ARTESYN
EMBEDDED TECHNOLOGIES

Customer Power Needs

…….and how to design for them

14 juni 2018
1931 Congrescentrum Den Bosch

POWER ELECTRONICS 2018

Common Customer PSU Needs

- Low Acoustic Noise
- Long life & Low Maintenance in the Field
- High Ingression Protection
- Communication Capability

Acoustic Noise

Acoustic Noise: Why is it important?

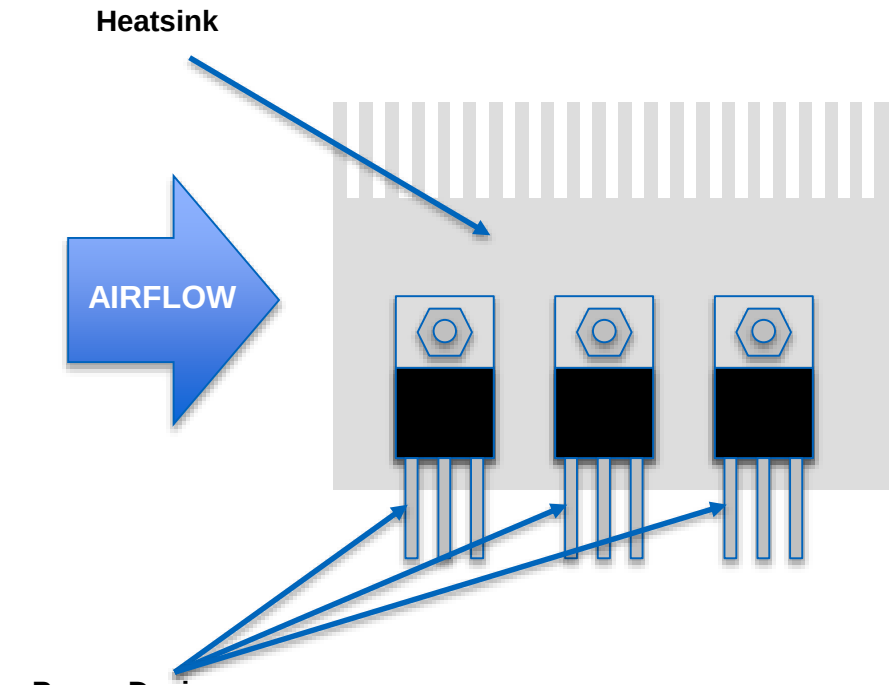
- Constant background noise can be irritating
  - Not good in environments where people work or live
- This can be worse if product is running overnight
  - Hospital beds, care home environments etc.
- Some applications require near silence
  - Music industry applications
  - Products located in museums, libraries etc.

Why is this critical for Power Supplies?

- Simple – Most PSUs have an internal fan!
- Ever thought to ask why?
  - Answer: The PSU needs it, not the end product
  - With a few exceptions, the end product has its own cooling

- Fan used to remove heat dissipated in the PSU
- Most heat comes from FETs, diodes & magnetics
- Heat dissipation by conduction (through metal case) is minimal

Forced Air Convection Cooling

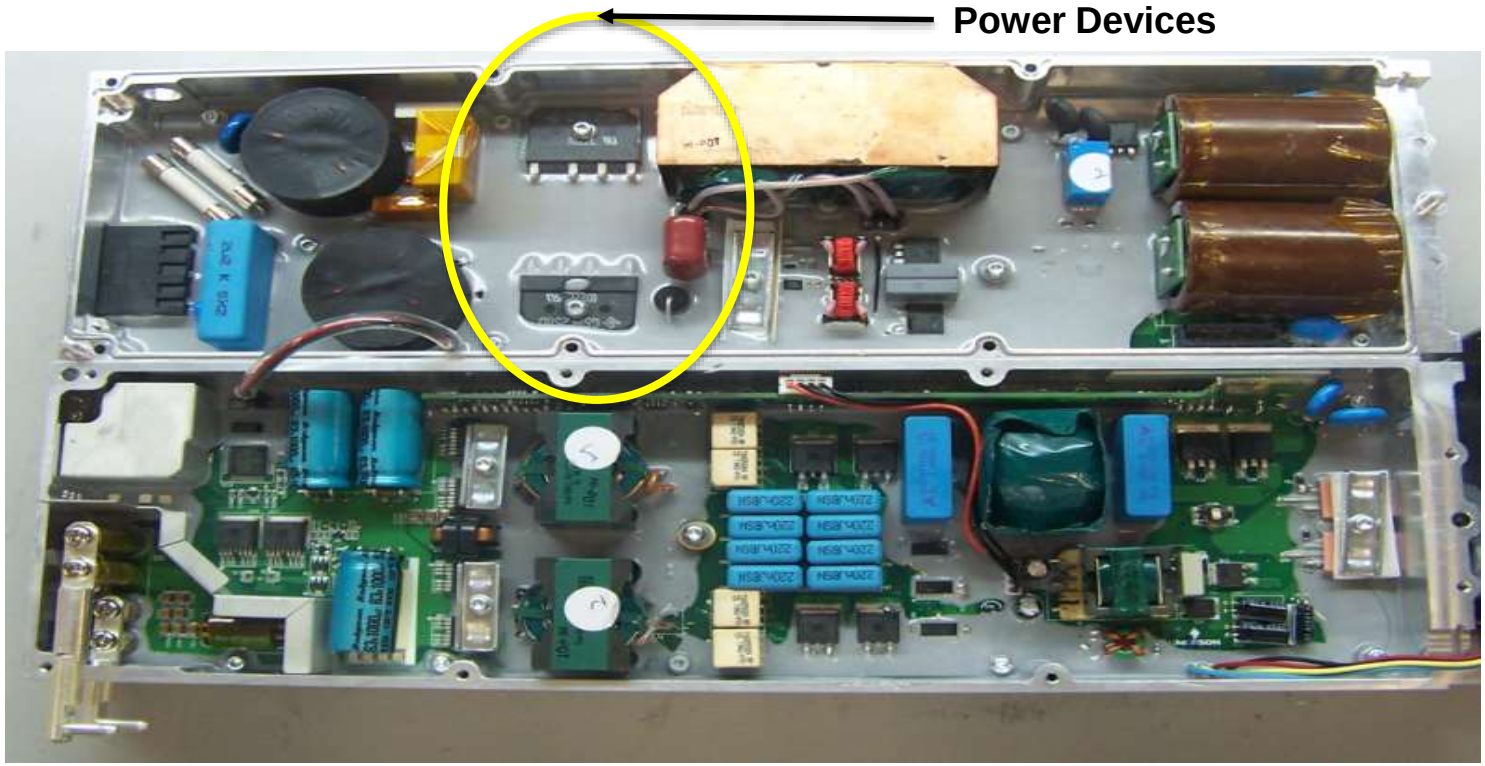


AIRFLOW

Why use a fan?

1) Allows the use of lower cost silicon and magnetics
   - Savings on power components are greater than cost of fan
2) PSU has full control over internal temperatures

Conduction Cooling



- Heat flows from silicon junction to **baseplate**
- Relies on natural conduction so **larger silicon** needed
- **Potting compound** may be added to improve heat flow
- **Magnetic construction more complex** to remove heat from core

How can acoustic noise be reduced?

