Pulsiv OSMIUM 100W Power Supply Reference Design — **No:** *PSV-RDAD-100FB*

FEATURES:

- **Input Voltage:** 85 – 264VAC
- **Output Voltage:** 48VDC
- **Output Power:** 100W (150W peak)
- **Average Efficiency:** 88%
- **Peak Efficiency:** 91%
- **No-Load Power:** 110mW
- **Inrush Current:** Eliminated
- **Harmonic Current:** Meets IEC61000-3-2 Class A

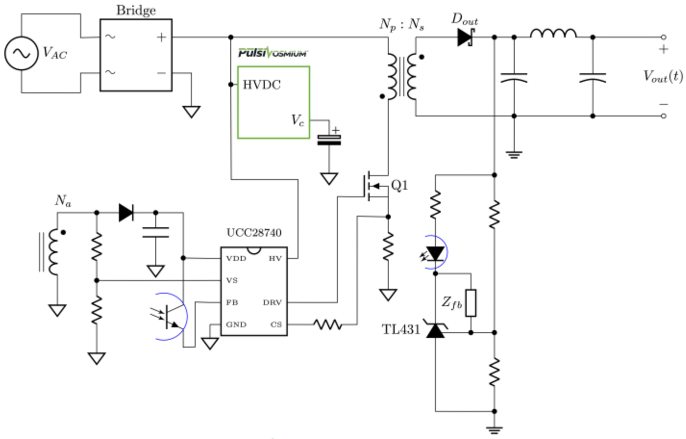

Fig.1 – Functional Schematic

APPLICATIONS:

- Battery Chargers & USB Compliant Power Adapters
- LED Lighting
- White Goods
- Televisions
- Industrial

OVERVIEW

The PSV-RDAD-100FB reference design combines the Pulsiv OSMIUM PSV-AD-250 microcontroller with a flyback DC-DC converter based on the Texas Instruments UCC28740. It delivers a compact, efficient & low cost solution for a broad range of 48V applications.

This circuit uses commodity system components to deliver results that exceed US DoE Level VI and EU CoC Tier 2 efficiency requirements:

- 79% at 1W *(EU CoC minimum requirement is >52%)*
- 90% at 10W *(EU CoC minimum requirement is >78%)*

The Pulsiv OSMIUM architecture maintains high power-factor and efficiency without using a PFC inductor; avoiding the need to boost the voltage into the power stage. This provides significant efficiency improvements at low power while delivering high efficiency across the full load range.

The Texas Instruments UCC28740 is an isolated-flyback power-supply controller that provides Constant-Voltage (CV) using an optical coupler to improve transient response to large-load steps. Constant-Current (CC) regulation is accomplished through primary-side regulation techniques. It processes information from opto-coupled feedback and an auxiliary flyback winding for precise high-performance control of output voltage and current.

FURTHER OPTIMIZATION

This reference design has been optimized for cost sensitive applications. Where efficiency or size are a priority, engineers can use alternative DC-DC topologies or replace system components as required:

- Active Clamp Flyback will improve average and peak efficiency by 1–2%
- Use of a synchronous rectifier will improve average and peak efficiency by 0.5%
- Modifications to the transformer (Litz wire and/or alternative cores) can:
  - Improve average and peak efficiency by a further 0.5%
  - Reduce overall volume by 20%
- Use of a half-active bridge will improve average and peak efficiency by 0.3%

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PERFORMANCE SUMMARY

PARAMETER	SYMBOL	MIN	NOM	MAX	UNIT
INPUT					
Input Voltage	V_{INAC}	90	115/230	264	VAC
Frequency	f_{LINE}	45	50/60	65	Hz
No Load Power	P_{NL}	-	-	0.11*	W
Brownout Voltage	V_{IN_UVLO}	-	-	80	VAC
OUTPUT					
Output Voltage	-	-	48	-	V
Output Current	-	-	2.1	3.1	A
Output Power	-	-	100	150	W
Primary-to-Secondary Insulation	-	-	3.0	-	kVrms

***Test Conditions:** $V_{INAC} = 115V$, $I_{OUT} = 0A$

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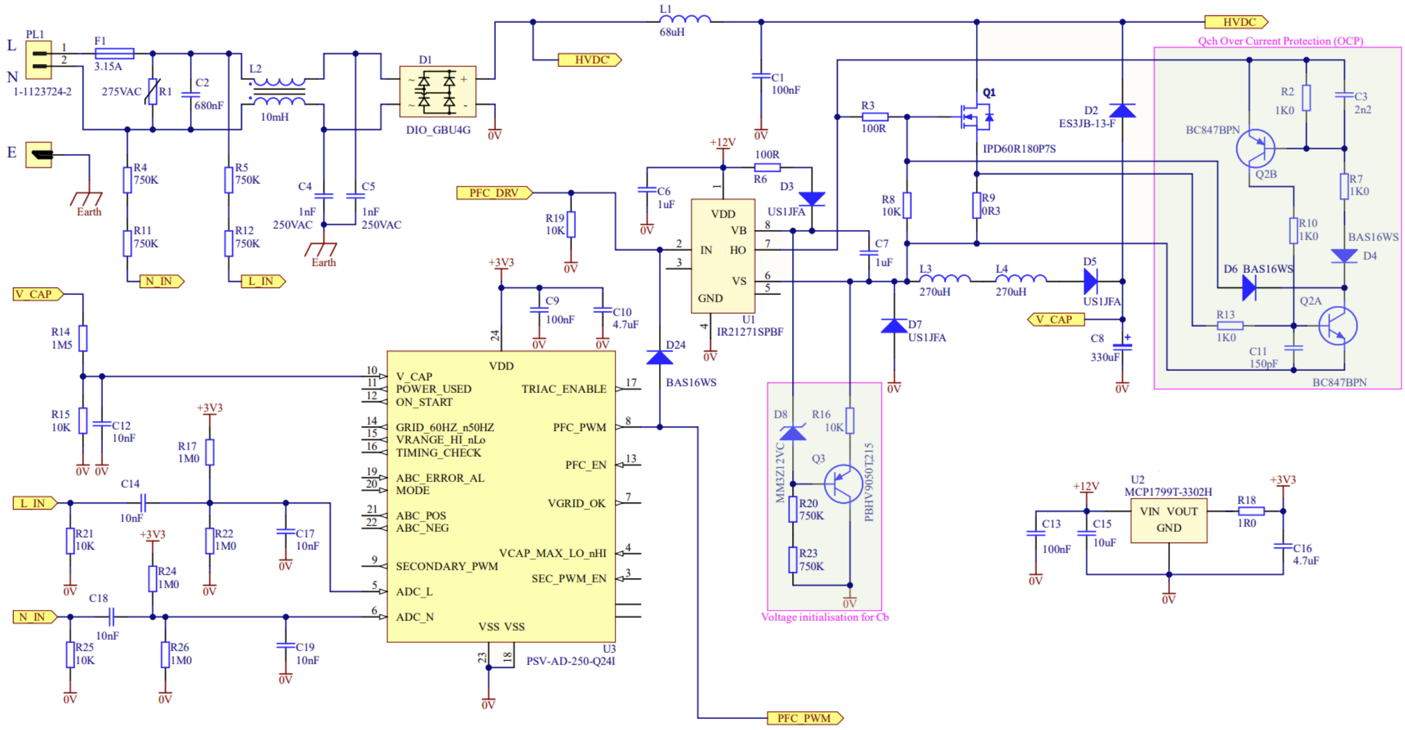
PULSIV OSMIUM FRONT-END SCHEMATIC



