ATR solutions for Rugged COTS applications

Rugged COTS needs:

Rugged COTS enclosure products are playing an increasingly pivotal role in the strategic thinking of defense and military planners shaped by the events of 9/11 and its aftermath. The fact that there is a decided emphasis on unleashing the latest technological advances into the combat theater of operations like “locate, identify and destroy” missions signifies a considerable investment in sophisticated equipment geared towards electronic warfare. This is evident as news reports of unmanned air vehicles (UAVs) like the Predator, are not only used in locate and identify, but destroy-missions successfully. Such skilled and innovative projections of military power are made possible by the use of ruggedized electronic equipment. The Air Transport Racks (ATR) fills an important niche in such mission-critical applications.

Introduction to ATR:

ATR has been a de-facto standard form factor for aircraft board electronic equipment since its beginnings in World War II days of 1940 when it was outlined in ARINC SK-230, the precursor to the present ARINC 404A. Two important ARINC drawings, the SK-141-10 and the SK-141-17 detailed the critical dimensions and tolerances for the initial 3 basic form factors, via the ½, 1 and 1 ½ ATR. The drawings became the basis for ARINC 404A. Thus, any equipment built per the ARINC standard should utilize the specified case sizes even if made by different manufacturers. They can be used interchangeably in equipment mountings and radio racks made by other manufacturers of ATR equipment. ATR chassis are very popular solutions for meeting today’s demanding requirements of avionic applications. A well-designed ATR chassis should also comply with the various military standards that are a prerequisite for these avionic applications.

ATR Case Sizes:

From these 3 initial case sizes, other sizes were standardized, like the ¼ and ¾ inch width sizes and short and long depths. See Table 1 for all the case sizes and their dimensions.

Design Criteria:

Given the overall mechanical dimensions for the various case sizes, ATR designs should be geared towards the following critical considerations:

- Operating temperature, humidity and altitude
- Structural integrity
- EMC
- ARINC 404 mechanical guidelines

The operating temperature and altitude at which the ATR equipment is expected to function has a significant impact on the type of cooling method chosen for the thermal solution. For all high altitude applications (> 55000 ft) or in applications where the operating temperature range is very wide (like -55 to 85°C), conduction cooling is the perfect solution. This requires the use of conduction cooled boards which are full MIL-grade and therefore quite expensive. The chassis also requires features like wedge locks in the card guides, ducts for coolant medium etc and good environmental seals. Such conduction cooled ATR systems will adequately meet the requirements, but they come at a high price in terms of cost and development time. On the other hand, if the operating temperature range is more narrow (-20 to + 65 °C) and the altitude is less than 50000 ft, forced air convection cooling (flow-through type) is ideal. This enables the use of COTS boards and modular COTS solutions for the chassis that are readily available and offered at a reasonable price. So, we are focusing our study on the design of convection cooled ATR chassis.

The air-moving device in the convection cooled chassis should meet the operating temperature and humidity range while delivering a high flow rate at the prevailing pressure. This is critical especially at altitudes above 15000 ft to 50000 ft, where air density is reduced. A practical and effective design would be to locate the air-moving device at the rear of the ATR enclosure creating a negative pressure environment that is conducive to flow-through type of cooling. The air intake, which can be either in the front or the sides, should incorporate a high-performance air filter. This is very essential if the equipment is on aircraft operating in a desert-like environment -- prone to dust and other contaminants. Figure 1 shows an example of a ¾ ATR based on a forced air convection solution and incorporates an efficient, washable, electrostatic air filter that provides a high degree of dust-arresting capability. Hermetically sealed thermostats and fan-fail alarm options quickly identify any over-temperature conditions brought upon by fan failures, clogged air filters, etc. These measures greatly enhance system reliability, a key for mission-critical applications

Figure 1

The ¾ ATR example above by Elma Electronic shows a forced air convection solution. The hermetically sealed thermostats and fan fail alarm options quickly identify over-temperature conditions.