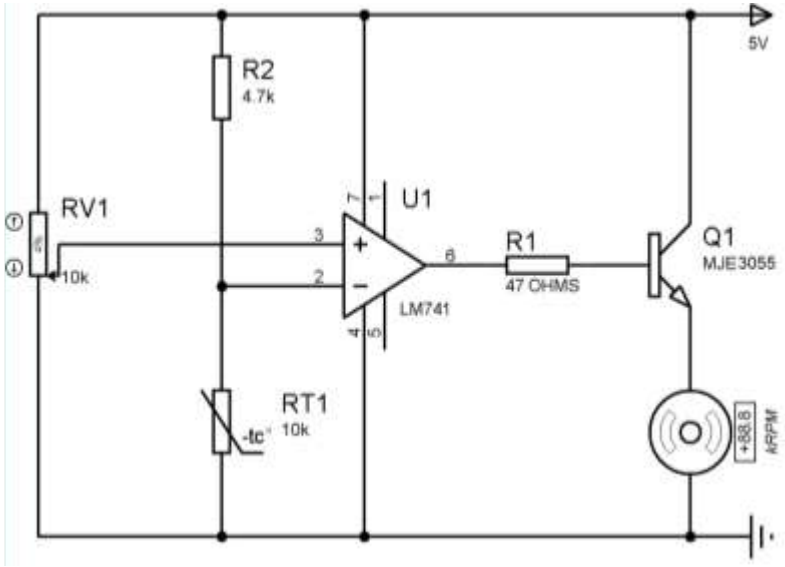
- 1. Implement fan speed control
  - Noise is proportional to fan speed
  - Fan speed can be tailored to operating conditions
  - Without FSC fan speed is set for worst case condition
    - Full output power, high temperature and low AC input voltage

- 2. Design the power supply for fanless operation
  - No fan, no acoustic noise
  - PSU is more expensive but has additional benefits

Fan Speed Control Circuits

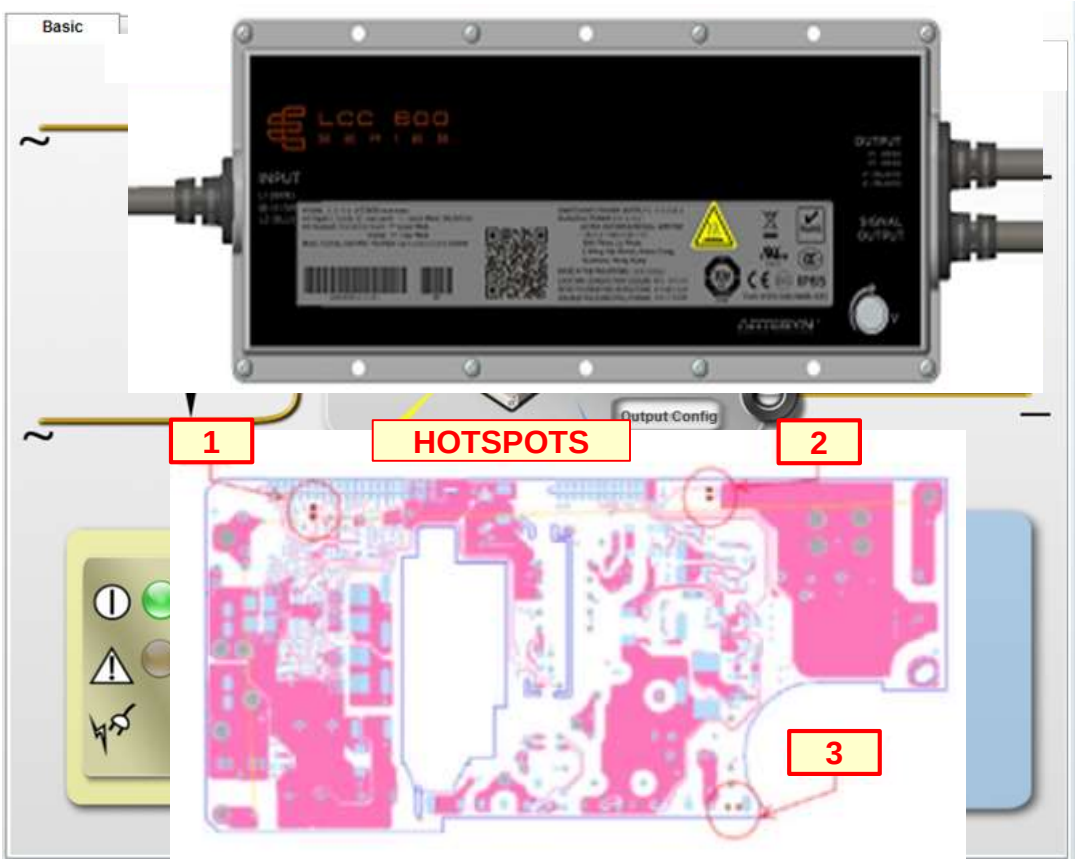
- FSC Circuits use sensors to determine fan RPM
  - A thermal sensor on the hottest location is simplest method
  - More complex methods monitor combinations (Temp, Iout, Vin)
  - Specially designed “Low Noise” fans can also be used

Example of Simple Thermistor Based FSC Circuit



Fanless Power Supply

- Need to maintain baseplate below max operating temp

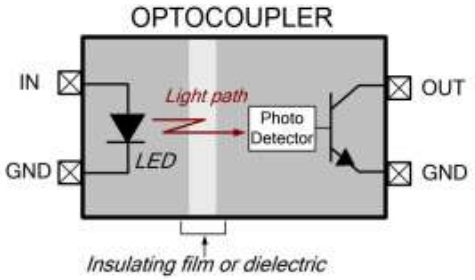


Long Life, Low Maintenance

PSU Life: What are the main drivers

1) Aluminium Electrolytic capacitors

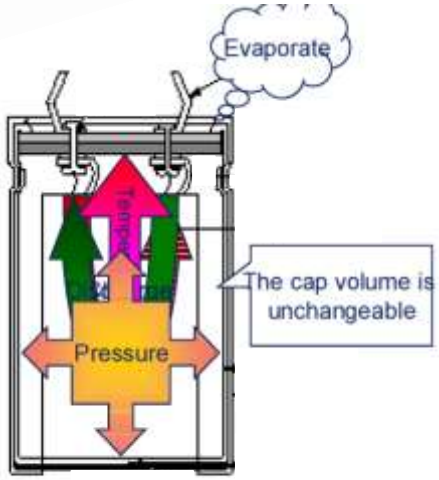
2) Opto-couplers



3) Fans

Electrolytic Capacitors

- All commercial PSUs use these
- Life limited by loss of electrolyte over time
- EOL Definition→ Capacitance drops by 20%
- Useful life is dependent on:
  - Component size/shape
  - Ratio of applied voltage versus rated voltage
  - Capacitor temperature rise due to ripple current
- In general a rise of 10ºC reduces life by 50%
- Careful design can ensure adequate lifetime
- Artesyn verifies compliance to published specs



$$Lx = Lo \times 2^{\frac{To-Tx}{10}} \times 2^{\frac{-\Delta T}{5}}$$

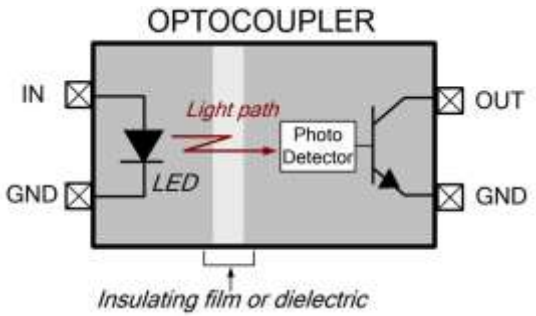
Electrolytic Capacitors

- Example Data from Qualification Test (50ºC, 100% load)
  - All E-Caps must meet spec at maximum load and temperature

