Why Planar Magnetics are Ideal for Harsh Environments

Jim Marinos
Payton America Inc.
1805 S. Powerline Rd, Suite 109
Deerfield Beach FL 33442
954-428-3326
Jim@paytongroup.com

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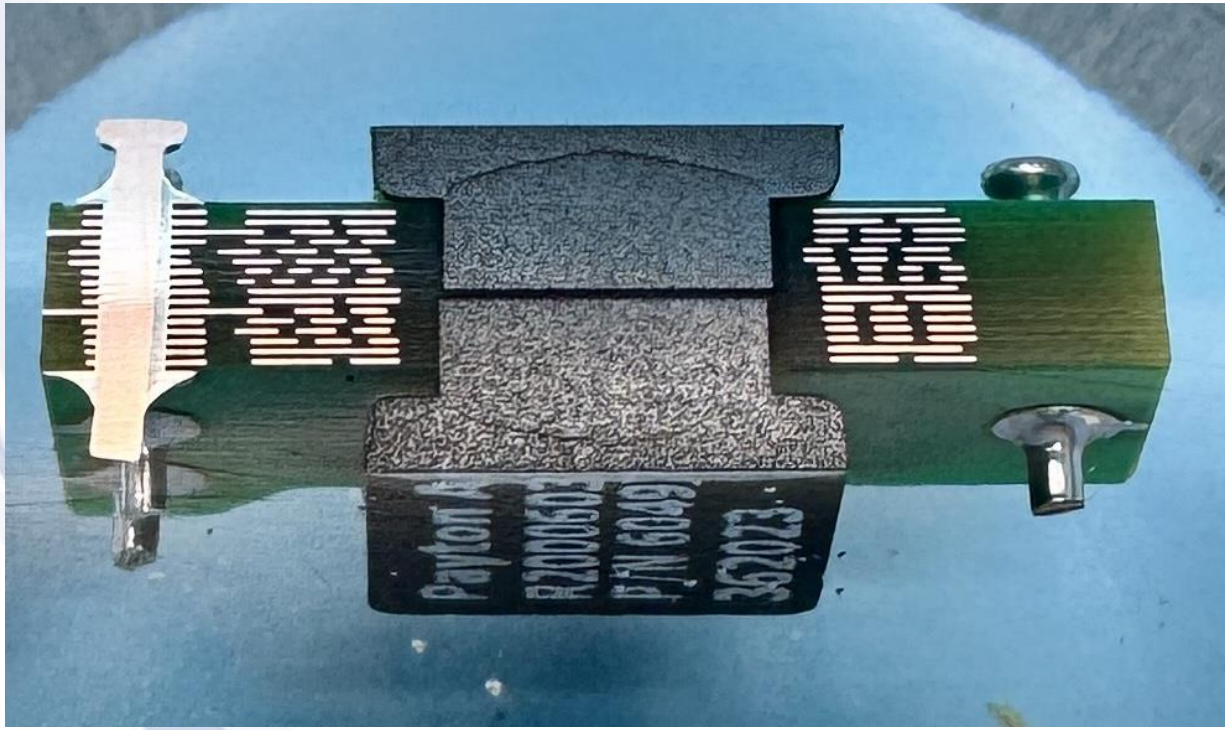

Who is Payton

- Established in 1987
- Design and manufacture of Planar Magnetics.
- Custom designs from few watts to 300kWatts
- Designs centers in the USA, UK and Israel
- US location is ITAR register and 100% DOD projects

Why Planar for Space

- Simple Construction.
- Reduced Size and Weight
- High efficiency up to 5Mhz
- Thermal management system, conduction cooling
- High Reliability & Repeatability based on few parts
- Screening per EEE-INST-002, Mil-Std-981 & MIL-STD-1580
- Over 300 designs for space applications
- Partial Discharge designs up to 20kVrms with detection level to 1pC

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Key Planar points

- simple construction
- Build in layers- high reliability and repeatability
- Easy to control the electrical parameters such as leakage and capacitance

