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MINIMIZATION OF FLIGHT DATA RECORDER FOR UNMANNED AERIAL VEHICLES AND ULTRALIGHT AIRCRAFTS

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Abstract

Flight data recorder is device that records various flight parameters and is able to survive the crash for increasing aviation safety. Aircrafts that can have an impact on the safety of flights in the airspace are becoming smaller and more accessible. Good examples are unmanned aerial vehicles or ultralight aircrafts. It would be appropriate to equip these objects into Flight Data Recorders in order to ensure that every crash will be accompanied by improvement of the aviation safety. While the legitimacy of FDR installation into manned objects is pretty obvious, for a UAV it is not as clear. There are some cases that the UAV has dropped and damaged some facilities or even dropped at human, additionally loss of often very expensive object should occur as rarely as possible. In both cases, the lifting capacity is very limited so there is requirement significantly to reduce the weight of the recording device. Minimum dimensions and weight are strongly dependent on the assumed conditions of the accident and on the size of the aircraft. The article describes design of the electronics module and partial concepts of the whole flight data recorder. Project is considered to provide a construction capable to be mounted on object with rigorous lifting capacity restrictions.

Keywords: *flight data recorder, semiconductor memory, UAV, aviation safety, accident, ultralight aircrafts*

1. Introduction

Almost all modern aircrafts contain two or more types of devices to record flight parameters. The first one is called as Flight Data Recorder and is used for storing flight data even after an accident occurs. Another type almost equally widespread is the Quick Access Recorder used in the exploitation process and ensuring the safety of flights [1]. The rapid growth in digital technology, including memories and microcontrollers, allows using these modern solutions to minimize size and weight of recording devices. A special area for development is the ability to mount the crash survivable recorder on Unmanned Aerial Vehicles or on ultralight aircrafts where lifting capacity is very limited. To be able to accomplish the task there is necessity significantly to lower the weight of such a recorder nevertheless keep an ability of surviving. It seems impossible to ensure survival on all terms contained in the regulations regarding to civil aircrafts. On the other hand, such lightweight object in case of crash behaves differently. It is able to conjecture that accelerations will be significantly lower and time of burning will be shorter especially on electrically propelled aircrafts. However, in order to get closer to these requirements, a completely new approach to design of Flight Data Recorder must be undertaken. The first major step is to reduce to minimum the size of the electronic module that has to survive crash. Subsequently consequently will be possible to reduce the volume and weight of the housing for electronics. The further step worthy of consideration would be the use of modern materials such as composites and innovative insulating materials in assembly of protection case. Another important issue is selecting electronics components capable of proper work at high ambient temperature conditions allowing using more efficient phase − change material into thermal block.

2. Specification for crash surveillance

Over the years, the requirements for Flight Data Recorders changed over time with the development of technology. The actual specification is described in the EUROCAE document ED-112 [2] (Minimum operational performance specification for crash protected airborne recorder systems). The article contains variety of requirements for software and hardware. One of the most important issues is ability of FDR to survive in conditions of crash. The flight data recorder shall be capable of preserving the recorded information when subjected to the three following sequences of tests:

a. Impact shock, penetration resistance, static crush, high temperature fire and fluid immersion,
b. Impact shock, penetration resistance, static crush, low temperature fire and fluid immersion,
c. Impact shock, penetration resistance, static crush, deep-sea pressure and sea water immersion.

Any integrated circuit cannot survive such as conditions therefore; the system is placed in the appropriate housing structure. Design of standard flight data recorder protection case is presented on Fig. 1. Simplifying the steal armour plate prevents from penetration and static crush in addition it must be sealed to withstand deep-sea pressure and seawater immersion. Isolation layer and phase − change material are able to protect unit from extremely high temperatures, in the case of burning. From the figure below, we can infer that along with decreasing size of memory unit it will be possible to trim all layers constituting the protection case.

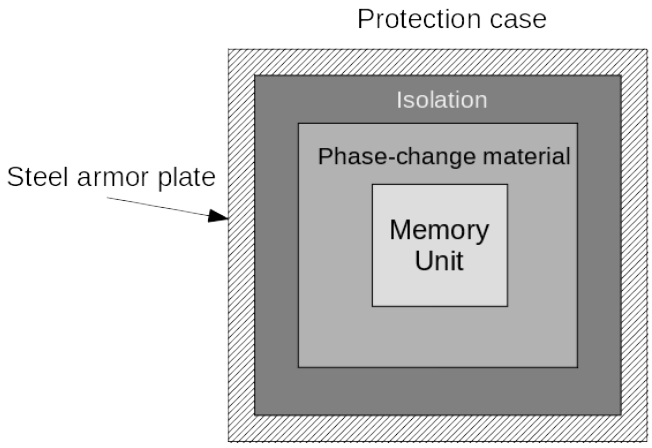

Fig. 1. FDR protection case

2. Project of minimalized Flight Data Recorder memory unit

In the majority of civil aircrafts Flight Data Recorder is integrated with Flight Data Acquisition Unit, however only FDR is protected from appearance of circumstances descripted in chapter 2. In this article there is presented another approach to arrangement of units. In this case, Flight Data Recorder and Flight Data Acquisition Unit are separated and connected via communication interface. In this case plastic optical fibre (POF) interface is selected. Such a solution allows for convenient deployment of components maintaining electromagnetic compatibility. Conceptual drawing is featured on the Fig. 2. It can by noticed, that protecting case secures only the absolute minimum elements and even media converter is foreseen not survive a crash.