Pulsiv has developed a unique way of converting AC to DC by applying patented switching techniques and integrating many system functions into one controller. The PSV-AD-250 controller regulates the charging of capacitor C8 by switching Q1 (current limit set by R9). Inductor L3/L4 is selected to ensure that sufficient charge is generated for the desired load requirements. Discharging C8 is achieved through D2 and controlled by the follow-on DC/DC converter or a load connected to HVDC. Diode D5 prevents C8 discharging through the body diode of Q1. D7 is a freewheeling diode associated with L3/L4.

The normalised High Voltage DC (HVDC) line and typical normalised capacitor voltage illustrate Pulsiv's unique approach. Energy is stored in C8 when the AC line is at a high voltage and used to supply the load when the AC line voltage is low. The Pulsiv OSMIUM front-end can achieve 0.96 power factor and a peak efficiency of 99.5%.

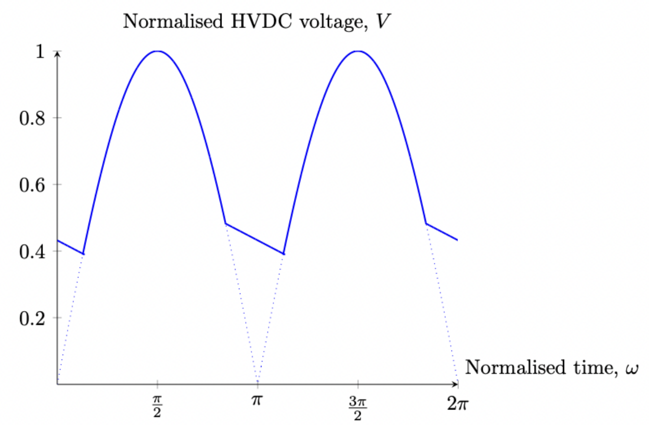


Fig.2 – NORMALISED Cs VOLTAGE

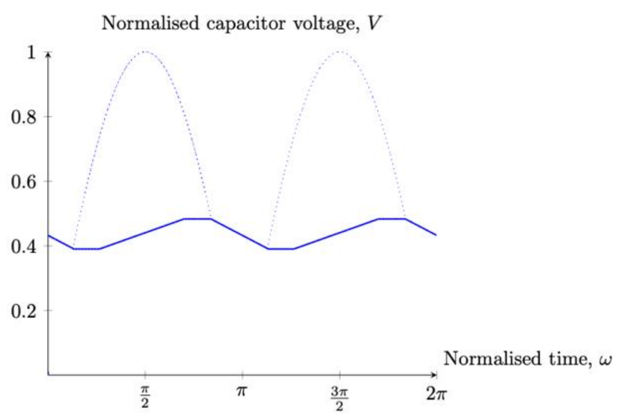


Fig.3 – NORMALISED HVDC VOLTAGE

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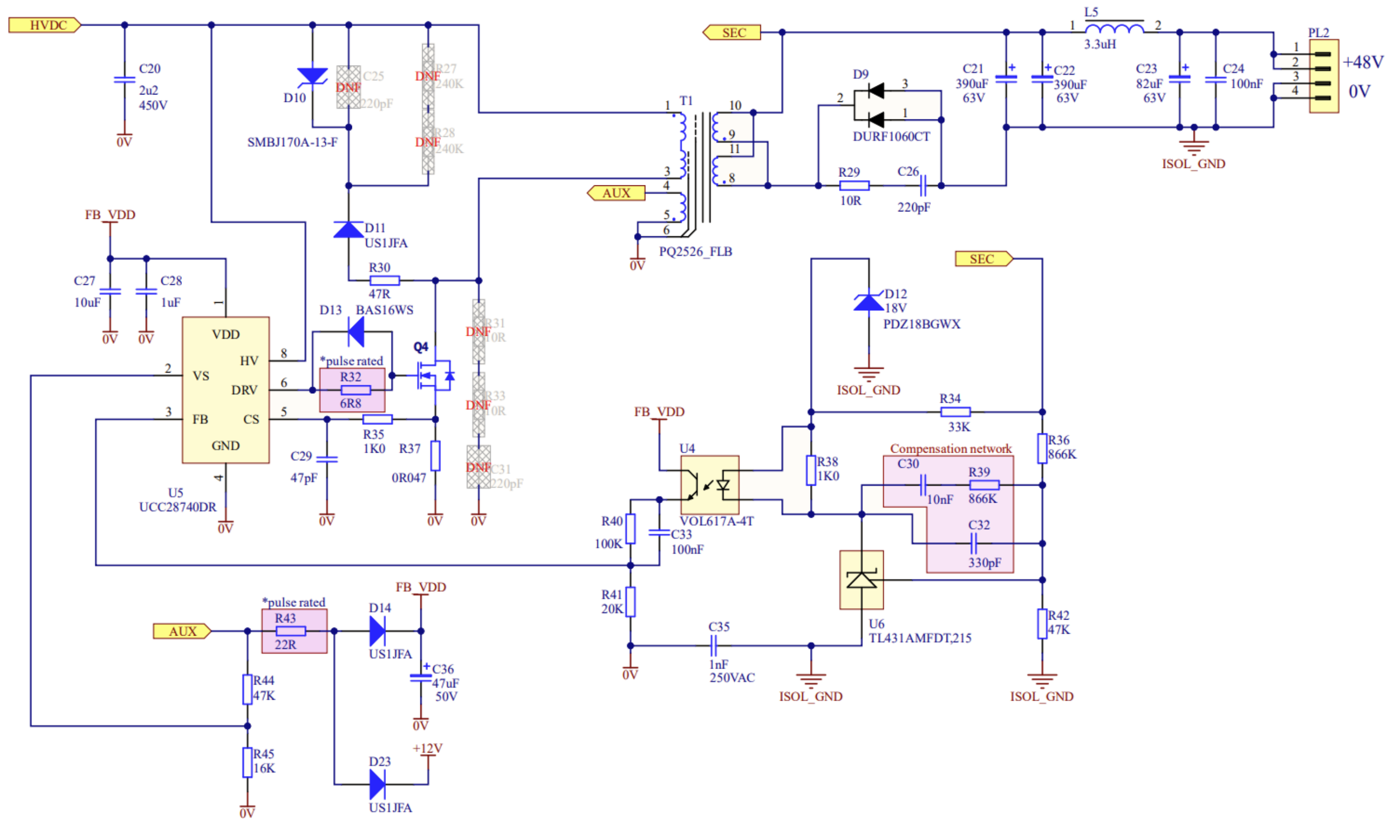
FLYBACK SCHEMATIC



The flyback converter used for this reference design is based on the Texas Instruments UCC28740. Please refer to https://www.ti.com/product/UCC28740 for further information.