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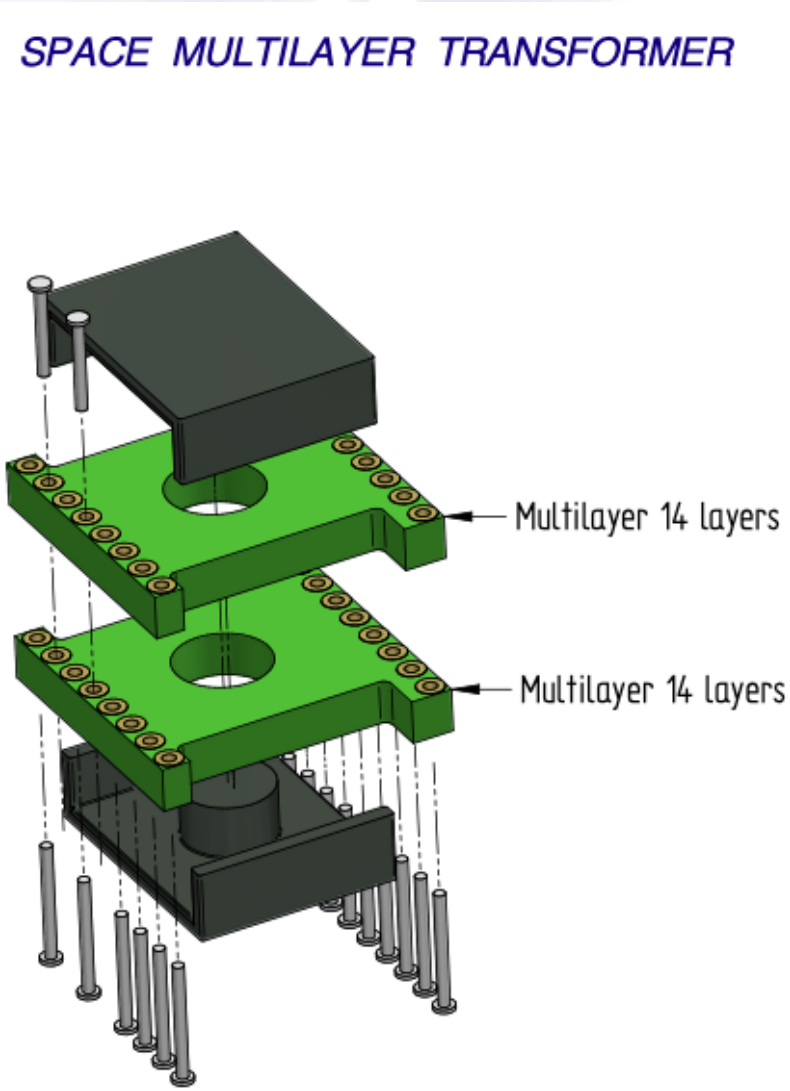
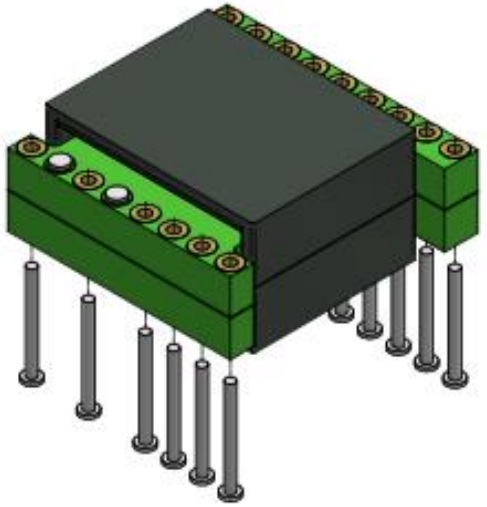
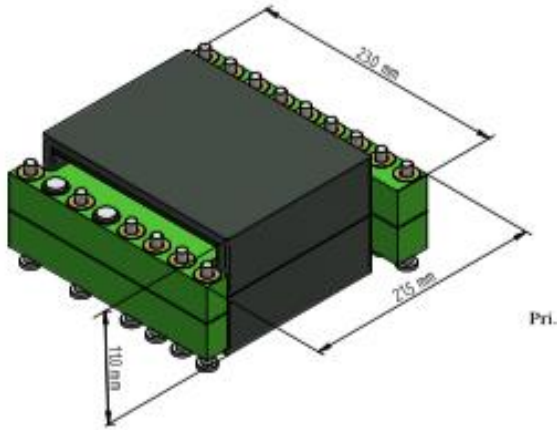
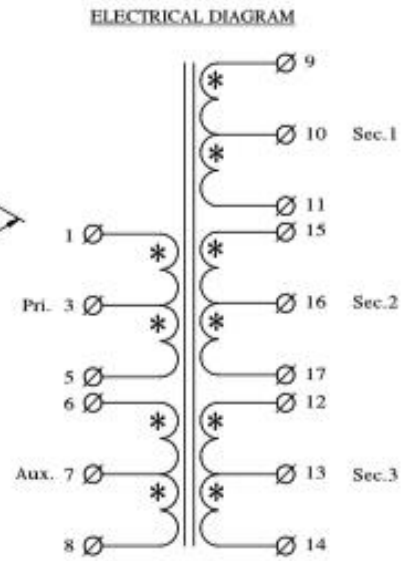
Simple Construction









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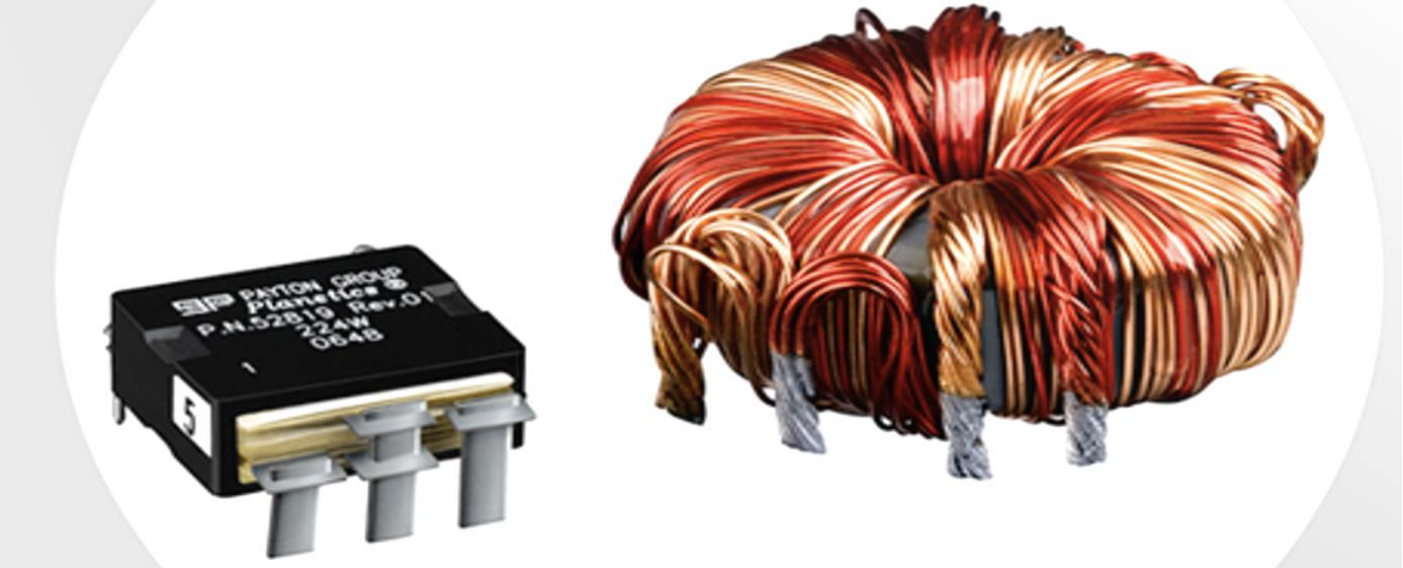
Size, weight, reliability, producibility, efficiency & cooling



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What makes a reliable Planar Design

1. Knowing the thermal conditions of the application.
2. Designing for maximum internal hot spot

   For example, a 12kWatt planar transformer, mounted on a cold plate at 90C with a thermal impedance between heatsink and hot spot of 0.6C/W and 100Watts of dissipation will yield a temp rise of 60C.