Memory unit consist of a microcontroller and two semiconductor memory chips. Each element is rated to proper work up to 125ºC ambient temperature. Application such as components allowing reduce amount and type of isolation and phase − below change material layers. The most common memory chips are rated to 85ºC and for these, thermal block maintain temperature lower than 60ºC. There are some additional elements not placed on the picture for example power supply unit which also meeting assumed temperature requirements. Project was held in

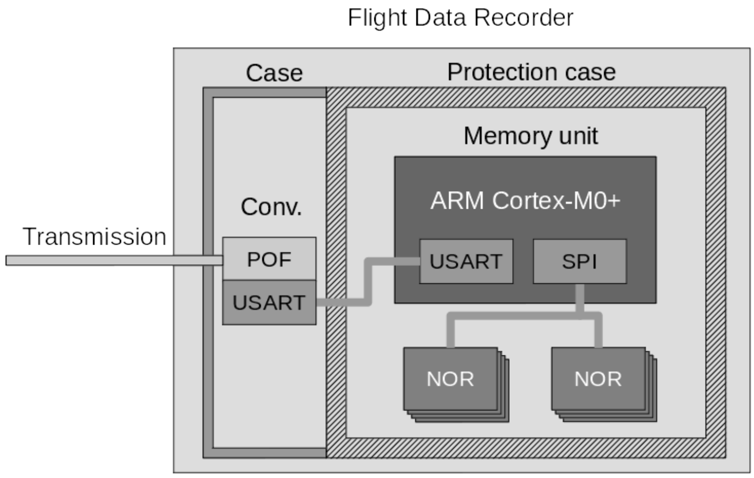

Fig. 2. Flight Data Recorder conception

Altium Designer and reaches diameter equal to only 18 mm. There were not used any Ball Grid Array (BGA) elements regarding to prototype character of solution. Commercial version can be further reduced as a result of application of BGA technology. Fig. 3 shows project of described module, which is compound from two connected PCB boards making small cylinder. Memory module from Cypress Semiconductor was placed on the coin with dimensions close to the PCB and also presented in order to introduce real scale of elaborated solution. The entire structure is characterized by simplicity and is imitated number of applied elements. Despite the higher density of storage space into NAND flash memory chips, NOR flash were selected due to easiness of use and excellent price to environmental conditions endurance factor [3].