The Pulsiv OSMIUM front-end solution is designed to interface with a DC-DC stage that operates from a wide DC voltage; requiring a smaller primary to secondary turns ratio in the transformer design. The benefits of this include:

- Leakage inductance is reduced – lower losses in primary clamp
- Secondary rms current is reduced – lower I^2R losses
- Secondary rectifier voltage requirement is increased – for a 48V design this is immaterial as secondary voltage will usually be too high for Schottky rectifiers in any case
- Lower reflected voltage at the primary – it may be possible to use a lower voltage MOSFET

In most cases this will result in a lower BoM cost, lower complexity and improved low-power efficiency.

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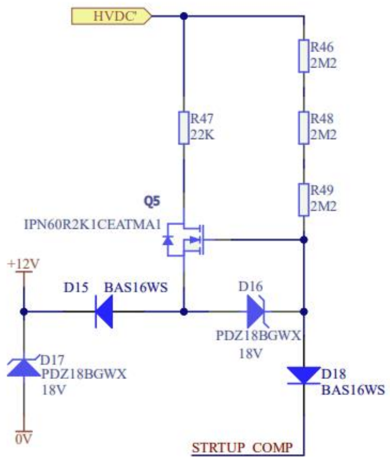
PULSIV OSMIUM START-UP CIRCUIT FOR UCC24740

In many designs, a high voltage start-up circuit in the flyback controller stage can be used to power-up the Pulsiv OSMIUM control circuit. In the case of the UCC24740 from Texas Instruments, there is not enough current available from the device's internal HV start-up circuit when the flyback is in standby mode. The HVDC start-up circuit around Q5 and R47 provide up to 4mA (at >80VAC in) to start the Pulsiv OSMIUM circuitry. Once the PFC capacitor C8 is charged to 73V by oscillator Q9/Q10, comparator circuit (Q6, Q7 and Q8) will turn off the HVDC start-up MOSFET Q5. Limiting operation to the pre-charge of C8 maintains a very low standby power.

Pulsiv OSMIUM HVDC Start-up Circuit



PULSIV OSMIUM ADDITIONAL CIRCUIT FOR STEP-LOADS ON START-UP

Unlike conventional boost PFC designs, the Pulsiv OSMIUM circuit must be running to supply full power. If the power supply is always started with little or no load on the output (standby mode) and the load is between approximately 600mW and 5W when first connected, the additional circuitry in this section is not required.

If the power supply is required to supply stepped loads or will start-up into a load >5W, it is necessary for capacitor C8 to be pre-charged on start-up after the grid is applied and kept charged during standby mode (zero output power). This can be achieved by several means including:

1. Providing a minimum load on the output to ensure there is enough energy available from the flyback converter to keep the Pulsiv controller in active mode at all times (approximately 2.4mA at 2.0V to 3.3V). This requires the flyback auxiliary winding to be sized correctly to supply the required load profile.
2. Provision of an auxiliary supply (buck converter) from the mains supply for the control circuitry. The Pulsiv OSMIUM circuits draw less than 8mA which requires a very economical and simple design.
3. The use of an additional free-running oscillator to keep C8 charged during standby and to provide instant power for stepped loads while the Pulsiv OSMIUM controller initialises.

The PSV-RDAD-100FB reference design uses method 3.

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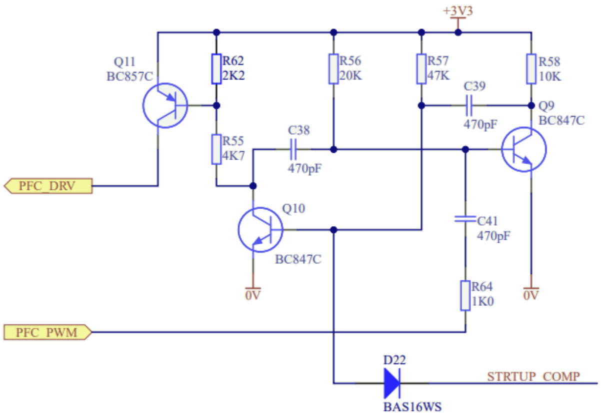
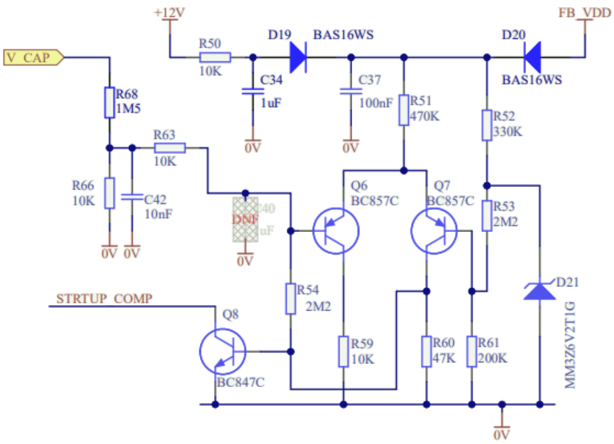
The flyback transformer auxiliary winding is used to power the Pulsiv OSMIUM circuit when the output is under load. Diode D23 (flyback schematic) ensures the Pulsiv OSMIUM circuit current is not drawn from the flyback controller HV start-up circuit. Q9 and Q10 are configured as a free-running oscillator. Signals from the Pulsiv OSMIUM controller and the oscillator are combined via Q11 and D24. At start-up or when a load is applied with the flyback in standby mode, the Pulsiv OSMIUM circuit derives its drive signal from the oscillator. As soon as the +12V supply reaches the UVLO threshold of driver U1 (Pulsiv OSMIUM schematic), C8 charges until the voltage reaches the level sensed by comparator Q9, Q10, Q11. At this point the oscillator output is modulated via D22 thus regulating and maintaining C8 voltage until the PWM signal is available from the Pulsiv OSMIUM controller. C41 and R64 ensure that the oscillator is synchronised with the controller generated PWM signal to prevent deleterious interaction should the oscillator start during transient conditions due to the C8 discharging below the comparator threshold. Depending on the minimum voltage selected for C8, the oscillator and high-voltage supply circuit may be turned on at high power levels during periods when C8 voltage drops.