Description			Measured Data			Result			
			Ta'	Tc	F	L		Conclusion	
PIN	Circuit code	Description	Calculated ambient temp.(°C)	Measured case temp.(°C)	Freq. Coeff	Estimated lifetime (hrs)	Estimated lifetime (yrs)	Customer requirement (hrs)	PASS or FAIL
201-011098-0000	C103	CAP-E 56U M 25V ZL	55.53	56.10	1.00	81,366	9.3	43,800	PASS
201-007693-0000	C105	CAP-E 56U M 35V YXG	48.50	48.50	1.00	131,400	15.0	43,800	PASS
201-008178-0000	C108	CAP-E 1M0 M 16V ZLH	73.50	74.30	1.00	91,521	10.4	43,800	PASS
201-008038-0000	C11	CAP-E M56 M 420V USC	43.00	43.50	1.00	100,328	11.5	43,800	PASS
201-013486-0000	C123	CAP-E M12 M 25V ZL	52.77	53.30	1.00	98,956	11.3	43,800	PASS
201-008038-0000	C24	CAP-E M56 M 420V USC	54.50	55.00	1.00	45,210	5.2	43,800	PASS
201-002504-0000	C317	CAP-E M27 M 35V ZL	55.63	55.70	1.00	131,007	15.0	43,800	PASS
201-002504-0000	C364	CAP-E M27 M 35V ZL	70.23	70.30	1.00	47,618	5.4	43,800	PASS
201-002504-0000	C368	CAP-E M27 M 35V ZL	67.03	67.10	1.00	59,444	6.8	43,800	PASS
201-012093-0000	C601	CAP-E 1M0 M 16V ZLH	74.50	75.30	1.00	85,383	9.7	43,800	PASS
201-012093-0000	C621	CAP-E 1M0 M 16V ZLH	75.30	76.10	1.00	80,769	9.2	43,800	PASS
201-013490-0000	C860	CAP-E M68 M 35V ZLJ	76.50	76.50	1.00	128,170	14.6	43,800	PASS
201-013490-0000	C861	CAP-E M68 M 35V ZLJ	71.40	71.40	1.00	131,400	15.0	43,800	PASS
201-013490-0000	C862	CAP-E M68 M 35V ZLJ	69.80	69.80	1.00	131,400	15.0	43,800	PASS
201-013490-0000	C863	CAP-E M68 M 35V ZLJ	78.10	78.10	1.00	114,716	13.1	43,800	PASS
201-013490-0000	C864	CAP-E M68 M 35V ZLJ	76.70	76.70	1.00	126,406	14.4	43,800	PASS
201-013490-0000	C865	CAP-E M68 M 35V ZLJ	75.30	75.30	1.00	131,400	15.0	43,800	PASS
201-013490-0000	C866	CAP-E M68 M 35V ZLJ	71.50	71.50	1.00	131,400	15.0	43,800	PASS
201-013490-0000	C867	CAP-E M68 M 35V ZLJ	77.30	77.30	1.00	121,385	13.9	43,800	PASS
201-013490-0000	C868	CAP-E M68 M 35V ZLJ	72.60	72.60	1.00	131,400	15.0	43,800	PASS
201-013490-0000	C869	CAP-E M68 M 35V ZLJ	71.80	71.80	1.00	131,400	15.0	43,800	PASS

Ta	ΔTj	A
Calculated ambient temp.(°C)	Actual core temp.	Ripple acceleration coefficient
55.53	1.69	9.85
48.50	0.11	9.99
73.50	2.00	9.75
43.00	3.31	9.70
52.77	1.63	9.85
54.50	3.31	9.70
55.63	0.59	9.95
70.23	0.59	9.93
67.03	0.59	9.94
74.50	2.00	9.74
75.30	2.00	9.74
76.50	0.18	9.98
71.40	0.18	9.98
69.80	0.18	9.98
78.10	0.18	9.97
76.70	0.18	9.97
75.30	0.17	9.98
71.50	0.17	9.98
77.30	0.17	9.98
72.60	0.17	9.98
71.80	0.17	9.98

Optocouplers



- Many commercial PSUs use these
- Used to transmit signals across safety barrier
- Degradation of emitter chip over time limits life
- End of Life Definition → CTR drops by 50%
- Useful life is dependent on :
  - Ambient temperature
  - Forward current of emitter diode
- Careful design can ensure adequate lifetime
  - 15 years is achievable under average operating conditions

Optocouplers

- Example Data from Qualification Test
  - All Opto-Couplers must pass at 50% and 100% PSU load

QA ENGINEERING

Opto Coupler CTR Margin Calculation rev 3.1

Model : LCM1500Q-T
Input Vin: 90-264Vac
AC Grid:
Amb Temp: 50°C
Load: 100%FL (24V/62.5A, 5Vsb/2A)
50%FL (24V/31.2, 5Vsb/1A)

Prepared By : Lorenzo R. Madariaga II
Checked By :