   This transformer will operate at 150C hot spot with an MTBF of 485,000 hours in an automotive environment.
3. Efficient cooling methods and materials

In mission-critical applications like space environments, where reliability is paramount, understanding and managing thermal conditions become even more crucial.

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Proper derating and cooling is the key to the MTBF

$\lambda\rho=\lambda b*\pi T*\pi Q*\pi E$ **Failure Rate /10ˆ6 Hours**

Base Failure Rate for Transformer - λb is 0.049 (F/10ˆ6) for power over 300Watts.
Temperature Factor - πT for a hot spot of 130C is 3.1
The Quality Factor - πQ for a MIL-SPEC type of transformer is 1
The Environment Factor - πE for GM is 12. πE can vary from 0.50 for SF (Space, Flight) to 610 for CL (Cannon, Launch)

So the $\lambda\rho$ for this transformer is 1.8 Total failures per million hours (FPMH)
The MTBF then will be $1/\lambda\rho$ = 555,000 Hours for a 130C hot spot transformer working in a Ground Mobile environment.

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Management of parasitics In Planar Magnetics

- Capacitance and leakage inductance are key parasitic parameters in most modern topologies. While in the past hard switching topologies inclined towards minimizing leakage inductance, today's more common LLC and DAB topologies tend to require specific leakage inductance values and minimizing of primary to secondary capacitance, and distributed capacitance.

- Leakage inductance can be achieved in multiple ways by using integrated or separate components, while capacitance requires tight control of winding type and insulation materials.

- The high repeatability is a result of keeping the parasitics controlled by design.

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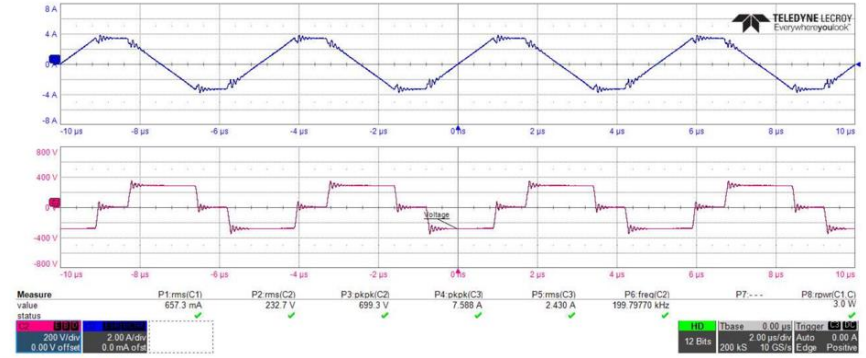
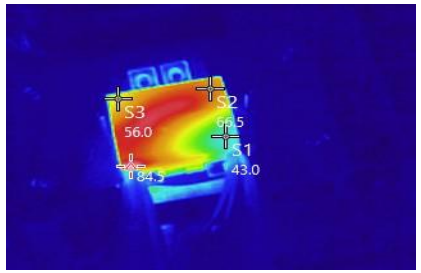
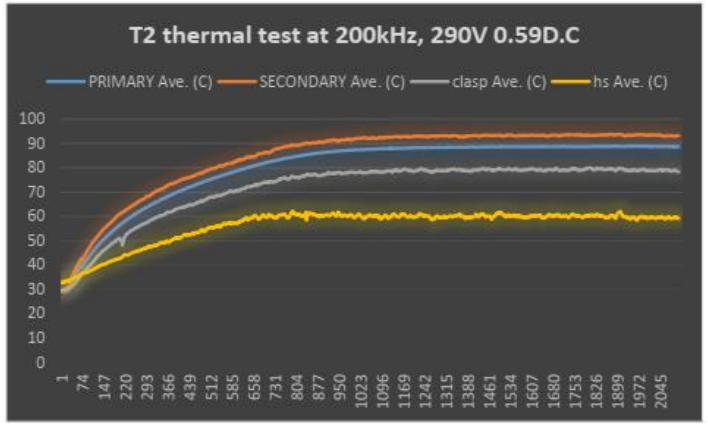
Real operating condition test system - Example

Test example for no load operation to test cor
losses showing asymmetrical heating a few minutes after start of operation due to airgap issues.

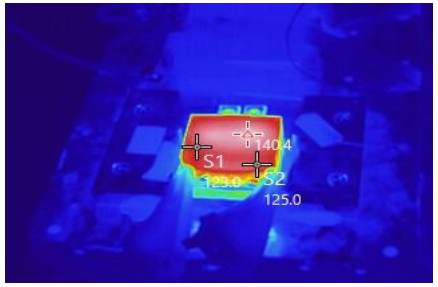


C2-Input Voltage.
C3-Input Current.





Following test, we have modified sample and retested to see issue solved.