Pulsiv OSMIUM Low Power Standby Oscillator



Comparator Q6, Q7, Q8 is powered from the UCC24740 HV supply until the auxiliary supply is available. The current draw from this pin should be limited to less than 100µA at 14V to prevent problems with the flyback controller entering standby mode. If a higher current comparator is used, this should be supplied from an alternative source. Approximately 20mW is required to provide 100µA from the rectified mains supply at 230V.

Pulsiv OSMIUM Standby & Start-up Comparator



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REDUCTION OF STANDBY POWER CONSUMPTION

A standby power measurement of 147mW at 230V was made using an experimental set up using the low power standby circuits described. This figure meets the requirements of the current energy efficiency standards for power supplies such as DoE Level VI and Ecodesign 2019/1782. In order to comfortably exceed future standby requirements of 150mW or less it is possible to reduce the standby power further. This can be achieved by replacing flyback 48V secondary regulator U6 with the advanced version ATL431. This will enable a reduction of the bias current. Dissipation in this circuit (R34, U4, U6) is in the region of 70mW. It should be possible to save 35mW by reducing bias current by 50%. Ensure that optocoupler U4 has sufficient gain for the feedback circuit to work correctly. Note also that power available from auxiliary windings will be reduced in standby mode due to the reduced load on the output. This will not affect operation when using the low power standby circuits as auxiliary power is not used by the Pulsiv OSMIUM circuit during standby.

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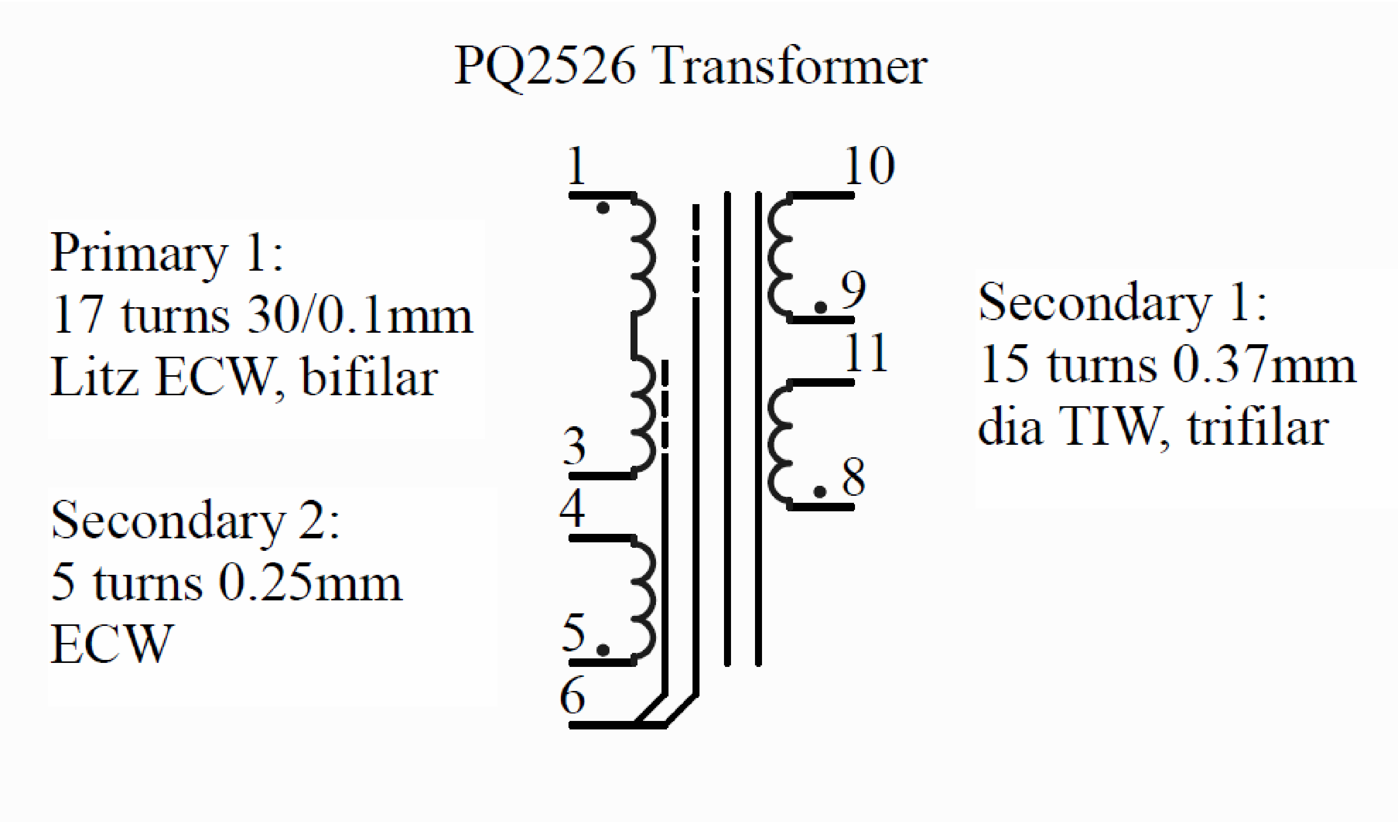
PULSIV OSMIUM FRONT-END BILL OF MATERIALS

