POWERING IN-FLIGHT ENTERTAINMENT EQUIPMENT FOR COMMERCIAL AIRCRAFT

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TDI POWER

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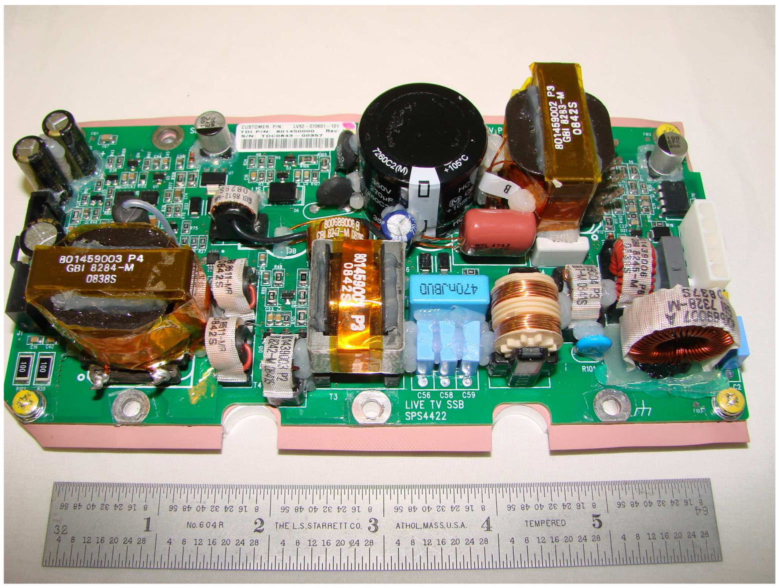
Executive Summary

Modern Commercial Aircraft are deploying more sophisticated passenger entertainment systems, which are putting increased demands on aircraft infrastructure. These systems present unique demands in terms of weight, efficiency, electrical noise, and safety.

Introduction

Most major airlines have installed, or are installing, in-flight entertainment equipment (IFE) with personal displays for every passenger. In many cases IFE is an after market retrofit into existing aircraft. As the number of IFE systems being deployed increases, there is also an increasing need for power converters (generally referred to as "PSU", or Power Supply Units) for these systems.



TDIPOWER: 100-watt Multiple Output Embedded IFE Power Supply

Powering IFE systems is not a trivial task and requires special methods due to specific electrical and safety requirements. Most IFE system PSUs fall into the power range of less than 100W, although some newer IFE products require higher power solutions of 300 watts, or more. While there are an abundance of commercial low-cost standard PSU products on the market in these power ranges, aviation standards generally preclude their usage in these applications.

This paper examines PSU requirements for IFE systems, along with differences from commercial power supply units designed to meet Information Technology Equipment (ITE) standards. This information is not presented as a detailed analysis, but rather to highlight some of the issues that need to be considered when designing or specifying a PSU for IFE.

General Characteristics of IFE Power Supplies

The main generic requirements for airborne equipment are set by the Radio Technical Commission for Aeronautics (RTCA Inc.) in the document DO-160 (latest revision "F"). Specific portions of RTCA/DO-160 detail the requirements applicable to IFE power supplies. Although RTCA, Inc is not an official government agency, their recommendations are generally based on industry consensus and are recognized as the aviation industry's standard. In addition, some aircraft manufacturers have proprietary documents with additional requirements for specific airplanes.

Important factors that need to be considered when designing a power system for IFE products include:

- AC Input Characteristics
- Input Current Harmonics
- Input Power Factor
- EMI, Conducted and Radiated
- Input Perturbations /Hold Up
- Weight
- Environmental

Input AC power characteristics

The nominal AC voltage for commercial airline aircraft is 115Vrms or 230Vrms. (Business jets, on the other hand, generally run on 28VDC systems.) DO-160 stipulates that 115Vrms systems have voltage limits between 97 and 134Vrms and may encounter voltage surges up to 180Vrms for 100ms. While these limits do not present a problem for most commercial PSUs, in the case of 230Vrms systems, all voltage levels are doubled. This means that in 230Vrms systems the PSU has to operate from 360Vrms input for up to 100ms. Due to the relatively long duration of this surge, it cannot be confined by voltage clamping devices, and most commercial PSUs would be damaged by this surge. PSUs for 230Vrms systems should have input components suitable to withstand 360Vrms indefinitely. If an active power factor correction (PFC) circuit is used, its storage capacitance may be charged to $360*\sqrt{2}=509$ VDC during the input voltage surge, which requires proper selection of storage capacitors.