Adding cooling clasp to this sample gave us the required temperature rise stabilization as seen on the right

Simulation verification of design - Ansys

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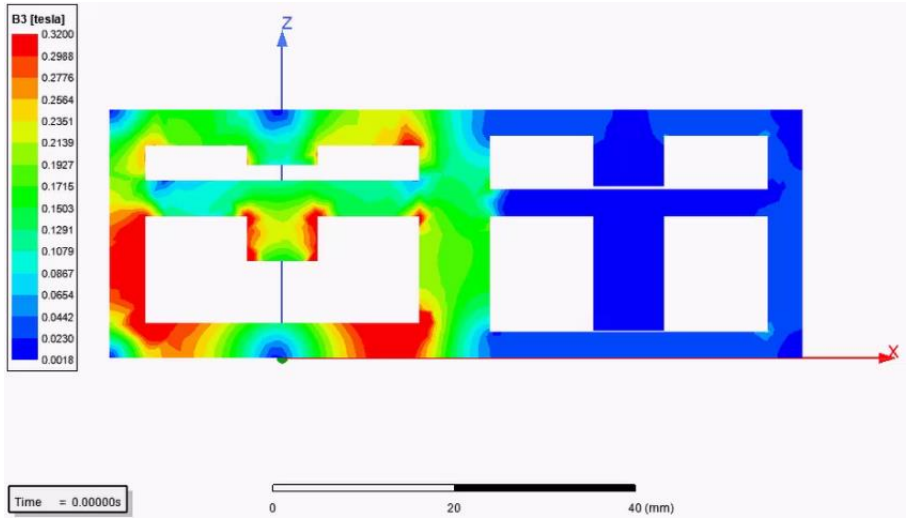
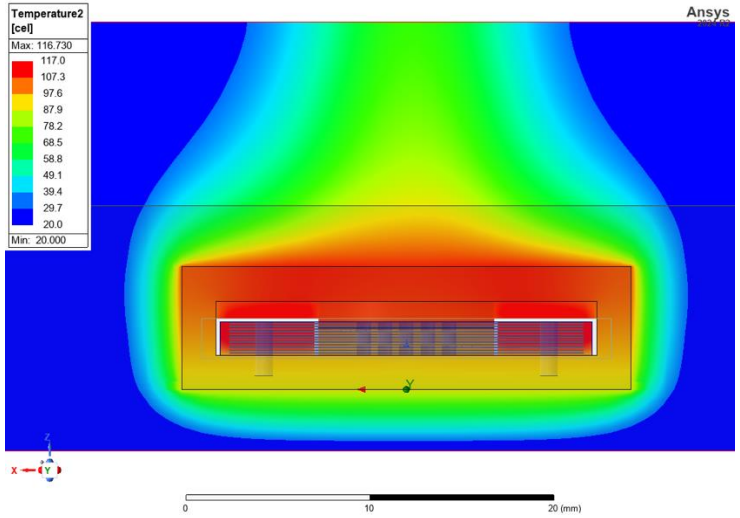
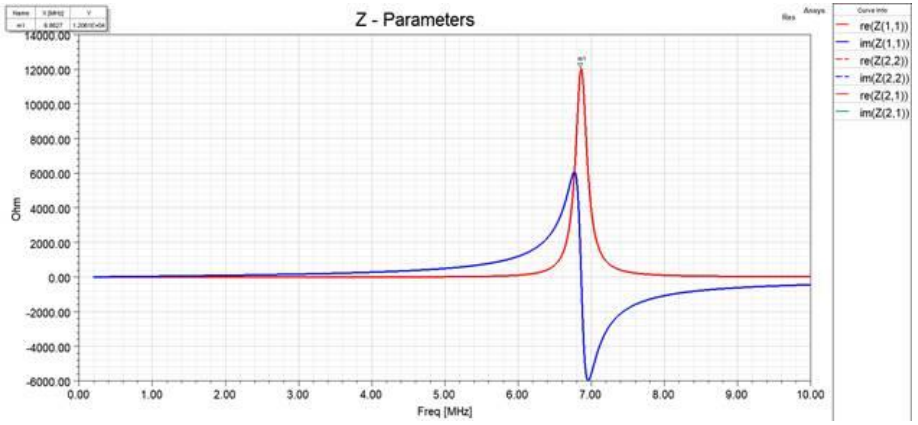
Integrated design flux distribution