Description	Designator	Quantity	MANUF#1	MANUF PN#1
CAP 1812 X7R 100NF 1KV 10% -55/+125	C1	1	KEMET	C1812X104KDRACTU
CAP PTH PP 0.68uF 305VAC 10% -40/+110	C2	1	EPCOS	B32922C3684K189
CAP 0402 X7R 2.2NF 50V 10% -55/+125	C3	1	WALSIN	0402B222K500CT
CAP PTH CER XY 1nF 250VAC 20% -20/+125	C4, C5, C35	3	KEMET	C901U102MYVDBA7317
CAP 0805 X7R 1u 25V 10% -55/+125	C6, C7, C28, C34	4	KEMET	C0805C105K3RECAUTO
CAP ELEC RAD 330uF 160V 20% -25/+105	C8	1	RUBYCON	160TXW330MEFC18X25
CAP 0603 X7R 100nF 50V 10% -55/+125	C9, C33, C37	3	TDK CORPORATION	CGA3E2X7R1H104K080AA
CAP 0805 X7R 4u7 25V 10% -55/+125	C10, C16	2	YAGEO	CC0805KKX7R8BB475
CAP 0402 C0G 150PF 50V 5% -55/+125	C11	1	KEMET	C0402C151J5GACTU
CAP 0402 X7R 10nF 16V 10% -55/+125	C12, C14, C17, C18, C19, C30, C42	7	TAIYO YUDEN	EMF105B7103KVHF
CAP 1206 X7R 100nF 100V 20% -55/+125	C13, C24	2	KYOCERA AVX	12061C104KAT4A
CAP 1206 X7R 10uF 50V 10% -55/+125	C15, C27	2	TDK	CL31B106KBHNNNE
CAP PTH MET RAD 2.2uF 450V 10% -40/+105	C20	1	PANASONIC	ECW-F2W225JA
CAP ELEC RAD 390uF 63V 20% -40/+105	C21, C22	2	RUBYCON	63ZLJ390M10X25
CAP ELEC RAD 82uF 63V 20% -40/+105	C23	1	RUBYCON	63YXG82MEFC8X16
CAP 0805 C0G/NP0 220pF 500V 5% -55/+125	C26	1	YAGEO	CC0805JRNPOBBN221
CAP 0603 C0G 47pF 50V 5% -55/+125	C29	1	YAGEO	CC0603JRNPO9BN470
CAP 0603 X7R 330pF 50V 10% -55/+125	C32	1	YAGEO	CC0603KRX7R9BB331
CAP ELEC RAD 47uF 50V 20% -40/+105	C36	1	RUBYCON	50YXJ47M6.3X11
CAP 0603C0G 470pF 50V 5% -55/+125	C38, C39, C41	3	YAGEO	CC0603JRNPO9BN471
DIO BRIDGE RECT SINGLE PHASE 1KV 6A SIP	D1	1	ON SEMI	GBU6J
DIO RECTIFIER 600V 3A SMB	D2	1	DIODES	ES3JB-13-F
DIO RECTIFIER 600V 1A SOD-123FL	D3, D5, D7, D11, D14, D23	6	ON SEMI	US1JFA
DIO GEN PURP 100V 0.2A SOD323-2 +150	D4, D6, D13, D15, D18, D19, D20, D22, D24	9	VISHAY	BAS16WS-E3-08
DIO ZENER 12V 200mW SOD323FL	D8	1	ONSEMI	MM3Z12VC
DIO RECTIFIER 600V 5A TO220V -55/+150	D9	1	LITTELFUSE	DURF1060CT
DIO TVS 170V 600W DO214AA	D10	1	DIODES INC	SMBJ170A-13-F
DIO ZENER 18V 625mW SOD-123	D12, D16, D17	3	NEXPERIA	PDZ18BGWX
DIO ZENER 6.2V 300mW SOD-232	D21	1	ONSEMI	MM3Z6V2T1G
FUS PTH MINI 3.15A 250V	F1	1	BEL FUSE	0697A3150-01
IND FER 68uH 2A 20% -40/+105	L1	1	WE	7447033
IND CHOKE 10mH@ 10kHz 1.4A 300V -40/+100	L2	1	SCHAFFNER	RN218-1-4-02-10M
IND SHD PWR 270uH2.05A 10% -40/+85	L3, L4	2	COILCREAFT	RFS1317-274KL
IND rod choke 5X20 3.3uH	L5	1	PRISMATIC	25402
TRN MOSFET N-CH 600V 0R18 TO252-3 -40/+150	Q1	1	INFINEON	IPD60R180P7SAUMA1
TRN NPN/PNP GEN PURP X2 45V 0.1A SOT23-6	Q2	1	NEXPERIA	BC847BPN,115
TRN PNP 500V 150MA SOT23 -55/+150	Q3	1	NEXPERIA	PBHV9050T,215
TRN MOSFET N-CH 650V 10A TO220V -55/+150	Q4	1	INFINEON	IPA65R125C7XKSA1
TRN MOSFET N-CH 600V 2R1 SOT223 -40/+150	Q5	1	INFINEON	IPN60R2K1CEATMA1
TRN PNP 45V 100mA SOT23 -55/+155	Q6, Q7, Q11	3	NEXPERIA	BC857CW,115
TRN NPN 45V 100MA SOT23 -65/+150	Q8, Q9, Q10	3	NEXPERIA	BC847C,215
VAR TVS 10MM DISC 3.5KV 275VAC	R1	1	TDK EPCOS	B72210S2271K101
RES 0402 TF 1K0 1% 0.062W -55/+155	R2, R7, R10, R13, R64	5	ROHM	SFR01MZPF1001
RES 0603 TF 100R 1% 0.1W -55/+150	R3, R6	2	STACKPOLE ELECTRONICS INC.	RMCF0603FT100R
RES 0805 TF 750K 1% 0.25W -55/+155	R4, R5, R11, R12, R20, R23	6	KOA SPEER	SG73S2ATTD754G
RES 0402 TF 10K 1% 0.062W -55/+155	R8, R15, R16, R19, R21, R25, R50, R58, R59, R63, R66	11	VISHAY	CRCW040210K0FKEDC
RES 1210 TF 0.3R 1% 500mW -55/+155	R9	1	YAGEO	RL1210FR-070R3L
RES 1206 TF 1.5M 5% 250mW -55/+155	R14, R68	2	YAGEO	RC1206JR-071M5L
RES 0402 TF 1M0 1% 0.062W -55/+155	R17, R22, R24, R26	4	VISHAY	CRCW04021M00FKEDC
RES 0603 TF 1R0 1% 0.25W -55/+155	R18	1	TE	CRGP0603F1K0
RES 0805 TF 10R 1% 0.125W -55/+155	R29	1	YAGEO	RC0805FR-0710RL
RES 1206 TF 47R 1% 250mW -55/+155	R30	1	YAGEO	RC1206FR-0747RL
RES 0603 TF 6.8R 5% 0.1W -55/+155	R32	1	VISHAY	CRCW06036R80JNEAIF
RES 0603 TF 33K 1% 0.1W -55/+155	R34	1	BOURNS	CR0603-FX-3302ELF
RES 0603 TF 1K0 1% 0.1W -55/+150	R35, R38	2	VISHAY	CRCW06031K00FKEA
RES 0603 TF 866K 1% 0.1W -55/+155	R36, R39	2	PANASONIC	ERJ3EKF8663V
RES 2512 TF 0.047R 1% 2W -55/+155	R37	1	TE	RLP73M3AR047FTDF
RES 0603 TF 100K 1% 0.1W -55/+155	R40	1	YAGEO	RC0603FR-13100KL
RES 0603 TF 20K 1% 0.1W -55/+155	R41, R56	2	YAGEO	RC0603FR-0720KL
RES 0603 TF 47K 1% 0.1W -55/+155	R42, R44, R57, R60	4	TE	CRGP0603F47K
RES 0805 TF 22R 1% 0.500W -55/+155	R43	1	VISHAY	CRCW080522R0FKEAHP
RES 0603 TF 16K 1% 0.1W -55/+155	R45	1	YAGEO	RC0603FR-0716KL
RES 0805 TF 2M2 1% 0.125W -55/+155	R46, R48, R49, R53, R54	5	YAGEO	RC0805FR-072M2L
RES 2512 TF 22K 5% 3W -55/+155	R47	1	TE	352222KJT
RES 0603 TF 470K 1% 0.1W -55/+155	R51	1	YAGEO	RC0603FR-07470KL
RES 0603 TF 330K 1% 0.1W -55/+155	R52	1	YAGEO	RC0603FR-0716KLRC0603FR-07330
RES 0603 TF 4K7 1% 0.1W -55/+155	R55	1	YAGEO	RT0603FRE074K7L
RES 0603 TF 200K 1% 0.1W -55/+155	R61	1	YAGEO	RC0603FR-07200KL
RES 0603 TF 2.2K 1% 0.1W -55/+155	R62	1	YAGEO	RC0603FR-072K2L
TRF PQ2526 FLYBACK	T1	1	PULSIV	PULSIV
IC FAN73611 PWR MAN GATE DRIVER 20V SOP-8	U1	1	ON SEMI	FAN73611MX
IC MCP1799T-3302H LDO 3.3V 80mA -40/+150	U2	1	MICROCHIP	MCP1799T-3302H
PSV-AD-250 CONTROLLER QFN-24	U3	1	PULSIV	PSV-AD-250-Q24I
IC OPTOCOUPLER 1-CH 60mA 5KV -55/+125	U4	1	VISHAY	VOL617A-4T
IC SWITCH CTRL CONST-VTG-CRNT -40/+125	U5	1	TI	UCC28740DR
IC SHUNT REG, ADJ, 1% SOT23-3	U6	1	NEXPERIA	TL431AMFDT,215

