Development of the Aircraft Structural Health Monitoring Equipment integrating Optical Sensor and Analog Sensor

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ABSTRACT

The structure of the aircraft has made lots of effort to secure the safety, and the safety is remarkably secured through the lifetime management and the non-destructive inspection. However, periodic inspection requires much time and expense, and various monitoring techniques for aircraft structures are required, especially when the SHM technique is studied for composite structures that cannot use traditional lifetime management techniques. For performing this monitoring, the predeveloped analog sensor has a limit in durability and cable weight. Therefore, the demand for the monitoring equipment of the new technique has been increasing, and FBG and PZT sensor are used representatively. In this paper, we have developed a device that can acquire analog sensor (Accelerometer and Strain gage) and FBG sensor, and support interworking with the Air Data Bus (MIL-STD-1553B, Ethernet) for real-time analysis. Also, it satisfies various military environmental requirements for use in military aircraft. The equipment which is introduced in this paper is expected to be used for SHM and lifetime management.

1. INTRODUCTION

The proportion of composite materials used in aircraft development is increasing. Using light and rigid composite materials can reduce the weight of the aircraft, giving advantages such as range, speed, and maneuverability. The monitoring method such as cracking of the composite material is hard to find. However, it can be detected using FBG sensors and PZT sensors. Currently existing monitoring devices are used as separate devices according to the sensors to be measured, but this development device can measure both using existed analog sensors and FBG sensor. Therefore, it is possible to integrate metal structures and composite structure at once. In this paper, we describe a schematic design method for monitoring equipment that integrates analog sensors and FBG sensors. In addition, the test method for mounting the device in the aircraft is described.

2. EQUIPMENT DEVELOPMENT

Figure 1. Equipment Picture

Table 1. Equipment Specification

Item	Specifications
Size	155(W) * 295(L) * 170(H)
Weight	5.5kg
Power	28VDC
Interface	MIL-STD-1553B ETHERNET
Channel	Strain Gage :36ch Accelerometer : 24ch Fiber Optic : 4ch
Wavelength Range	1510nm ~ 1595nm
Signal Code	NRZ-L
Word Size	16bit
Sampling Rate	1KHz(MAX)
Bitrate	1Mbps
Recorder	32GB Compact Flash Memory Card

2.1. Module Design

The development of monitoring equipment is designed as follows.

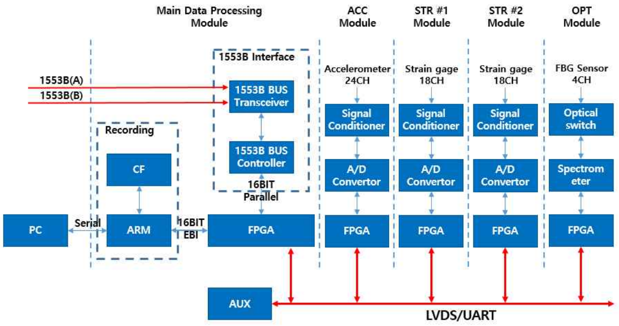


Figure 2. Equipment Internal Architecture

The internal module consists of four sensor modules and a main data processing module. The measurement module consists of an acceleration module, two strain gauge modules, and an optical measurement module. The main data processing module has the function of processing and storing the measured data from each sensor and processing the 1553B flight data.

$$\text{Vout} = \frac{V_B}{2}\left[\frac{\Delta R}{R}\right]\left[1 + \frac{R2}{R1}\right]$$

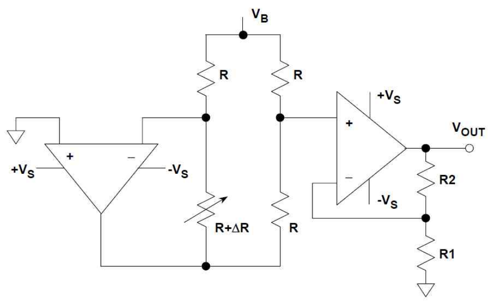


Figure 3. Linearizing a single-element varying bridge

The optical measurement module is able to reduce the size and weight by using the photodiode array method.