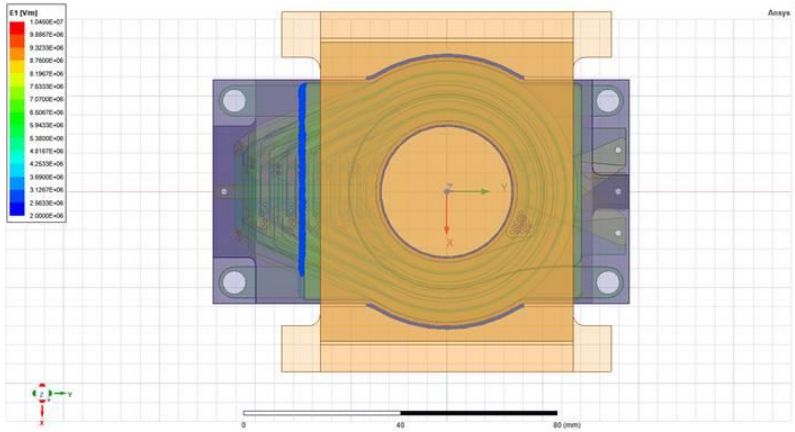
Thermal check



Impedance analysis

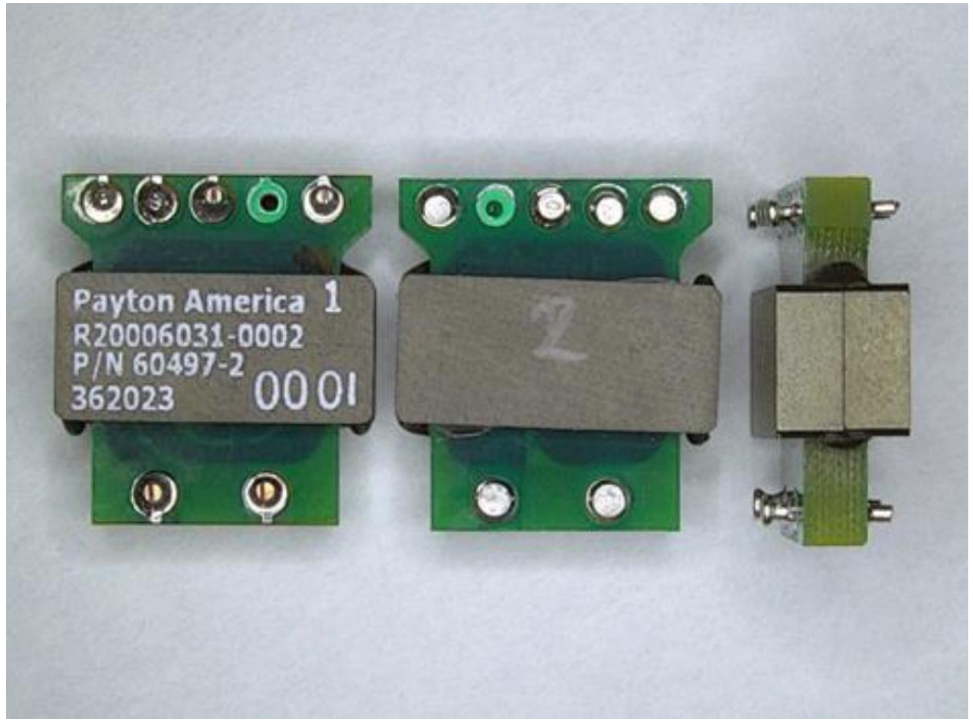


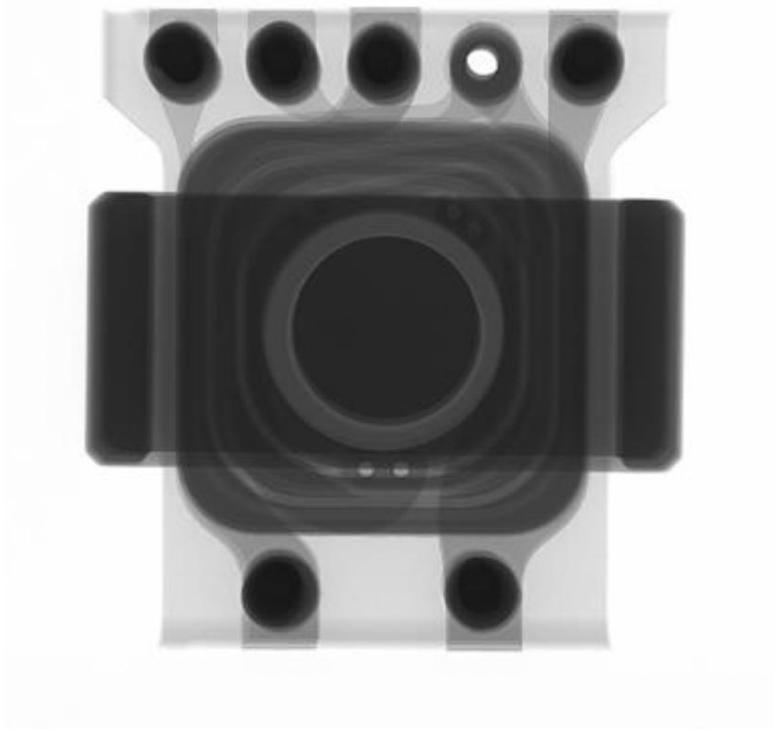
Electric fields – PD risk



DPA per MIL-STD-1580C, Req 15.1 & MIL-STD-981C, B, B

- External PMA
- Radiographic
- Internal Visual
- Internal PMA

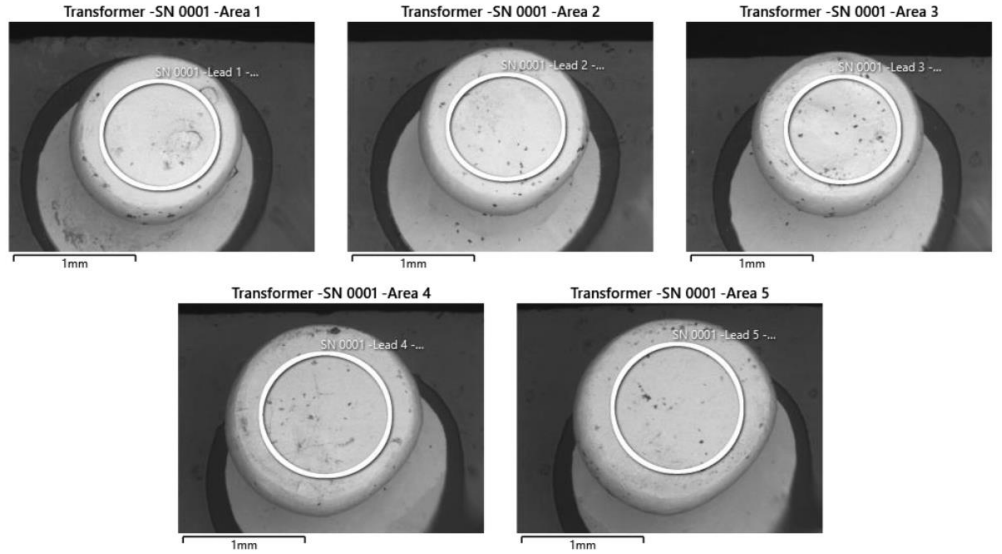




External Prohibited Material Analysis example.