FLYBACK TRANSFORMER DESIGN

The published results were achieved using a very compact transformer based on a PQ2625 ferrite core optimised for low cost (N95, 3C95, 95 material of similar gapped to 94 µH).

. Further efficiency improvements are achievable using alternative designs. The transformer design is detailed here:



NOTE:

Primary to auxiliary turns ratio will allow constant current operation down to an output voltage of approximately 20V. Adjust this ratio if a lower constant current output voltage is required. Note that whilst the flyback circuit is compatible with auxiliary supply voltages up to 35V, the power supply to the Pulsiv OSMIUM circuits should be kept in the range 12.5V to 18V. If a higher auxiliary voltage is desired, a simple clamped emitter follower circuit can be used to drop the Pulsiv OSMIUM supply voltage.

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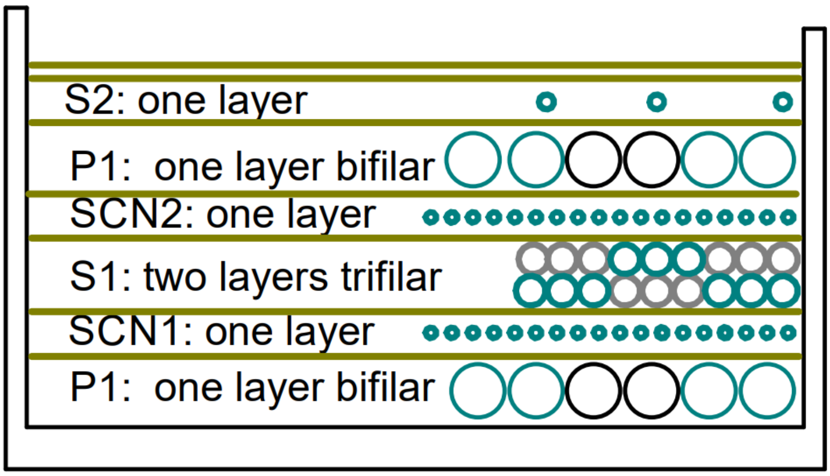
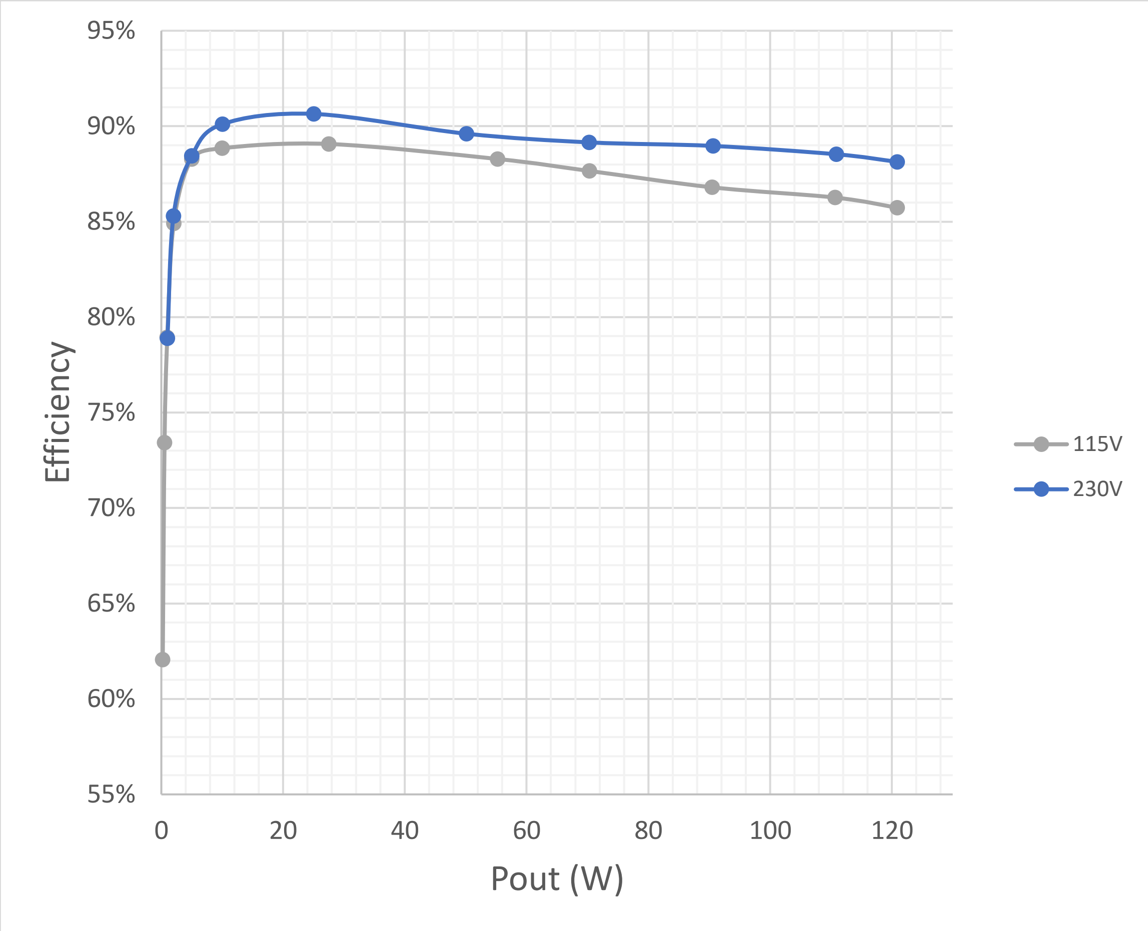
WINDING DETAILS