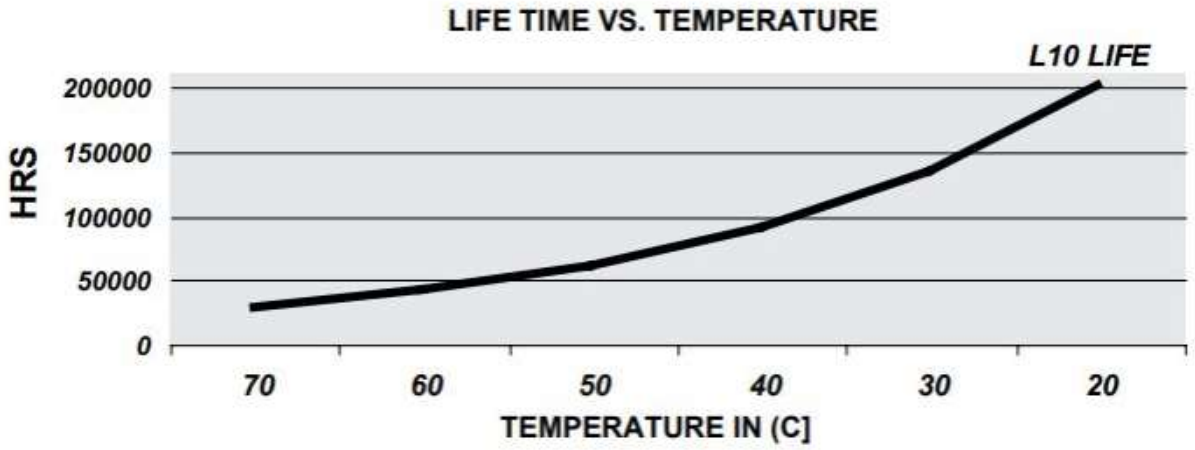
Prime Parts

						CTR Multiplying Factors						
Ckt Code	Description	Ifed(mA)	Itrans(mA)	Minimum Reqd CTR	CTRmin (spec)	CTR Derating	Ifed Normalization	Amb Temp Factor	Aging, 5yrs	Worst Case Actual CTR	% CTR Margin	Pass/Fail
IC104	OPTO-CPL PS2561L2-1-V-A-H	9.5	0.48	5.05	200	0.8	0.95	0.8	0.8	97.28	1825.33	PASS
IC11	OPTO,LIN,6V,1.4V,5kVrms,30mA,100°C,-55°C,SMD-4	0.9	0.27	30.00	80	0.8	0.9	0.8	0.8	36.864	22.88	PASS
IC402	OPTO-CPL PS2561L2-1-V-A-H	1.9	0.03	1.58	200	0.8	0.9	0.8	0.8	92.16	5736.80	PASS
IC403	OPTO-CPL PS2561L2-1-V-A-H	2.35	0.43	18.30	200	0.8	0.9	0.8	0.8	92.16	403.67	PASS
IC404	OPTO-CPL PS2561L2-1-V-A-H	0.01	0.001	10.00	200	0.8	0.9	0.8	0.8	92.16	821.60	PASS
IC405	OPTO-CPL PS2561L2-1-V-A-H	2.35	0.43	18.30	200	0.8	0.9	0.8	0.8	92.16	403.67	PASS
IC406	OPTO-CPL PS2561L2-1-V-A-H	13.94	2.73	19.58	200	0.8	0.9	0.8	0.8	92.16	370.59	PASS

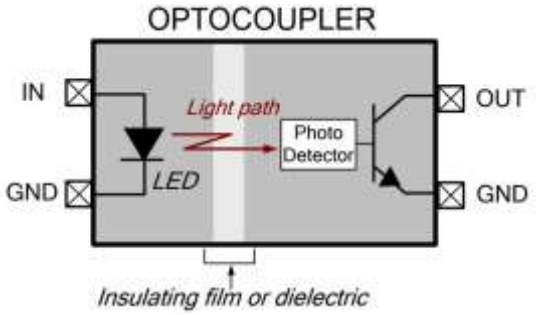
Legend :
Measured data or Simulated data from SIMETRIX42
Based on Vendor Specifications

Fans

- Most commercial PSUs use these
- Useful life is limited by fan bearings waring out
- Driving factors:
  - Ambient temperature
  - Type of bearing (sleeve ~50% life of ball bearing)



Which is Least Manageable w.r.t. Life



- Commercial PSUs usually designed for 5 years life (min)
  - **BUT** this is under worst case conditions
  - Low line voltage (Japan), max load, max ambient temp
- Average conditions ~40% load, 20°C, higher line voltage
  - E-caps/optocouplers >15yr life versus 5yr at worst case
  - Fan has a finite revolutions before wear out, worse at high temp
- No fan is best way to ensure low maintenance, long life

Downside of the Fan

- Dust/debris ingression – see below pictures
- Much worse has been seen
  - Corrosion from saline solution (Dialysis machine)
  - Insects and even lizards!!!

Open Frame are fanless too!

- But need a fan to deliver max power
- Two power ratings (conducted & forced air)
- Radiated EMI is uncontrolled – take care!
  - An EMI shield will be needed, almost certainly
- Cooling technology is same as fan-cooled
  - Very low cost due to no fan or box

Fanless: Things to watch out for

- For a PSU with fan, system compliance is easy
  - If system max ambient is within PSU spec, no issue
  - If PSU meets radiated EMI end system likely to also
- For open frame fanless PSUs
  - Thermal compliance is a customer responsibility
  - Specified airflow is needed for full output power
  - Radiated EMI compliance is up to the end customer
- For baseplate fanless PSUs
  - EMI and thermal are not an issue PROVIDED…
  - Customer maintains baseplate below max temp

High Ingression Protection

What is IP Rating?

Rating	Protect Against / Object Size — Solids
0	**0** No protection
1	**> 50 mm** Any surface of a body - like the back of a hand; no protection against deliberate contact
2	**> 12.5 mm** Fingers or similar objects no greater than 80mm in length
3	**> 2.5 mm** Tools, thick wires, and such like with a diameter of 2.5mm or more
4	**> 1 mm** Most wires, screws and such like longer than 1mm
5	**Dust protected** Most dust until quanity exeeds operating limits
6	**Dust tight** Complete dust tight

Rating	Protect Against / Object Size — Liquid
0	**No protection** No protection
1	**Dripping water** Vertical dripping water/condensation
2	**Dripping water when tilted up to 15°** Vertical dripping water has no effect when the enclosure is tilted up to 15°
3	**Spraying water** Water spray up to 60° from the vertical
4	**Splashing of water** Water splash/spray from any direction
5	**Water jets** Water projected by a nozzle/jet (6.3 mm) from any direction
6	**Powerful water jets** Water projected by powerful jets (12.5 mm nozzle) from any direction
7	**Immersion up to 1 m** Tempoary immersion into water (up to 1 m of submersion).
8	**Immersion beyond 1 m** Continuous immersion in water (beyond 1m)

IP65

How do you design for High IP Rating?

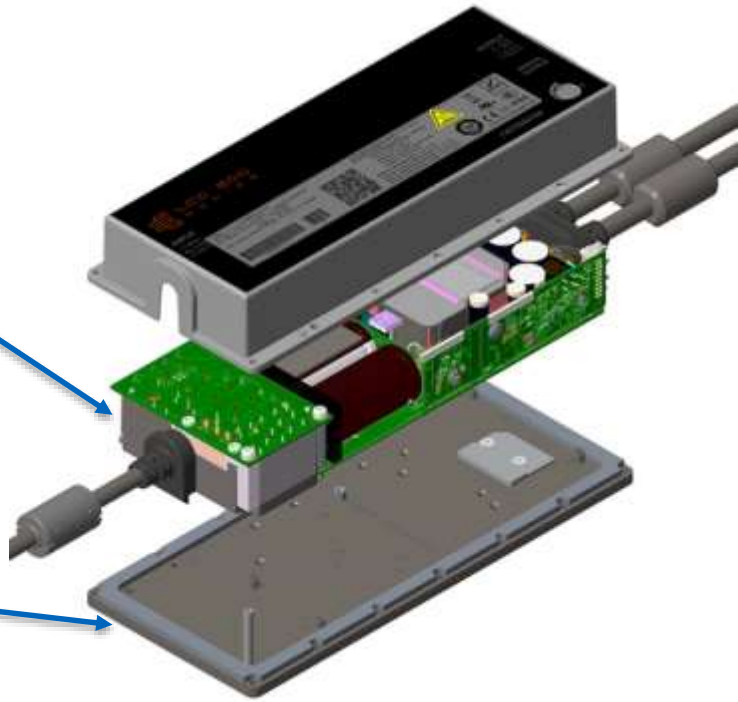
- Product can't contain a fan
- Design appropriate sealing on enclosure