Structural integrity of the enclosure is another major consideration in ATR designs. Owing to their application environments, the equipment will be subject to high vibration (random or sinusoidal) as well as shock levels. The mechanical frame must be robust, yet light enough to be deployable. Conduction cooled ATRs are usually machined enclosures or welded double-walled enclosures with machined card guides. These provide excellent resistance to shock and vibration, but end up weighing more and are quite expensive. Moreover, they do not lend themselves to modularity. A viable and proven design for convection cooled ATRs is the use of formed aluminum sheet metal in 2 mm thickness for the frame. A standard aluminum extrusion-based Eurocard card cage inside reinforces this frame adequately while ensuring a low mass. The significant advantage of this approach is the inherent flexibility to develop modular and cost-effective solutions in a shorter timeframe. The capability to design removable panels for maintenance access is another plus. The ¾ ATR shown in Figure 3 demonstrates this approach. The side walls are easily removable, a feature that helps in system assembly and maintenance. Keeping the center framework as a separate formed sheet metal item ensures modularity. The 3D model of the chassis highlights this concept. This approach makes it easy to expand the ATR design from the ¼ to the 1 ½ design by changing only the center frame and keeping the side access panels the same. In most cases, an isolation mechanism is not required since the ATR mounting tray already has isolators for meeting the vibration profiles. However, if one is required, the isolation mounts have to be installed within the confines of the ATR case size.

Electro Magnetic Compatibility (EMC) of the enclosure is of utmost importance to the system's integrity and should be dealt with systematically from the component level

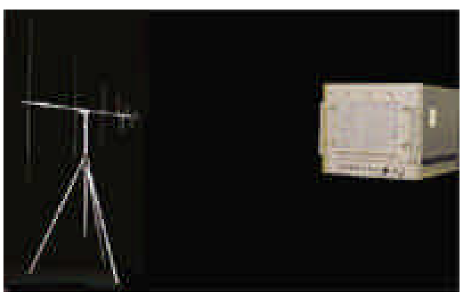
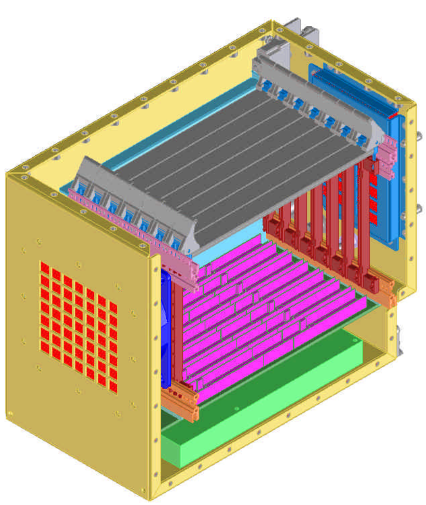


Figure 2 ***shows a radiated Emissions testing in progress***



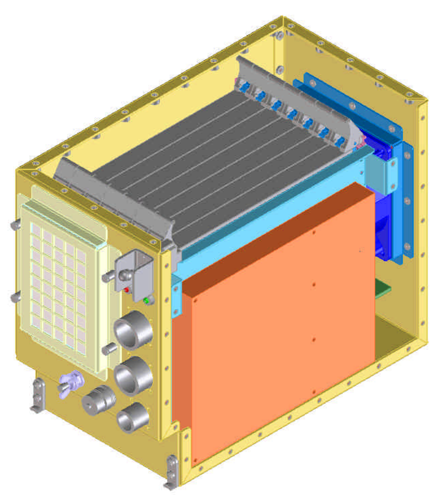


Figure 3

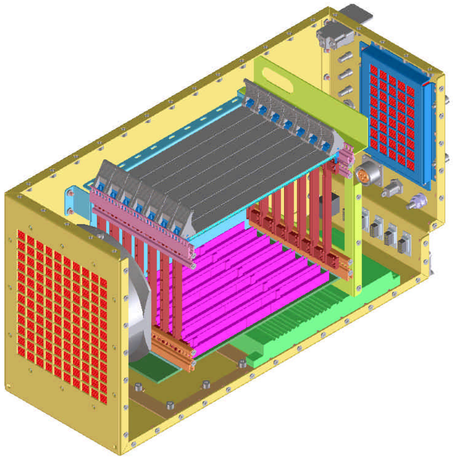
The models above illustrate a design using formed flanges and the bolted construction. This facilitates flat EMI gaskets for added attenuation while ensuring modularity.