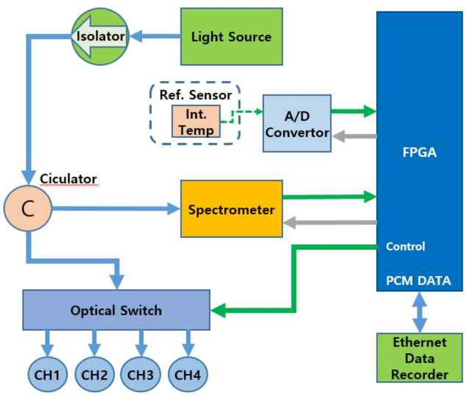


Figure 4. Optical Module Internal Architecture

Also, strain values can be calculated using the following equations with the measured wavelength values.

$$\mu\varepsilon = \left(\frac{\Delta\lambda}{\lambda_0}\right) 1 * 10^6 / F_G - \varepsilon_{TO}$$

$$\varepsilon_{TO} = \Delta\lambda\left[\frac{C_1}{F_G} + CTE_S - C_2\right]$$

Table 2. Strain gage Calculation Variable

Variable	Description	Value	Units
F_G	Gage Factor	0.796@22℃	-
C_1	Gage Constant 1	6.156@22℃	μm/m℃
C_2	Gage Constant 2	0.70	μm/m℃
ΔT	Temperature Change	Measured	℃
CTE_S	CTE of Test Specimen	User Defined	μm/m℃
$\Delta\lambda$	Wavelength Shift	Interrogated	nm
λ_0	Nominal Wavelength	Initial Value	nm

2.2. Environmental Test and EMI/EMC Test

Environmental test is performed based on MIL-STD-810G environmental test and MIL-STD-461F electromagnetic compatibility test for use on aircraft. MIL-STD-810G has been operated under the various environmental conditions such as acceleration, vibration, impact, altitude, temperature and humidity. MIL-STD-461F is conducted under the conditions of conducted emission and radiated emission for electromagnetic compatibility.

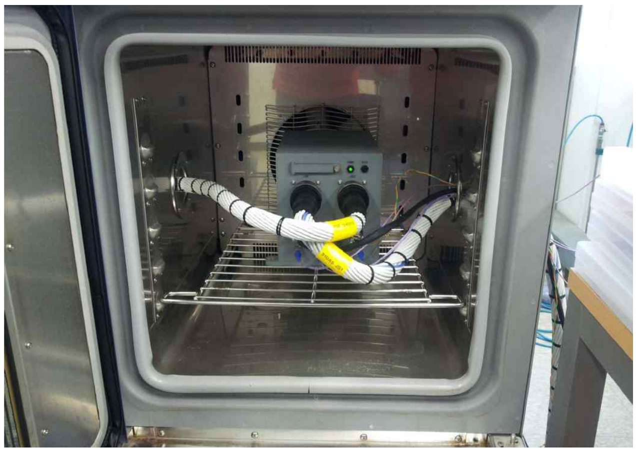


Figure 5. MIL-STD-810G Temperature, Humidity Test

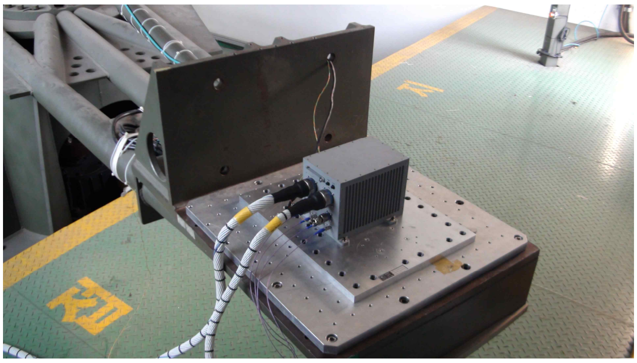


Figure 6. MIL-STD-810G Acceleration Test

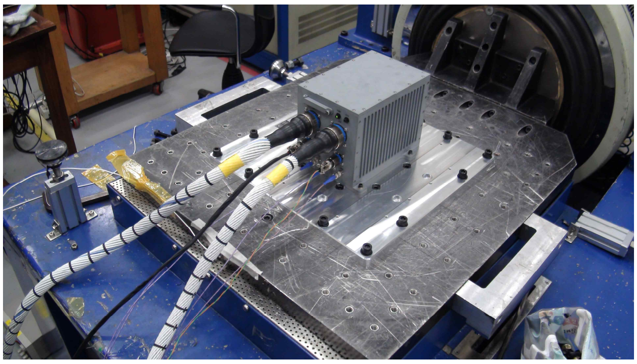


Figure 7. MIL-STD-810G Vibration, Shock Test

Figure 8. MIL-STD-810G Altitude Test

Figure 9. MIL-STD-461F EMI/EMC Test

The environmental requirements for each test are as follows.