Aircraft primary power can be constant frequency or variable frequency. Constant frequency systems, designated by category A (CF), operate at 400 Hz, nominal, and may encounter frequency variations between 360 and 440Hz.

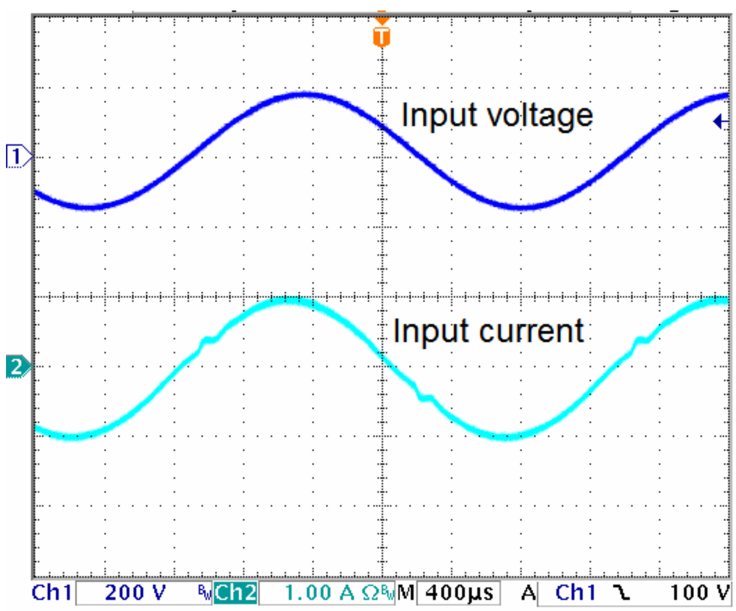
Variable frequency systems may encounter frequencies between 320Hz and 920Hz for category A (WF). Careful attention to the design of the stability components in the PFC section is critical in this case, as the frequency range more than doubles. Most off-the-shelf PSUs are not designed for this frequency range and may have trouble during transients. In particular, IFE PSUs that operate at higher input frequencies require careful input component selection.

Commodity PSUs designed for 50/60 Hz operation may use metalized polyester film capacitors as part of their input EMI filter circuits due to their lower cost and generally smaller size. However, polyester film dielectric losses are normally an order of magnitude higher than for polypropylene film, and increase with frequency, making them a poor choice for IFE applications.

Current Harmonic Limits

Most commercial PSUs are designed to meet the harmonic current requirements of IEC 61000-3-2 for Class A equipment. Here, the IEC standard sets only absolute harmonic limits (given in amperes). The lower the unit's power level, the easier it is to meet these limits. More stringent relative limits (given as ratio to the first harmonic) are set for personal computers, monitors and TV receivers that operate from 75 to 600W, which are classified as Class D.

Unlike commercial PSUs, aircraft electronics have to meet relative limits for harmonics. These are more stringent then IEC limits for class D, and are irrespective of the power level, with no minimum power threshold. DO160F only allows disregarding harmonics below 10mA or 0.25%, whichever is higher. To achieve these demanding specifications, input current needs to have low THD and be exactly in phase with input voltage, as shown below. The illustration in Table 1 compares commercial and aircraft harmonic current limits calculated for equipment with input power 100W, with a 1st harmonic of 1A.