Stage	Winding	Function	Turns / material	Termination	Tape layer
1	P1 (1-3) 17 turns total	Primary 1 First stage	9 turns 30/0.1mm ECW Litz Wind bifilar as a single layer.	Start: pin 1 Finish: exit at top of bobbin to continue at stage 5	1 layer of tape
2	SCN1	Screen	80 turns 0.1mm ECW Wind evenly across width	Start: Pin 6 End: do not terminate	1 layer of tape
3	S1 15 turns total	Secondary 1	15 turns 0.37mm TIW Wind trifilar on 2 layers	Start: Pin 8 / 9 Finish: Pin 10 / 11	1 layer of tape
4	SCN2	Screen	80 turns 0.1mm ECW Wind evenly across width	Start: Pin 6 End: do not terminate	1 layer of tape
5	P1 (1-3) 17 turns total	Primary 1 second stage	8 turns 30/0.1mm ECW Litz Wind bifilar as a single layer.	Start: from stage 1 exit top of bobbin Finish: pin 3	1 layer of tape
6	S2 (5-4)	Secondary 2	5 turns 0.25mm ECW Evenly spiral-wind across the width.	Start: pin 5 Finish: pin 4	1 layer of tape

LAYER STACK



EFFICIENCY

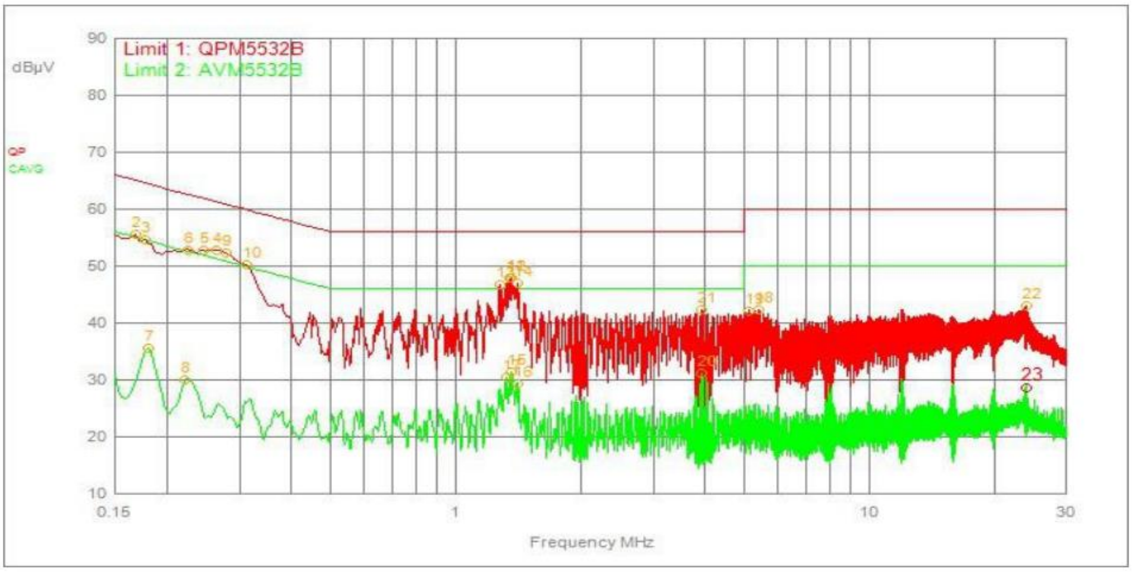


EFFICIENCY	Average 25% to 100%	100%	75%	50%	25%	10%	No load
115V							
PSV-RDAD-100FB	88.0%	86.6%	87.5%	88.6%	89.3%	88.8%	0.110W
DoE Level VI regulation	**>88%**					**-**	**<0.210W**
230V							
This design	89.6%	88.8%	89.2%	89.6%	90.6%	90.1%	0.150W
Ecodesign 2019/1782	**>88%**					**-**	**<0.210W**