7328-019-01B_PN 60497
Transformer - External PMA

03/28/2024



Spectrum Label	SN 0001 -Lead 1 - Side 1 -Solder	SN 0001 -Lead 2 - Side 1 -Solder	SN 0001 -Lead 3 - Side 1 -Solder	SN 0001 -Lead 4 - Side 2 -Solder	SN 0001 -Lead 5 - Side 2 -Solder
Sn	80.18	88.49	82.98	76.44	53.48
Pb	19.82	11.51	17.02	23.56	46.52
Total	100.00	100.00	100.00	100.00	100.00

Statistics	Sn	Pb
Max	88.49	46.52
Min	53.48	11.51
Average	76.32	23.68
Standard Deviation	13.50	13.50

1. QUALIFICATION PLAN

Group Number	Tests	Paragraphs
GROUP I (2 Samples)	Solderability	3.5; 4.7.2
GROUP II (2 Samples)	Dielectric withstanding voltage at atmospheric pressure	3.11; 4.7.9.1
	Dielectric withstanding voltage at barometric pressure	3.11; 4.7.9.2
	Insulation resistance	3.13a; 4.7.11
	Electrical characteristics	3.14; 4.7.12
GROUP III (6 Samples)	Corona discharge	3.16; 4.7.14
	Thermal shock	3.7.1; 4.7.4.1
	Winding continuity	3.20; 4.7.18
	Vibration	3.18; 4.7.16
	Shock	3.19; 4.7.17
	Dielectric withstanding voltage at reduced voltage	3.11; 4.7.9
	Insulation resistance	3.13b; 4.7.11
	Winding continuity	3.20; 4.7.18
	External Visual & Dimensions Inspection	3.24; 4.7; 1.1.1
	Electrical characteristics	3.14; 4.7.12
GROUP IV (2 Samples)	Life	3.26; 4.7.23
	Dielectric withstanding voltage at reduced voltage	3.11; 4.7.9
	Insulation resistance	3.13c; 4.7.11
	External Visual & Dimensions Inspection	3.24; 4.7; 1.1.1
	Electrical characteristics	3.14; 4.7.23
DPA	DPA	MIL-STD-1580C, Requirement 15.1

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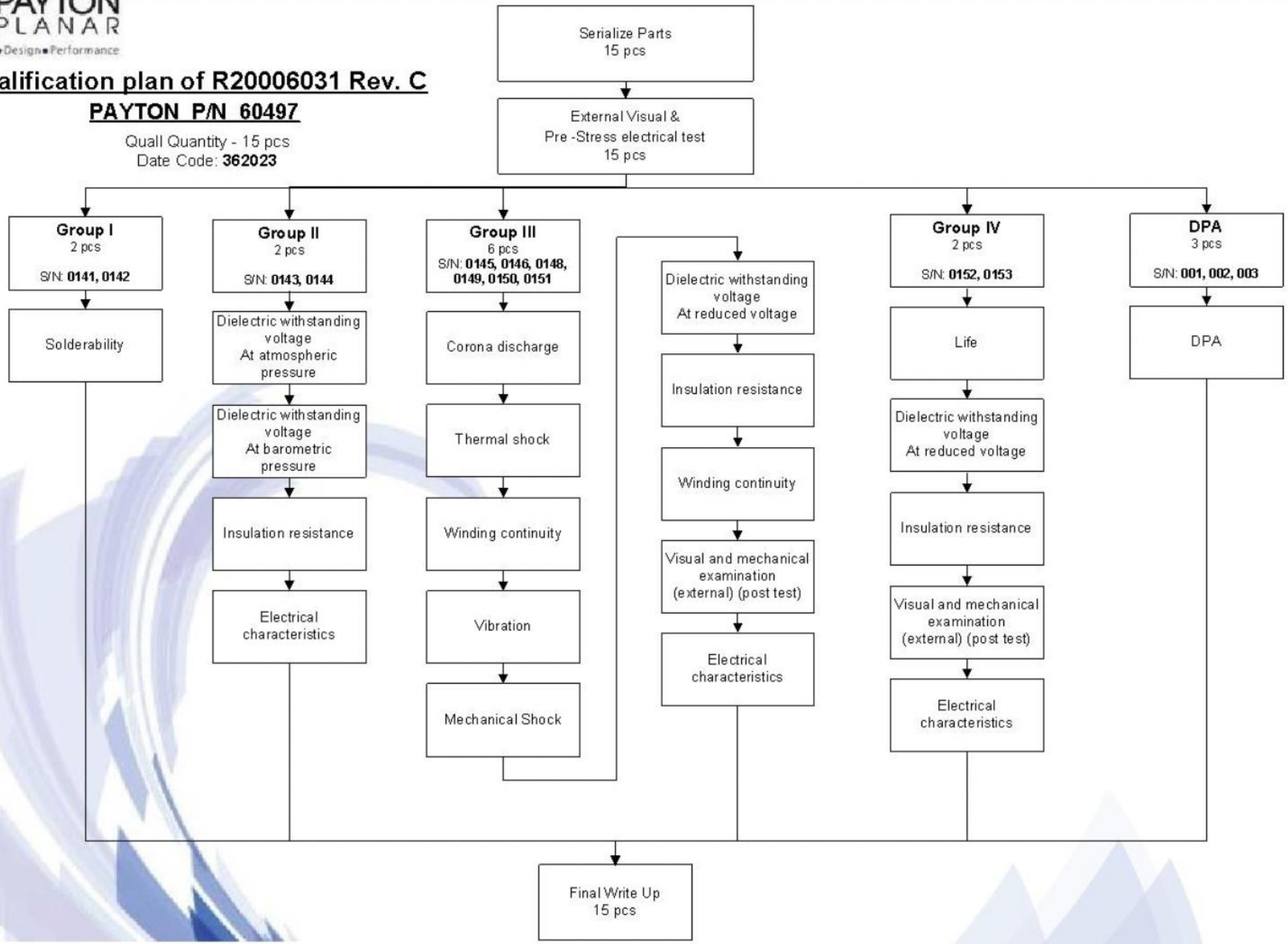
Qualification plan of R20006031 Rev. C

PAYTON P/N 60497

Quall Quantity - 15 pcs
Date Code: **362023**



2. EXECUTIVE SUMMARY

Fifteen (15) serialized transformers 60497-2 (DC: 362023 S/N 001-003,0141-0146, 0148-0153) were received for Environmental testing per MIL-PRF-27G, MIL-STD-202H, J-STD-002D, MIL-STD-1580C and Payton Test File (60497-2). The following table summarizes the tests that have been performed.