Grommet:

Used between cover and baseplate.
Creates seal for Input/Output cable

Seal:

Foam gasket between cover and baseplate
Material: closed cell silicone foam
Flammability rating: UL94 V-0
Temperature range at -55 to 200 °C

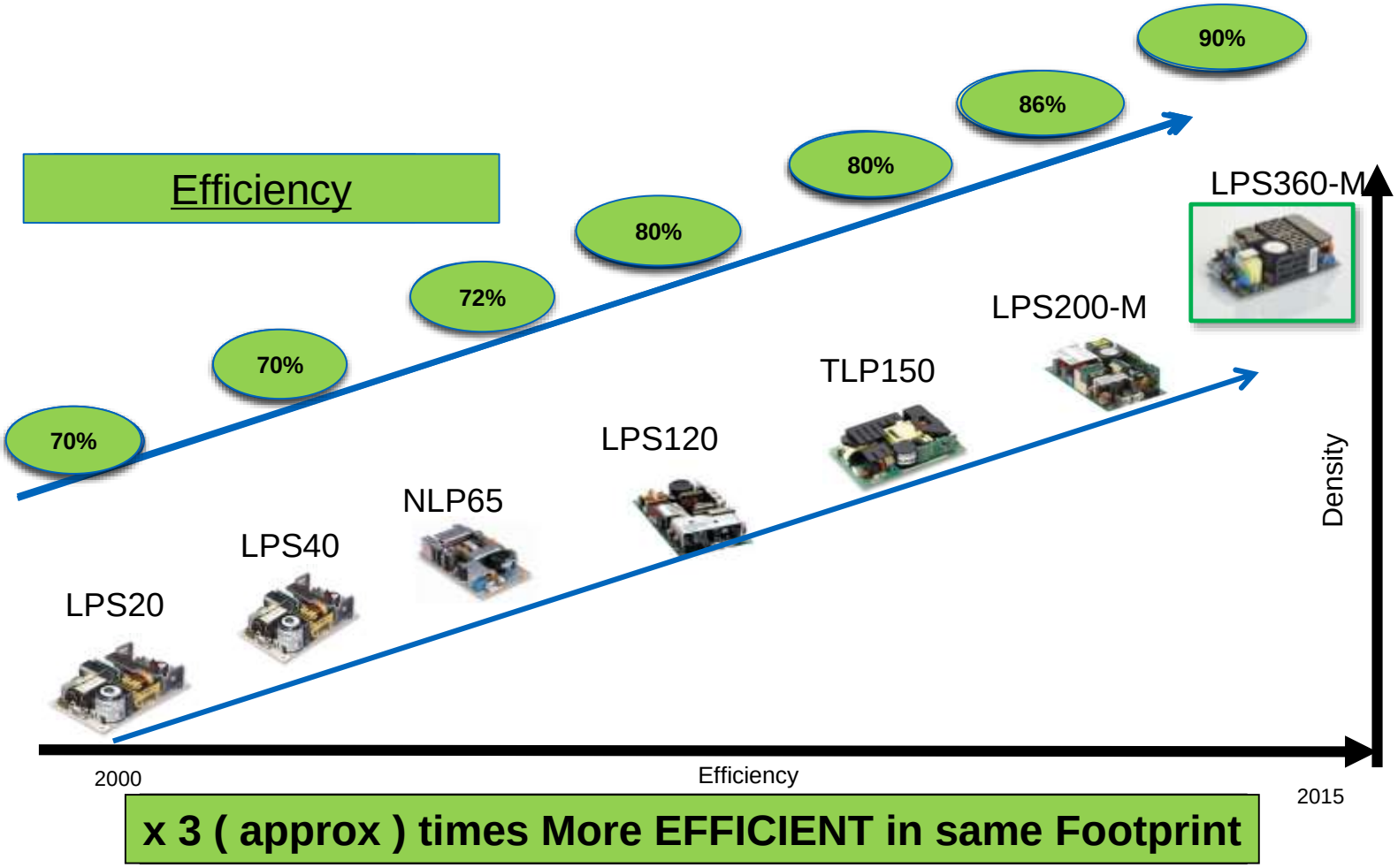


I Need High Efficiency

Or do you mean you want more in a given space?

Power Density Trend

The Power Density : of a PSU is a measure of how effectively the PSU utilises the available Space



x 3 (approx) times More EFFICIENT in same Footprint

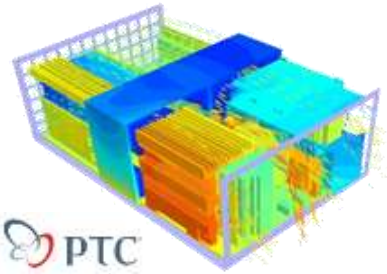
Server Efficiency & How to Get There!

PSU Load	80 PLUS	80 PLUS BRONZE	80 PLUS SILVER	80 PLUS GOLD	80 PLUS PLATINUM	80 PLUS TITANIUM
50%	80%	85%	89%	92%	94%	96%
100%	80%	82%	85%	87%	89%	91%