CONDUCTED EMISSIONS

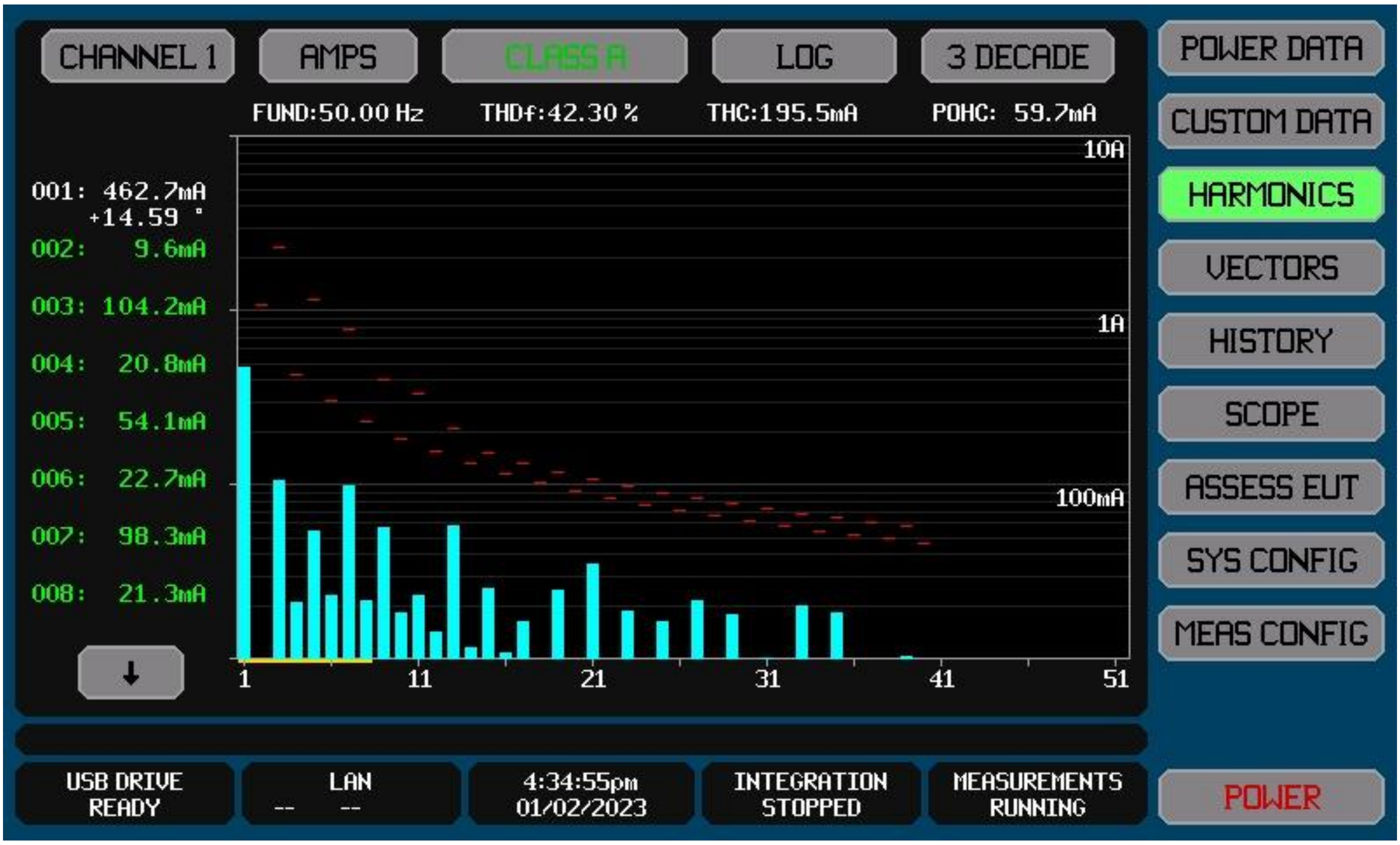
Full conducted emissions test of the Pulsiv Osmium development system to EU and US standards are available to download here:

https://pulsiv.co.uk/wp-content/uploads/dlm_uploads/2022/10/EMC-FCC-Full-Test-Report-Combined-1.pdf



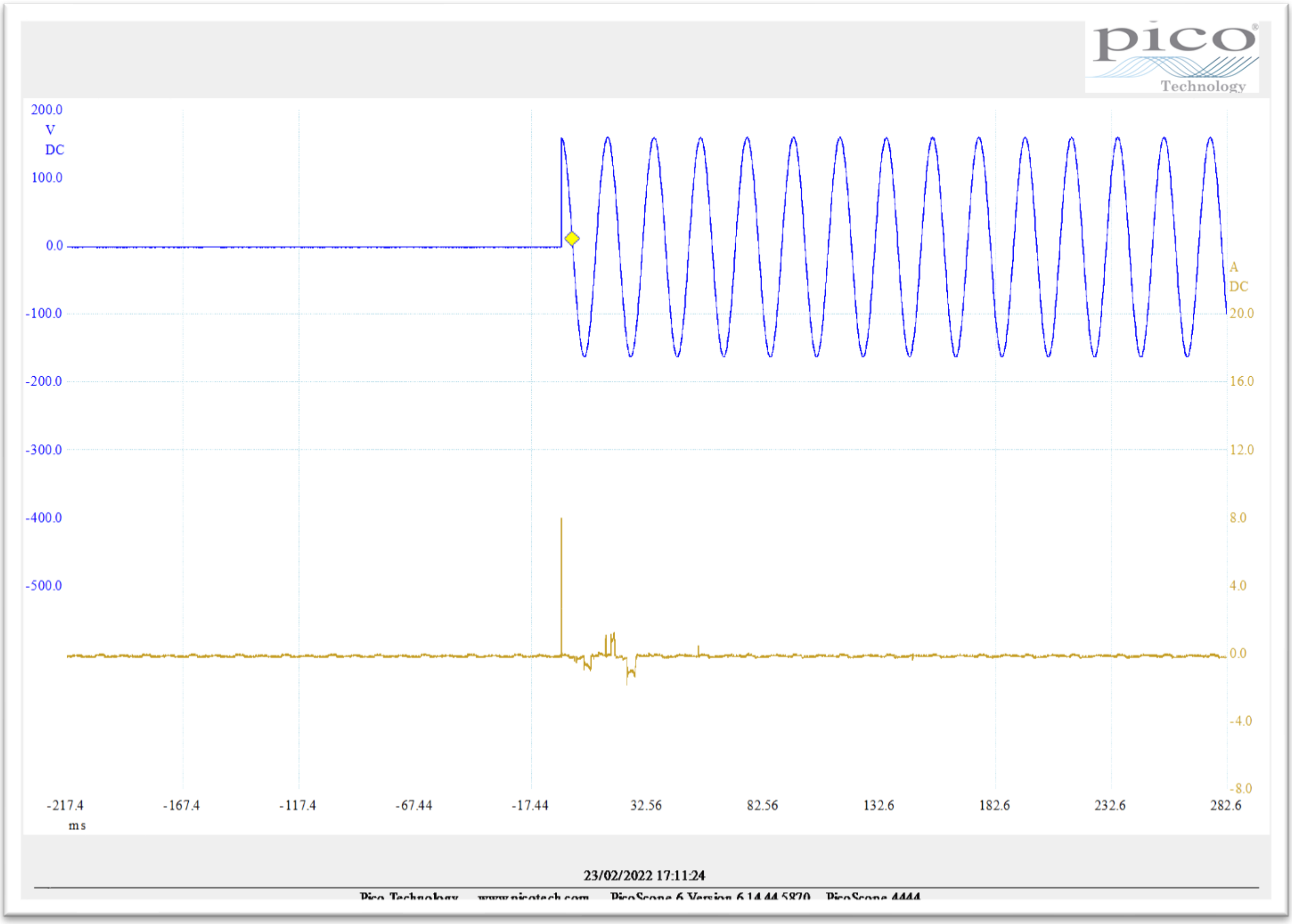
Conforms to EN55032 Class B

HARMONICS



Conforms to EN61000-3-2 Class A

INRUSH CURRENT



- Blue: HVDC
- Brown: line current

The current spike shown is caused by the X capacitor and the voltage slew rate of the test equipment. It is less than 100uS and does not count towards inrush current as measured using industry standard techniques and guidelines.

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