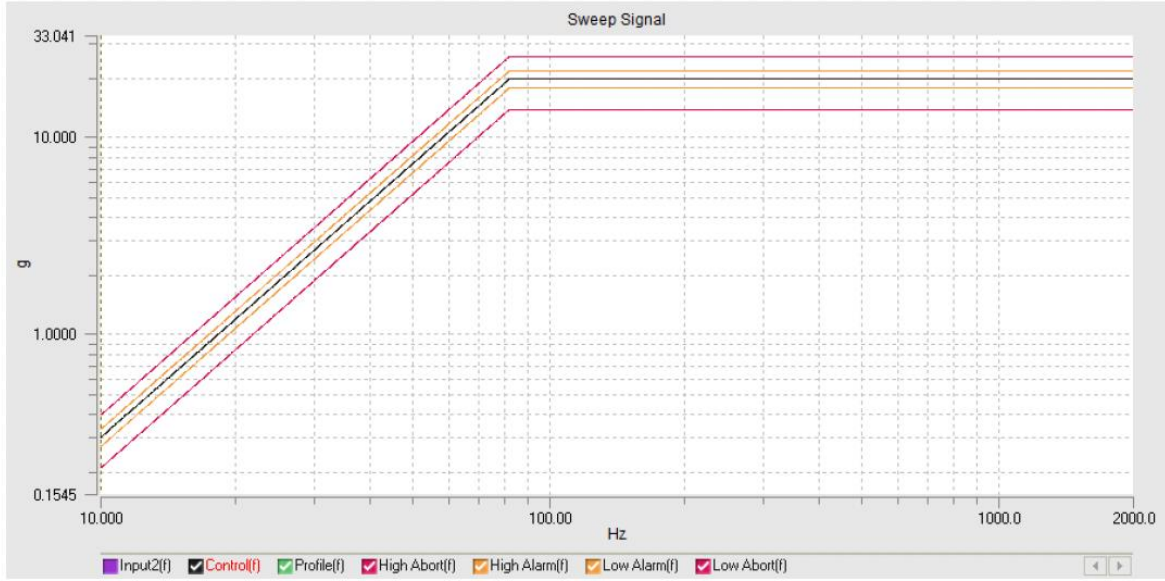
Group Number	Tests	TESTED	Sample Size	Pass/Fail	Report
GROUP I (2 Samples)	Solderability	02/04/024	2	Pass	60497-362023-1-1
GROUP II (2 Samples)	Dielectric withstanding voltage at atmospheric pressure	04/01/2024	2	Pass	60497-362023-1-2
	Dielectric withstanding voltage at barometric pressure	04/01/2024		Pass	
	Insulation resistance	04/01/2024		Pass	
	Electrical characteristics	04/02/2024		Pass	
GROUP III (6 Samples)	Corona discharge	12/17/2023	6	Pass	60497-362023-1-3
	Thermal shock	12/18/2023		Pass	
	Winding continuity	12/19/2023		Pass	
	Vibration	03/04-06/2024		Pass	
	Shock	03/06-07/2024		Pass	
	Dielectric withstanding voltage at reduced voltage	03/10/2024		Pass	
	Insulation resistance	03/10/2024		Pass	
	Winding continuity	03/10/2024		Pass	
	External Visual & Dimensions Inspection	03/10/2024		Pass	
	Electrical characteristics	03/10/2024		Pass	
GROUP IV (2 Samples)	Life	12/14/2023-03/10/2024	2	Pass	60497-362023-1-4
	Dielectric withstanding voltage at reduced voltage	03/10/2024		Pass	
	Insulation resistance	03/10/2024		Pass	
	External Visual & Dimensions Inspection	03/10/2024		Pass	
	Electrical characteristics	03/10/2024		Pass	
DPA	DPA	03/29/2024-04/01/2024	3	Pass	7328-019-01B

8. VIBRATION

Parameter Name	Parameter Value
Axes	3 (X,Y,Z)
Frequency Range	10-2000-10 Hz
Duration per Axis	4 hrs.
Max Vibration Level	20 g-pk
Number of Sweep Cycles	24
Sweep Rate	10 min/sweep