Table 3. Environmental Test Requirement

Test		Requirement	Remarks
Altitude/Low Temperature Operating		45000ft	
High Temperature Operating		43℃, 50℃	
Low Temperature Storage		-33℃	
High Temperature Storage		35℃, 63℃	
Humidity		95% ~ 100%	
Acceleration		MIL-STD-810G Method 513.6	
Vibration		MIL-STD-810G Method 514.6	
Shock		MIL-STD-810G Method 516.6, Procedure I	
EMI/EMC	CE102	10KHz ~10MHz, Power Leads	Aircraft, Army, Including Flight Line
	RE102	2MHz ~ 18GHz, Electric Field	

As a result of the test, the environmental test according to MIL-STD-810G confirmed that the data is normal even under various conditions.

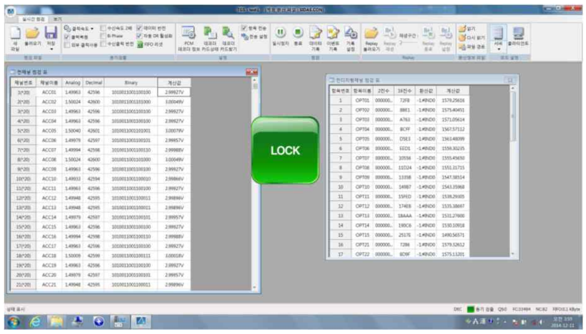
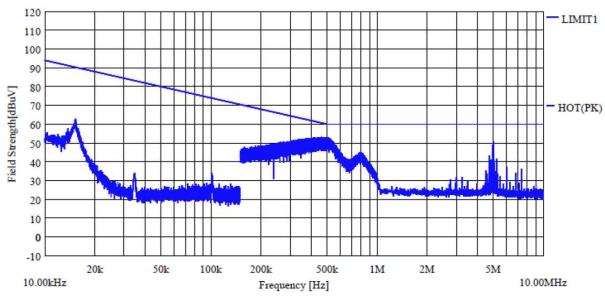


Figure 10. Test Result Display (If not good result, Unlock display with Red Color)

The results of the electromagnetic compatibility test according to MIL-STD-461F are as follows.



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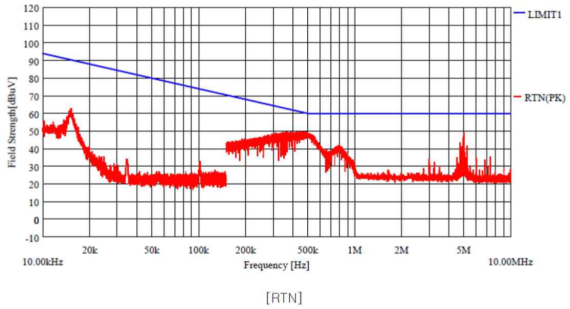

Figure 11. MIL-STD-461F CE102 Result

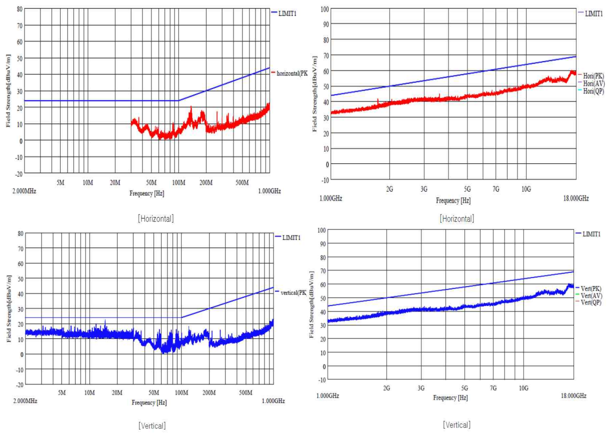

Figure 12. MIL-STD-461F RE102(2MHz~18GHz) Result

3. CONCLUSION

The developed structural monitoring equipment is tested with MIL-STD-461F and MIL-STD-810G standards in order to comply with the aircraft, and received the appropriate results. The development equipment is expected to be able to check the status of the aircraft structure in the future. Furthermore, it is expected to be used for managing SHM and structure lifetime, so that appropriate replacement timing for aircraft structures can be identified, and cost and risk management can be anticipated.

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BIOGRAPHIES

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He was born in September 18, 1984 in Pohang, Kyungbook., Korea. He graduated from the department of avionics engineering in Hanseo University, Korea in 2010 (B.E.). Also, he graduated with Master's Degree in avionics system in February 2014 (M.S.). He is in Danam Systems avionics team since November, 2013. His field of interest is Fiber Optic, SHM.

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