVMAINF			40.26	A	Worst case average current of forward rectifier at VMIN (single device rating)
247	IDAVMAINC			41.38	A	Worst case average current of freewheeling diode at VMAX(single device rating)
248	IRMSMAIN			10.53	A	Maximum RMS current, Main output capacitor
249	PD_LOSS_MAIN			35.00	W	Conduction loss of forward diode
250						
251	**Second Output**					
252	ISFWD2RMS			0.00	A	Full load forward diode RMS current at nominal input voltage
253	ISCATCH2RMS			0.00	A	Freewheeling diode RMS current at nominal input voltage
254	IDAVOUT2F			0.00	A	Worst case average current of forward rectifier at VMIN (single device rating)
255	IDAVOUT2C			0.00	A	Worst case average current of freewheeling diode at VMAX(single device rating)
256	IRMSOUT2			0.00	A	Maximum RMS current, Main output capacitor
257	PD_LOSS_OUT2			0.00	W	Conduction loss of forward diode
258						
259	**Diode Derating**					
260	VPIVMAINF	1.00		19.66	V	Main Forward Diode peak-inverse voltage (at VDSOP), including derating
261	VPIVMAINC	1.00		14.48	V	Main Catch Diode peak-inverse voltage (at VOVOFF_MAX), including derating
262	VPIVOUT2F	1.00		0.00	V	Output2 Forward Diode peak-inverse voltage (at VDSOP), including derating
263	VPIVOUT2C	1.00		0.00	V	Output2 Catch Diode peak-inverse voltage (at VOVOFF_MAX), including derating
264	VPIVB	1.00		N/A	V	Bias output rectifier peak-inverse voltage (at VDSOP), including derating
265						
266						
267	**Hiper-TFS STANDBY SECTION (FLYBACK STAGE)**					
268	**ENTER APPLICATION VARIABLES**					
269	VACMIN			85	V	Minimum AC Input Voltage
270	VACMAX			265	V	Maximum AC Input Voltage
271	fL			50	Hz	AC Mains Frequency
272	VO_SB	12.0		12.0	V	Output Voltage (at continuous power)

273	IO_SB	1.00		1.00	A	Power Supply Output Current (corresponding to peak power)
274	IO_SB_PK			1.00	A	Peak output current
275	POUT_SB			12.00	W	Continuous Output Power
276	POUT_SB_TOTAL			12.32	W	Total Standby power (Includes Bias winding power)
277	POUT_SB_PK			12.32	W	Peak Standby Output Power
278	n	0.85		0.85		Efficiency Estimate at output terminals. Under 0.7 if no better data available
279	Z			0.50		Z Factor. Ratio of secondary side losses to the total losses in the power supply. Use 0.5 if no better data available
280	tC			3.00	ms	Bridge Rectifier Conduction Time Estimate
281						
282						
283	**ENTER Hiper-TFS STANDBY VARIABLES**					
284	Select Current Limit	**INC**		Increased Current Limit		Enter "LOW" for low current limit, "RED" for reduced current limit (sealed adapters), "STD" for standard current limit or "INC" for increased current limit (peak or higher power applications)
285	ILIM_MIN			0.70	A	Minimum Current Limit
286	ILIM_TYP			0.75	A	Typical Current Limit
287	ILIM_MAX			0.80	A	Maximum Current Limit
288	R(EN)			107	kΩ	Enable pin resistor
289	fSmin			124,000	Hz	Minimum Device Switching Frequency
290	I^2fmin			66.8	A^2kHz	I^2f (product of current limit squared and frequency is trimmed for tighter tolerance)
291	VOR			100	V	Reflected Output Voltage (VOR < 135 V Recommended)
292	VDS			10.0	V	Hiper-TFS Standby On State Drain to Source Voltage
293	VD_SB			0.70	V	Output Winding Diode Forward Voltage Drop
294	KP			1.55		Ripple to Peak Current Ratio (KP < 6)
295	KP_TRANSIENT			1.22		Transient Ripple to Peak Current Ratio. Ensure KP_TRANSIENT > 0.25
296						
297						
298	**ENTER BIAS WINDING VARIABLES**					
299	VB			16.0	V	Bias Winding Voltage
300	IB			20.0	mA	Bias winding Load current
301	PB			0.32	W	Bias winding power
302	VDB			0.70	V	Bias Winding Diode Forward Voltage Drop
303	NB			5.3	turns	Bias Winding Number of Turns
304	VZOV			22	V	Over Voltage Protection zener diode voltage.
305						
306						
307	**UVLO VARIABLES**					
308	RLS			3.92	MΩ	Line sense resistor (from Main converter section)
309	V_UV_ACTUAL			100	V	Typical DC start-up voltage
310						
311						
312	**ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES**					
313	**Core Type**	**EE25**		**EE25**		Enter Transformer Core
314	AE			0.40	cm^2	Core Effective Cross Sectional Area
315	LE			7.34	cm	Core Effective Path Length
316	AL			1420	nH/T^2	Ungapped Core Effective Inductance
317	BW			10.20	mm	Bobbin Physical Winding Width
318	M			0.00	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
319	L	2		2		Number of Primary Layers
320	NS_SB			4		Number of Secondary Turns
321						
322						
323	**DC INPUT VOLTAGE PARAMETERS**					
324	VMIN_SB			117	V	Minimum DC Input Voltage
325	VMAX_SB			375	V	Maximum DC Input Voltage