Development Tools & Applications

Power Supply Modeling

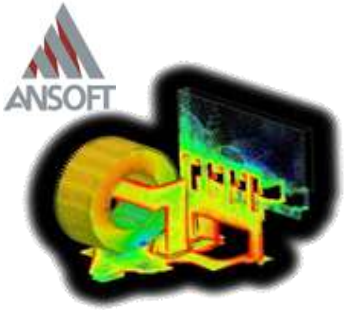
FLOTHERM

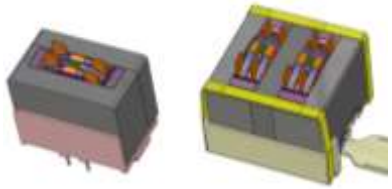


PTC

Advanced Magnetics

ANSOFT



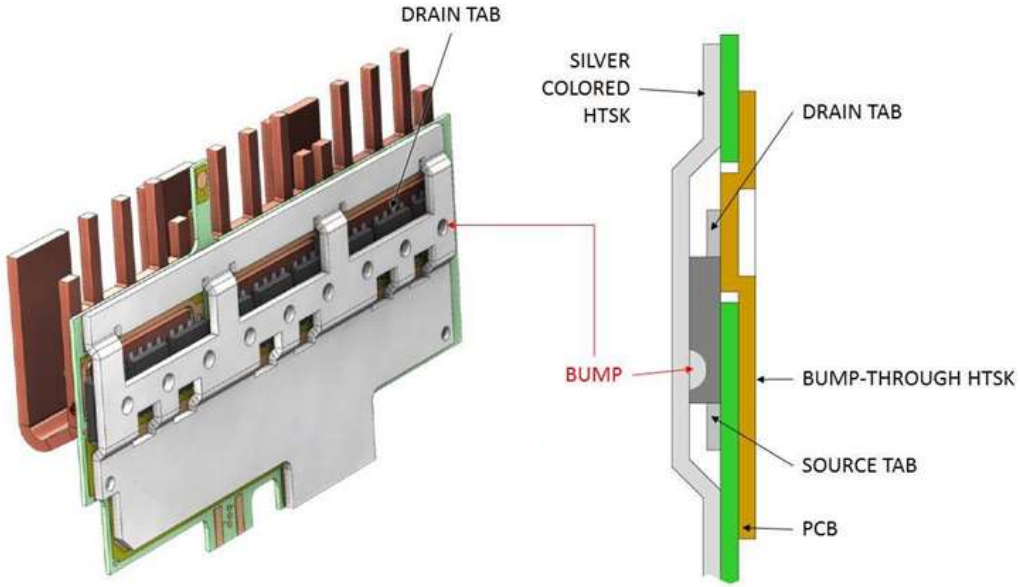


Technology Enablers

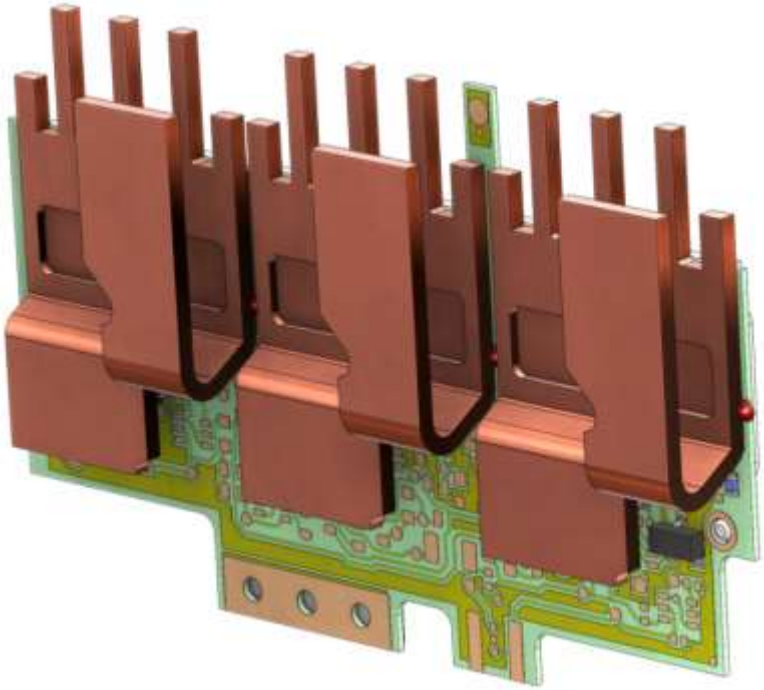
- Enhanced Packaging Techniques
- Greater Magnetics Efficiency
- Improved Thermal Management
- Digital Control Enhanced Efficiency Optimizers
- Total Part Count Reduction
- Applying Latest Silicon Technologies

Better Packaging: Solderable Heatsinks

- Minimize conduction path: No PCB conduction
- Fewer solder joints in power path
- Thermal impedance down by 85%



Bottom Side - Structural busbar + Power FETs

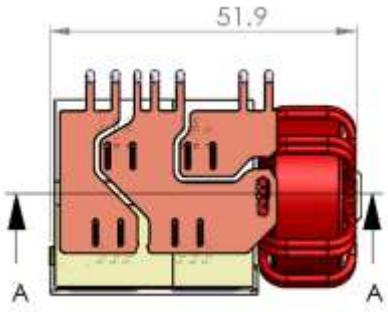


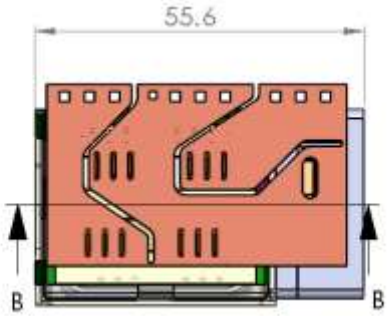
Top Side - upper busbars + SMDs

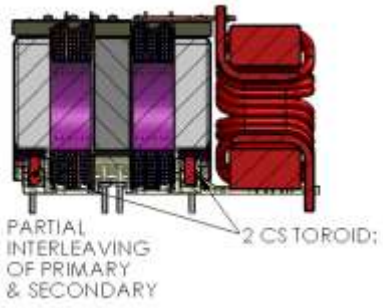
Lower Loss Magnetics

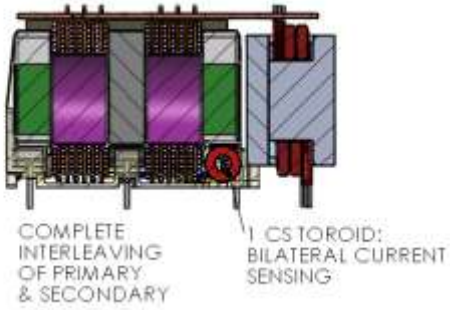
PREVIOUS: 1.6kW

NOW: 2.2kW







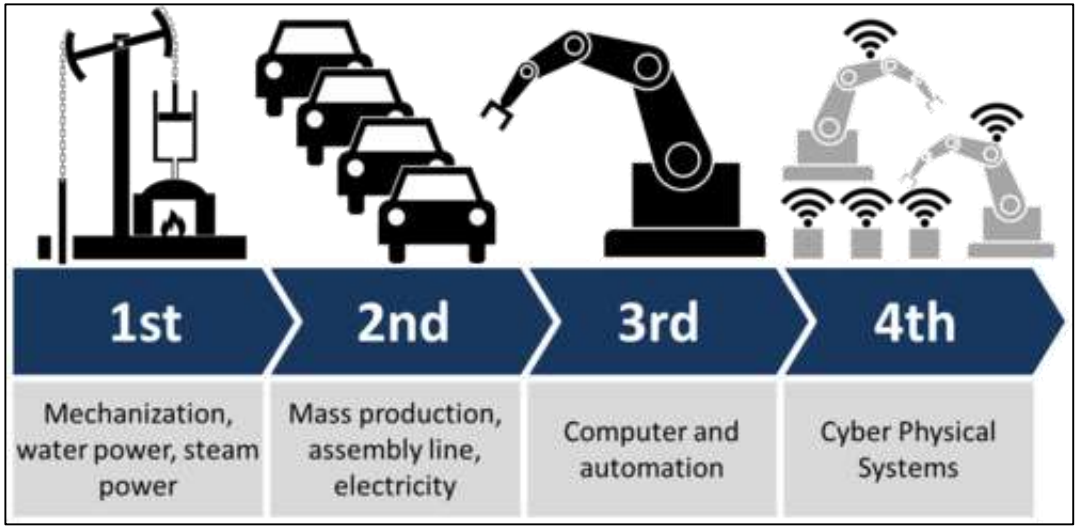


- *Combining Transformer and flat wire heavy current inductor*
- *7% larger **BUT** 38% more power*
- *Utilized self-bonded wire and flat wire automation*
- *More window area*
  - *More copper for higher power capabilities*
  - *Or room for additional turns for higher peak efficiency*
- *Used on Titanium Efficiency designs*

Flat Wire Inductors

Internet of Things & Manufacturing 4.0

- We have all heard of these!