AC input Voltage and Current

Harmonic order	EN61000-3-2 class A	EN61000-3-2 class D	DO-160E
2	1.08	-	0.005
3	2.30	0.340	0.050
4	0.43	-	0.005
5	1.14	0.190	0.060
6	0.30	-	0.005
7	0.77	0.100	0.043
8	0.23	-	0.005
9	0.40	0.050	0.017
10	0.18	-	0.003
11	0.33	0.035	0.027
12	0.15	-	0.005
13	0.21	0.029	0.023

Table 1 – Input current harmonic limits calculated for 100W power supply with 1st harmonic of 1A

RTCA/DO160 sets a much more stringent requirement for harmonic content than the IEC. In addition, harmonic content for aircraft equipment has to be verified with a distorted input voltage waveform of >8% total harmonic distortion (THD) to ensure stability under realistic power conditions. As such, the EUT should not draw harmonic currents greater then 1.25% of the specified requirement for every 1% of distortion in the corresponding harmonic of the input voltage. As a result of these requirements, the input PFC/ Harmonic circuitry in IFE products are generally larger and take up more area.

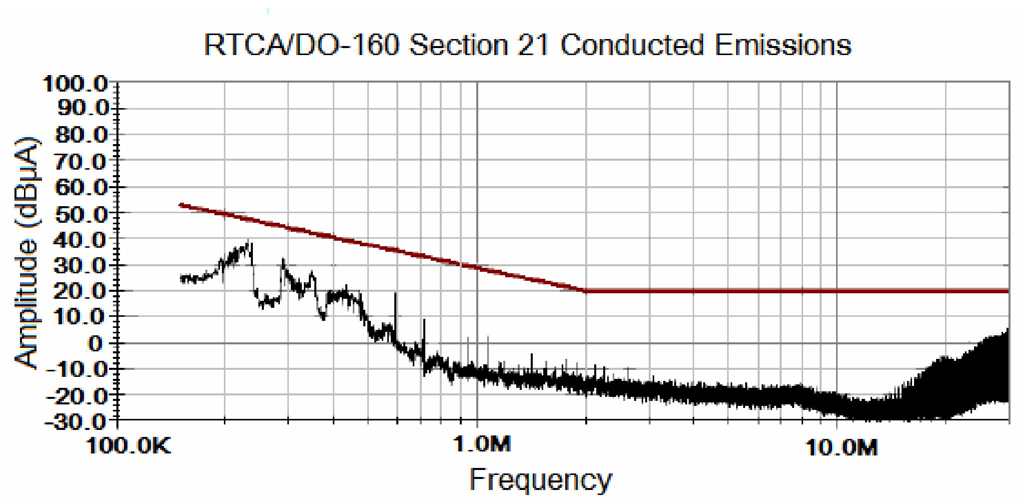
Power Factor

For a certain designation of equipment >20 VA, RTCA/DO160F specifies power factor (PF) limits as a function of input power level. For example, equipment with combined power >150VA should have PF>0.968 leading or >0.8 lagging. This is generally not a problem for commercial PSUs that employ active PFC circuits with a 50/60Hz input. However, meeting the above limits with input frequencies up to 800 Hz is complicated due to the presence of across the line capacitors in EMI filters that draw non-compensated "leading" currents proportional to the AC input frequency. As a result, meeting aircraft's PF requirements may require a combination of active and passive power factor correction.

EMC requirements

Aircraft equipment is divided into five categories for EMI requirements, depending on location and separation between the equipment and aircraft radio antennas. IFE normally falls into Category M. Methods for measuring radio-frequency emissions differ for aircraft equipment as compared to IEC/EN methods used on commercial equipment. This precludes direct comparison of the requirements. For example, per DO160/RTCA, the emissions are measured with peak detector, as opposed to a quasi-peak detector for commercial equipment. Likewise, conducted emissions are specified for currents as measured with a clamp-on current probe for DO160 testing, versus voltage measurements on a 50-ohm resistor for commercial equipment.