326						
327						
328	**CURRENT WAVEFORM SHAPE PARAMETERS**					
329	DMAX_SB			0.35		Duty Ratio at full load, minimum primary inductance and minimum input voltage
330	IAVG			0.13	A	Average Primary Current
331	IP_SB			0.70	A	Minimum Peak Primary Current
332	IR_SB			0.70	A	Primary Ripple Current
333	IRMS_SB			0.28	A	Primary RMS Current
334						
335						
336	**TRANSFORMER PRIMARY DESIGN PARAMETERS**					
337	LP_SB			441	uH	Typical Primary Inductance. +/- 10% to ensure a minimum primary inductance of 401 uH
338	LP_TOLERANCE			10.0	%	Primary inductance tolerance
339	NP_SB			31	turns	Primary Winding Number of Turns
340	ALG			445	nH/T^2	Gapped Core Effective Inductance
341	BM			2784	Gauss	Maximum Operating Flux Density, BM<3000 is recommended
342	BAC			1392	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
343	ur			2053		Relative Permeability of Ungapped Core
344	LG		Warning	0.08	mm	!!! INCREASE GAP>>0.1. Increase NS, increase VOR,bigger Core
345	BWE			20.4	mm	Effective Bobbin Width
346	OD			0.65	mm	Maximum Primary Wire Diameter including insulation
347	INS			0.07	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
348	DIA			0.58	mm	Bare conductor diameter
349	AWG			24	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
350	CM			406	Cmils	Bare conductor effective area in circular mils
351	CMA		Info	1474	Cmils/Amp	CAN DECREASE CMA < 500 (decrease L (primary layers), increase NS,use smaller Core)
352						
353						
354	**TRANSFORMER SECONDARY DESIGN PARAMETERS**					
355	**Lumped parameters**					
356	ISP			5.5	A	Peak Secondary Current
357	ISRMS			2.35	A	Secondary RMS Current
358	IRIPPLE			2.13	A	Output Capacitor RMS Ripple Current
359	CMS			470	Cmils	Secondary Bare Conductor minimum circular mils
360	AWGS			23	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
361						
362						
363	**VOLTAGE STRESS PARAMETERS**					
364	VDRAIN			605	V	Maximum Drain Voltage Estimate (Assumes 20% zener clamp tolerance and an additional 10% temperature tolerance)
365	PIVS			60	V	Output Rectifier Maximum Peak Inverse Voltage
366						
367						
368	**Forward DC-DC System efficiency**					
369	P_MOSFET_MAIN_TOTAL			7.62	W	HiperTFS losses
370	P_XFMR_LOSS			6.6	W	Main transformer losses
371	P_MAIN_OUT_DIODE			35.0	W	Output diode losses
372	P_CIN_ESR			0.47	W	Bulk capacitor ESR losses
373	P_IND_MAIN			3.4	W	Output choke losses
374	OTHER_LOSSES			2.45	W	Other losses (includes PCB traces, clamp loss, magamp loss etc.)
375						
376	EFFICIENCY_STDBY			85.0%		Estimated efficiency of flyback power supply
377	EFFICIENCY_MAIN			86.3%		Estimated Forward efficiency
378	EFFICIENCY_SYSTEM			86.2%		Estimated System efficiency (forward + standby)
379	**Other Losses**					

382	**Detailed Mosfet Loss Information**					
390						