- It is all about equipment communications & control

Artesyn New Products

Open Frame

LCM

Configurable

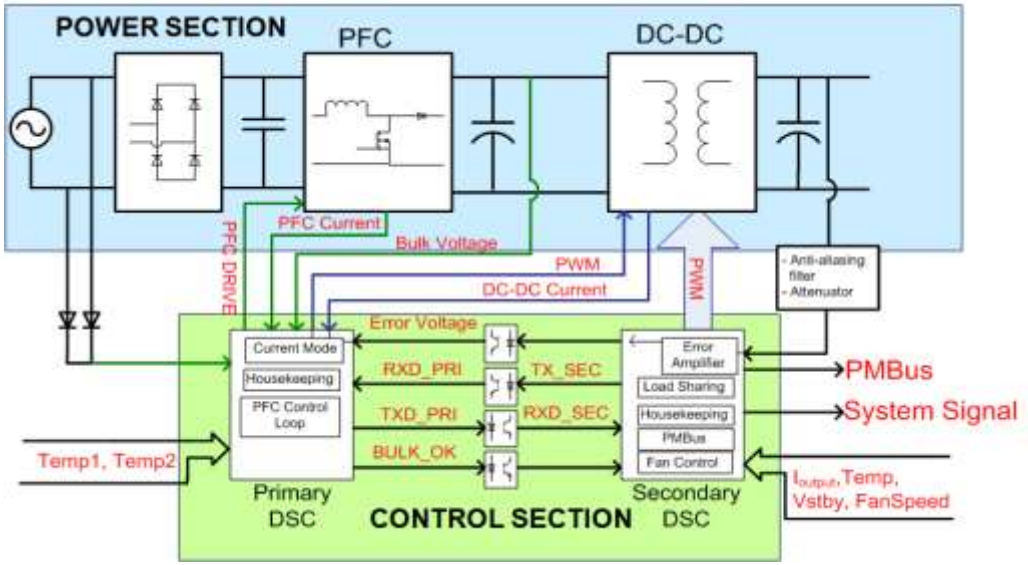
LCC

DC-DC

- Artesyn is the MARKET LEADER in Digital Power
- Our digital products now in production for >16 years

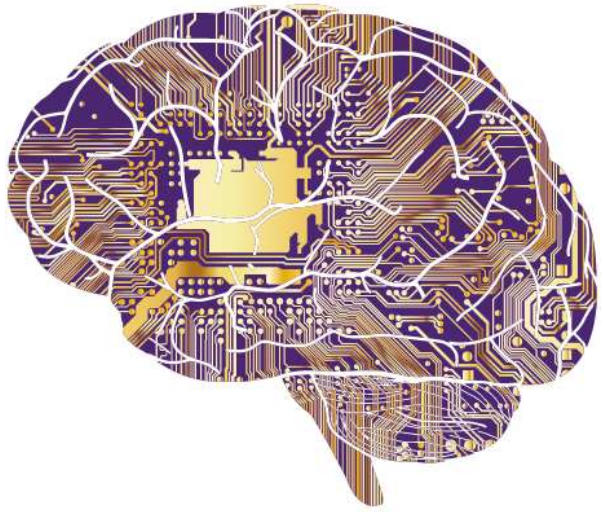
Benefits of Digital Control

- Basic power conversion now consolidated in software modules
  - Eliminates learning stage (as for every new analog or ASIC solution)
- Industry specified set-point & accuracy can be met with standard ADCs
- Load transients can be handled more effectively
  - Due to capability of “predictive and adaptive” control algorithms
  - Feedback loop can now be tailored to operating conditions
- House-keeping and sensing networks are much simpler



Benefits of Digital Control

- Intelligence
  - Efficiency optimization at operating conditions
  - Self calibration
  - Self diagnostics
  - Predictive failure detection (fan, e-caps etc.)
  - Intelligent EMI management
  - Allows 2-way Communications in end application



Many others Features in progress . . .
Limited only by IMAGINATION

Digital Control & Component Count

LPS200

LPS360

- LPS360 differentiation through IP
  - First fully digitally controlled low power open frame product in the market
  - Lowest industry parts count
  - Single board assembly translates to low manufacturing costs

LPS360 : LPS200 Comparison

Output Power	Component Count	PCB Assemblies
+92%	-42%	-67%

Real Life Applications for These

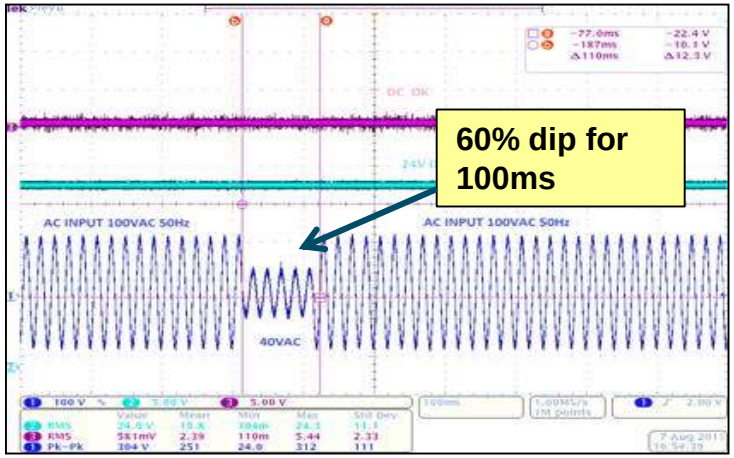
Low acoustics,
Long life
High IP Rating
Communication capability

Dialysis Water Purification Equipment

- Customer Requirements — Standard?
  - Output = 24V, 450W ✓
  - <35dBA acoustic noise at full load ✗
  - Meet EN60601-1 ✓
  - Meet EN60601-2 with no UPS ✗

- Required Mods for Acoustic Requirement
  - Firmware mod to limit max fan speed
  - Use low noise fan

- Required Mod for EMC Requirement
  - Firmware mod to reduce bulk cap UV point
  - Increase bulk capacitance



Banking Automation Service Terminals

Customer Requirements	Standard?
– Output = 24V, 600W	✓
– Easy Maintenance	✗
– 7 year product life	✗

- Required Mod for Easy Maintenance Requirement
  - Use Mate n Lock connectors for the DC output

- Required Mods for Extended Life Requirement
  - Change e-caps for long life parts
  - New fan with lifetime of 70,000h @ 40°C

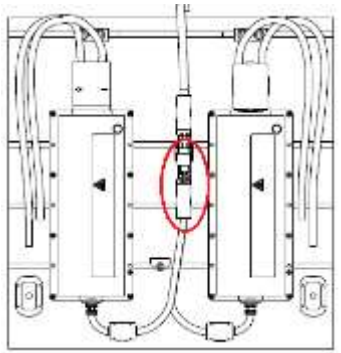
IP64 & Acoustic Specifications

- Electronic machines for automated weaving
- Large (up to 4.5m long) complex pattern capability
  - Upholstery, carpets, tapestry, and fabrics
- Massive linear power supplies previously used
  - No fans allowed due to dust and acoustic noise