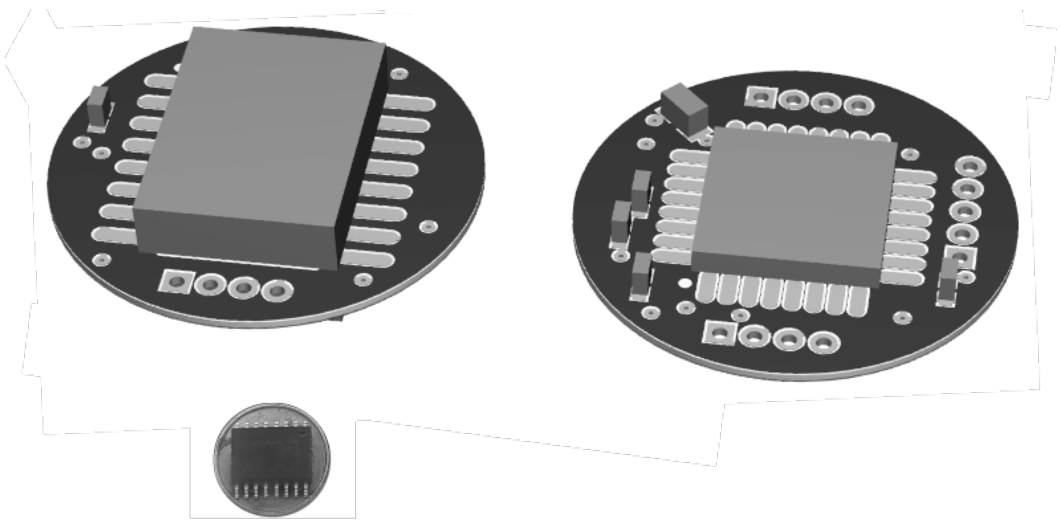

Fig. 3. Flight Data Recorder PCB project

3. Recording system arrangement considerations

Planned arrangement is presented on the Fig. 4. This is the second most spread installation of recording system on civil and military aircrafts. The possibility of unrestricted and optimal deployment of components has to be considered as undeniable advantage of such a solution. However, the disadvantage is a necessity to equip the object with reliable transmission medium to connect the registration system components. Another very important aspect is high system integration in unmanned aerial vehicles which pretty often means that module for recording every important parameter is already embedded [4, 5]. In this case, the only feature missing is presence of crash survivable memory module. In that situation, flight data acquisition unit is superfluous. Peeled architecture is conducive to such a situation. UAV should be equipped with Flight Data Recorder with accordingly manufactured media converter located outside protection cover. For General Aviation aircrafts and other small flying objects, we meet the very different avionics, which often entails individual approach to constructing of the Flight Data Acquisition Unit. Figure simplifies all incoming parameters to the three main groups, but in each of this group parameters can exist in forms that require completely different measurement methods. It is possible that for two seemingly similar aircrafts completely different electronic components must be applied. Building a universal device can be very expensive and extremely difficult. The easiest solution seems to be a situation where the manufacturer of the aircraft provides FDAU equipped with the standard data bus. This would enable a simplification of the entire system similarly to previously mentioned UAV case. Unfortunately, enforcement of mounting a relatively sophisticated unit on often-inexpensive object is difficult. It can be predicted that the formation of appropriate legal regulations will result in decreasing accessibility of small manned flying objects.

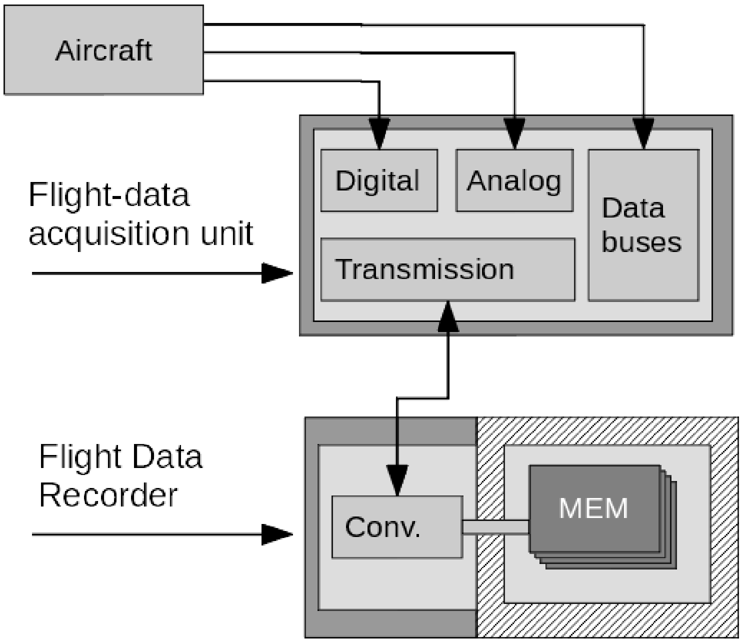

Fig. 2. Recording system memory space organization

4. Software assumptions

Air Force Institute of Technology possesses experience in the software production for Flight Data Recorders. Among other things, created high reliability recording system for flash devices can be counted as evidence. Despite the fact that it was developed for NAND memory chips, characterized by complicated handling procedures and much higher memory capacities, it is intended to adopt examined software procedures for NOR memory. Due to simpler handling procedures and regular synchronous serial communication interface, selection of the microcontroller with fewer resources seems reasonable [6]. Additionally microchips based on Cortex M0+ architecture are transparent and widely approachable for severe environmental conditions. Another important advantage is very low price, which has large significance for small and comparatively inexpensive flying objects. The current solutions are based on three extracted software layers:
1. main program,
2. recording system,
3. memory handling.

Main program controls receiving procedures of data and takes control over entirety. Recording system takes over some wear-levelling task but mainly it is responsible for providing suitable arrangement of records and manages writing and reading procedures. And finally, memory handling is responsible to communication with memory [7]. In comparison to the NAND chips minor edits has to be done in recording system and main layer, whereas memory handling changes into much easier version.

5. Conclusion

Variety of objects that fits into anticipation for developed solution is wide. They are very different from each other. Therefore, it would be wise to produce single project of electronic module as small as possible and few projects of protection cover, which depending on the sizes will be cover less or more strict assumed crash conditions. A matter of choosing the adequate level of protection will be very difficult. It is understandable that the determination of such requirements would have to be supported by concrete researches including crash tests. Examination of this type entails the huge costs. However, such works seem to be sorely needed in the time, in which there is no doubt that UAV's will be operating in newer and newer innovative applications [8]. Produced device is characterized by 64 MB memory space what allows to store any parametric data for sufficient amount of time in purpose of accident analysis. Make usage of BGA elements will result in even greater reduction of size, while simultaneously allows for the enlargement of recording area. There are no contraindications that the experience acquired while pursuance of this project will be transferred to modify Flight Data Recorders for regular aircrafts.

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