Pic. 10 Z-Axis Vibration Test

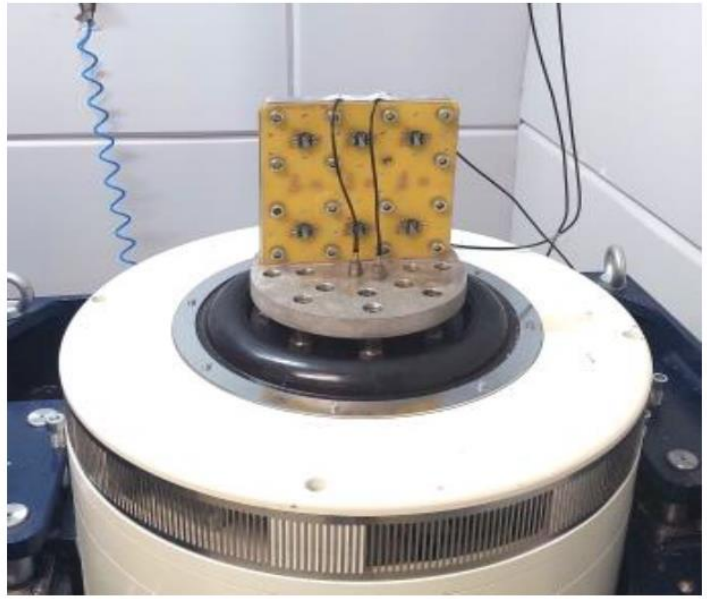
Graph 4 Z-Axis Vibration Performance



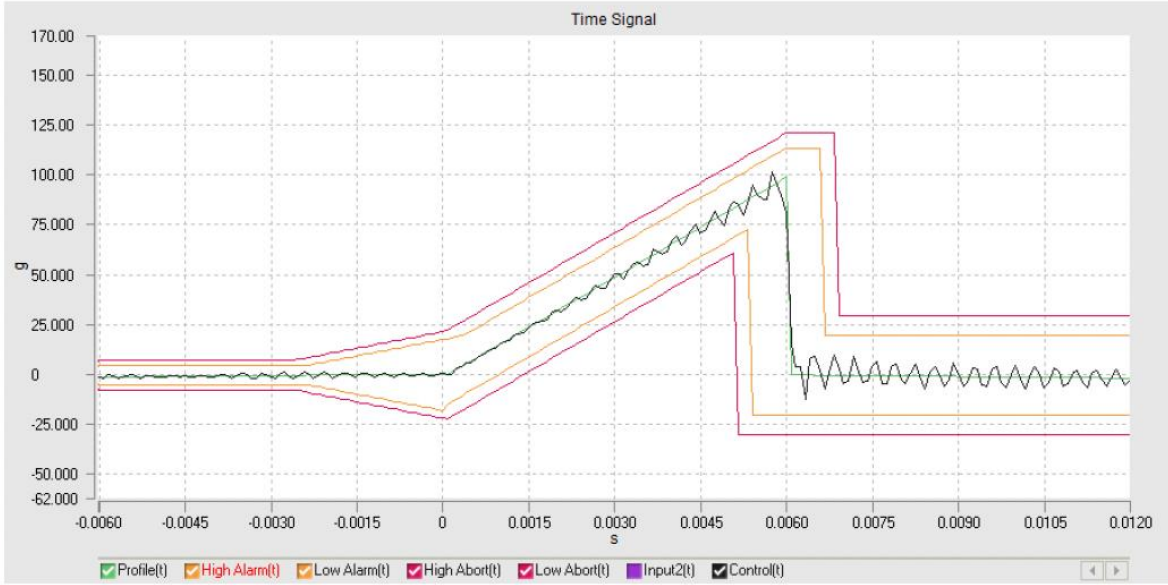
9. MECHANICAL SHOCK

Parameter Name	Parameter Value
Axes	3 (±X,±Y,±Z)
Shock Form	Sawtooth
Shocks per Axis	6 (3 each direction)
Total No. Shocks	18
Pulse Duration	6 msec
Shock Amplitude	100 g

Pic. 11 X-Axis ShocK Test



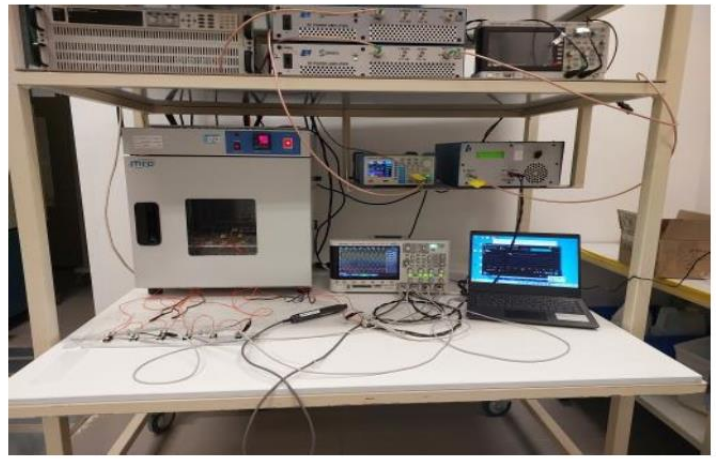
Graph 5 X-Axis Shock Performance



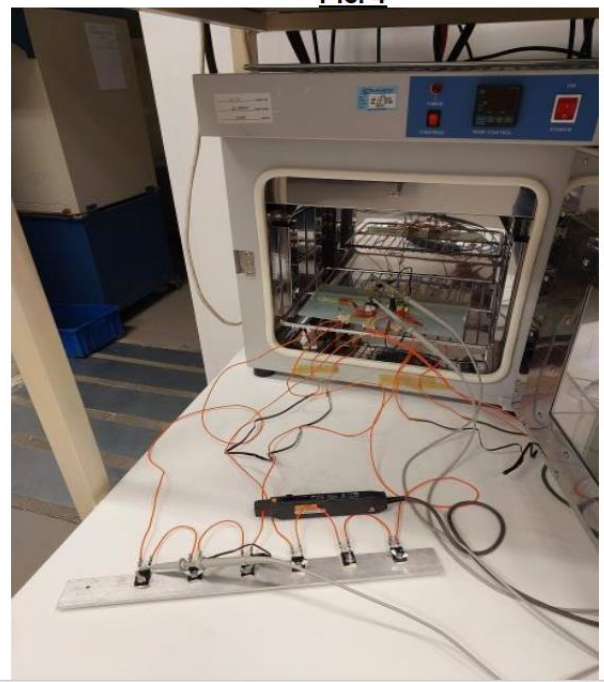
5. LIFE

Part Number	60497 Rev.00
Total output power	10 Watt DC
of power supply	(5V/1.8A dc
	13-15V/0.1A dc)
Life Test Load Conditions	
Input Wave	Full Sinus
Frequency	**200kHz**
Input Voltage	12.8 Vrms
Sec. 1 (7-9)	
Prim. to Sec. turn ratio	12:3
Secondary Voltage	3.2 Vrms
Max. Secondary Current	**2.67 Arms**
Secondary Power	8.54 VA Rms
Sec. 2 (4-5)	
Prim. to Sec. turn ratio	12:8
Secondary Voltage	8.53 Vrms
Max. Secondary Current	**0.2 Arms**
Secondary Power	1.71 VA Rms
Total output (all secondaries)	**10.25 VA Rms**

Pic. 3



Pic. 4



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Lifetime prediction of Planar Magnetics for Harsh Environments

- Inductance
- Multilayer Boards
  - Laminates and Prepregs, Tg,Td,Thermal,Moisture
- Ferrite Cores MnZn
- Ferrite glue
- Partial discharge

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