Another major difference is that DO160F/RTCA establishes conducted emission limits in the range up to 152 MHz, while the EN55022 range is to tops out at 30 MHz. This higher upper frequency limit generally requires a combination of magnetic element shielding, special PCB layout and peak voltage limiting networks in order to achieve compliance for IFE equipment. A commercial PSU compliant with EN55022 class B requirements will not necessarily meet DO160/RTCA limits.



Conducted EMI Spectrum of typical Power Supply

Momentary power interruptions

Transfer of power from a ground source to an on-board generator can result in power interruptions for up to 200 ms. For equipment with digital circuits DO160/RTCA specifies a variety of interruption patterns from 2 to 200 ms. The resulting hold up time requirement is an order of magnitude higher then the 16-20ms typical for commercial PSUs. Compliance requires much larger bulk storage capacitance. These can provide a significant design challenge in terms and size and weight (see the following section).

In turn, the larger charging energy demanded by these capacitors may require an unusually large size of inrush current limiting resistor as compared to commercial PSU. This is especially true for equipment in the DO-160 "Designation I" category, with specific limits to cold and "hot restart" inrush currents.

Weight

Weight is probably the single most important requirement next to safety. Weight costs money, and as fuel prices rise so does the attention to weight on commercial aircraft. Operators are looking at many different ways to reduce the weight of the plane. As new IFE products are designed, lower weight requirements for systems are driving new PSU requirements to be smaller and less weight. To comply with these requirements modern power design techniques are being deployed to drop the weight of power products to 50% of present solutions. A typical embedded 100w multi-output unit needs to weigh 1 pound, or less.

To achieve these requirements a collaborative design effort between the PSU vendor and the IFE electronics manufacturer is required. By considering the PSU early in the design and careful attention to details, an integrated approach to heat-sinking, efficiency and assembly will reduce the size and weight of the entire product. A typical commercial off-the-shelf product will not be optimized for these requirements and additional size and weight will result.

Environmental

Environmental conditions that the power system will be subject to will vary depending upon where the device is located within the plane. Typically, interior cabin temperature range can be -20°C to +50°C ambient. The wide range results from planes left overnight in Alaska or on the tarmac in Arizona. In addition, when the plane is operational, PSUs that are embedded within IFE electronic assemblies may see an additional temperature rise of typically 10-20°C. Because of this, PSUs for commercial aviation typically need to be designed for -20 to +70°C operation.

Vibration requirements can also be quite severe. These are typically specified as Category T, combining profiles with both sine and random vibration levels. The resulting total environmental test conditions are more typical of a MIL STD unit than that of a commercial PSU. As a result, a more detailed design and test protocol is required to insure compliance.

Failure Mode Effect Analysis and Containment

Any electronic assembly can experience failure. However, on commercial aircraft failure mode effects can be catastrophic if not properly understood and contained. This requires the PSU supplier to conduct extensive failure mode effects analysis (FMEA) and testing to assure that no single component failure will result in a safety compromising event, including fire, smoke or burning smell.

In some cases, this requirement will result in redundant connection of components in series or parallel, so that the failure of one component won't overstress another component to the point where it compromises safety.

Reliability

Beyond FMEA, commercial aircraft manufacturers have high expectations as to equipment durability and reliability. This will require special attention be paid to design for reliability considerations. These start with conservative component de-rating guidelines, such as those laid out in the Navy document NAVSO P-3641A. Along with conservative design margins, a comprehensive program of Highly Accelerated Life Testing (HALT) and production Highly Accelerated Stress Screening (HASS) provide what TDI Power believes are best practices for assuring reliability. Please reference TDI Power White Paper TW0059: Power Conversion Reliability for additional details regarding reliability best practices.

Conclusion

Power supplies for IFE require special design methods due to specific aviation electrical and safety requirements, which generally preclude usage of off-the-shelf commercial power supplies. The best approach is to understand the design requirements early in the system configuration and work with the PSU manufacturer to integrate the PSU into the IFE assembly. Careful attention to detail will result in a product that is safe, reliable, meets all the DO-160 requirements and will save weight while providing outstanding product value.