(Boards, power supplies, line filter, fans) to the enclosure subsystem level. An electronic device is considered to be Electro-magnetically compatible with its environment if it is neither susceptible to the spurious emissions (both conducted and radiated) from neighboring equipment nor exceed certain levels of such emissions into its environment. Figure 2 shows radiated emissions testing in progress on a COTS chassis to determine its shielding effectiveness. . The Shielding Effectiveness (SE) is a measure of the degree of attenuation (in decibels) that an enclosure provides to unintended Electro-magnetic radiation. An 80 dB attenuation means that the enclosure attenuates 99.99 % of EMI. To achieve these levels, several critical factors should be considered in the design of the enclosure. For example, the material, material thickness, material conductivity, overlapping flanges to minimize seams, EMI gaskets with high attenuation and good environmental performance, optimum bolt spacing, optimum aperture size, proper electrical bonding with mating surfaces, etc. Sophisticated software is available to calculate the SE of enclosures to different frequencies. A general and simple rule of thumb for maximum aperture size is approx. 1/50 λ where λ is the wavelength and is calculated using the formula λ (cms) = (3 x 10*4)/ f , where f is the frequency of the offending signal in MHz. The Elma ATR design is based on the aforementioned factors. The choice of 2mm aluminum throughout the enclosure ensures a high conductivity, while the aluminum extrusions for the card cage minimizes the use of dissimilar metals, a source for galvanic corrosion. The 3D model shown in Figure 3 illustrates this design using formed flanges and the bolted construction, which facilitates flat EMI gaskets for added attenuation. Honeycomb filters located at the air intake and exhaust apertures provide over 80 dB attenuation while ensuring maximum percentage of open area for airflow.

The entire ATR chassis has a conductive, corrosion-resistant coating per Mil-C-5541, class A. Other elements of such a chassis include power supplies and fans which meet MIL-STD-461D levels of conducted and radiated emissions, shielded and hermetically sealed switches, LEDs and fuse holders and optimum routing of power wiring to reduce electrical noise. If additional filtering for conducted emissions is needed, a Mil-STD-461 compatible line filter integrated into the power input meets the requirements.
ARINC 404 mechanical guidelines should be followed in the these areas:

- Allowable projections in the front and rear of the unit
- Weight and center of gravity limits
- Hold down types to secure the front of the case to the rack
- Connector type (MIL-C-81659), location and relationships
- Indexing pin arrangements
- Electrical bonding practice

The popularity of the VMEbus architecture in the military hardly needs to be emphasized. The robustness of the mechanical packaging (in terms of the Eurocard card cage, the plug-in boards with their shielded face plates, locking handles and high reliability connectors) in conjunction with higher bandwidth, speed, power and increased I/O that VME64X yields, makes it ideal for rugged COTS applications. The 6U 160mm form



factor is an ideal fit for the different case sizes and the orientation of the card cage facilitates flow through type convection cooling. Innovative VME backplane designs can further ease the difficulties in the available space for I/O cabling or lack thereof. Certain high-speed buses like Mercury Raceway are widely used on the P2 for higher throughput. Figure 4 shows the 3D model of a ¾ long ATR, which provides an easily removable panel on the bottom for access to Raceway.

In conclusion, ATR-based electronic equipment designed properly by considering these guidelines

Figure 4
¾ Long ATR with access panel below P2 for Mercury Raceway access.

will provide a rugged, high-performance, reliable and compliant platform for mission-critical avionic applications at a reasonable price and timeframe.

Ram Rajan
VP of Engineering
Elma Electronic
510-656-3400
ramr@elma.com
www.elma.com

TABLE 1 - ATR CASE DIMENSIONS

ATR SIZE	W +/- .03in	L1 +/- .04in	L2(MAX) in	H(MAX) in
Dwarf	2.25	12.52	12.62	3.38
1/4 Short	2.25	12.52	12.62	7.62
3/8 Short	3.56	12.52	12.62	7.62
3/8 Long	3.56	19.52	19.62	7.62
1/2 Short	4.88	12.52	12.62	7.62
1/2 Long	4.88	19.52	19.62	7.62
3/4 Short	7.5	12.52	12.62	7.62
3/4 Long	7.5	19.52	19.62	7.62
1 Short	10.12	12.52	12.62	7.62
1 Long	10.12	19.52	19.62	7.62
1 1/2	15.38	19.52	19.62	7.62