Application: Jacquard Weaving Machine

- 15Vdc-525W : Electromagnets
- 24Vdc-320W: Fans & Control
- 48Vdc-200W: Options
- Add thermal Pad
- Remove trimpot/cont. cable
- Specific output V, I settings
- Cable changes

- **Fanless 600W @ 15V x 20**
- **Fanless 600W @28V x 2**
- **Fanless 600W @ 48V x 1**
- **Simple mod**
- **Simple mod**
- **Standard options**
- **Simple mods**



IP65 & Communication/Control Need

Smart Management & Maintenance

Communication
- Secure global 4G communication
- Immediacy of data exchanges / feeds

Smart Management
- Centralised configuration
- Centralised data collection
- Automated alerts

Smart Reporting
- Full data reporting
- Live and historic
- Client web dashboard
- SLA reporting on KPIs

Smart Monitoring
- Temperatures
- Humidity
- Fans
- Brightness
- Media player / router
- Power
- CMS / RDM® communication

Smart Maintenance ®
- Remote fixes
- Trouble ticketing
- On-site maintenance management
- Asset management
- Modular swap-outs

End-to-End Services
- Helpdesk
- Hosting
- SIM management
- Remote updates
- Consultancy

Application: 75”& 80” 2-Sided Displays

- 24Vdc-1.4kW: Screens
- 48Vdc-320W: Fan Tray
- 12Vdc-100W: Electronics
- I²C for remote monitoring
  - Temp, Voltage & Current
- High reliability
- High IP rating

- **Fanless 600W @ 24V x 3**
- **Fanless 600W@ 48V**
- **Fanless 250W@ 12V**
- **Standard Feature**
  - **All can be monitored**
- **Fanless (standard)**
- **IP65 standard option**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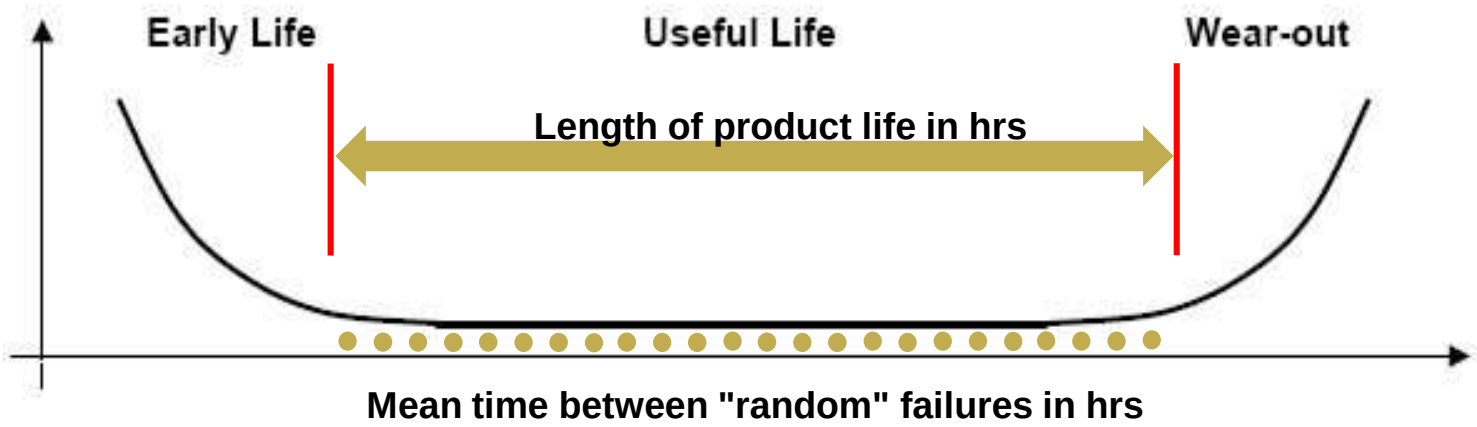
POWER ELECTRONICS 2018

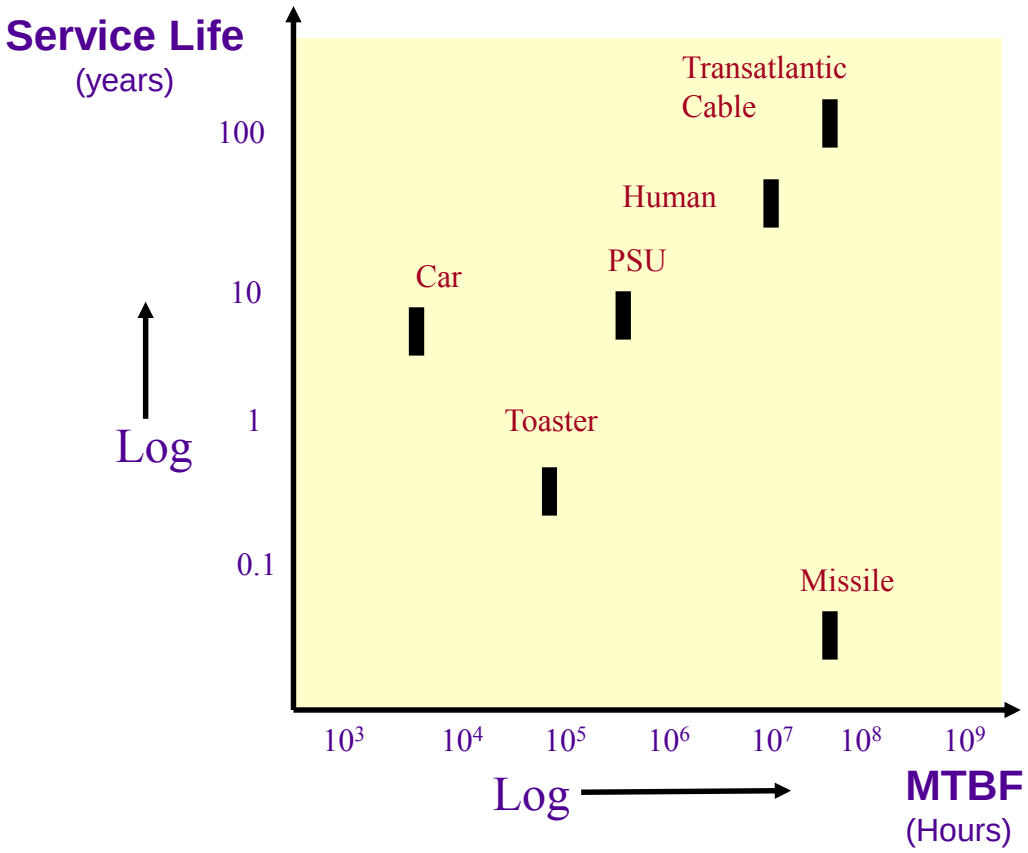
Useful Life of a Product

- Life is dependent on components with a wear-out mechanism
- Many of these are necessary in PSU design



Putting Life into Perspective

Relative Product Lifetime



Relative Component Lifetime