6

Reliability, Failure Rates and Lifetime Prediction

6.1 Accelerated Life Tests and Lifetime Prediction

6.1.1 Thermal Ageing at 200°C and 250°C

Based on the temperature profiles supplied by Turbomeca, estimates of the operating lifetime expected by extrapolating results from temperature storage tests at 200°C and 250°C for 1000 hours have been made and are presented in Table 6.1.

6.2 FMEA and Reliability Prediction

A preliminary FMEA has been carried out based on the functional block description of the design of the HIGHTECS module containing the HIGHTECS hybrid circuit and a high temperature pcb containing resistors (2).

The main failure modes that may result in undetected erroneous data being sent are improper operation of the ADC on the ASIC, the voltage regulators and drift in capacitor and resistor values. The probability of erroneous data transmission is mainly controlled by the ability of the BIT function to flag warnings of when the various functional blocks do not function correctly.

The estimated values derived from the FMEA for the two temperature profiles provided by Turbomeca are presented in Table 6.2.

6.2.1 Module Weight and Dimensions

A breakdown of the weight of the prototype HIGHTECS Module is presented in Table 6.3.

The target weight for the HIGHTECS module was 500 gms, the actual weight was 986 gms of which over 80% was accounted for by the stainless

Table 6.1 Estimate of operating lifetime after extrapolation of temperature storage results for 1000 hours at 200°C and 250°C

Temperature Profile Supplied by Turbomeca	Average Operating Temperature	Storage Test Temperature	Test Time	Estimated Lifetime
1	84.4°C	200°C	1000 hours	61 years
		250°C	1000 hours	22 years
2	68.5°C	200°C	1000 hours	298 years
		250°C	1000 hours	109 years

Table 6.2 Summary of values derived from FMEA on HIGHTECS module

Factor	Temperature Profile 1	Temperature Profile 2
Total failure rate for HIGHTECS Module	$50.69/10^6$ flight hours	$41.42/10^6$ flight hours
Mean time between failures	19,730 hours	24,143 hours
Probability of no data transmitted	15.89×10^{-6} flight hours	12.98×10^{-6} flight hours
Probability of undetected incorrect data transmission	1.57×10^{-6} flight hours	1.29×10^{-6} flight hours
BIT failure detection cover	91.7%	91.6%

Table 6.3 Breakdown of weight by component for prototype HIGHTECS module

Component	Weight, gms
Stainless steel enclosure (exc connectors)	606
Stainless steel lid	113
Connectors	117
Mounting plate	48
High temperature pcb with resistors	48
Hybrid circuit (containing resistors)	38
Miscellaneous (washers, gaskets, etc)	16
Total	**986**

steel enclosure, lid and connectors. A significant reduction in weight of the HIGHTECS module can be achieved through selection of lighter materials (e.g. aluminium) for the enclosure and lid, although plating of the aluminium may be necessary to withstand the environment.

The target and actual dimensions of the prototype HIGHTECS module is presented in Table 6.4.

The actual dimensions of the prototype HIGHTECS module exceed the target dimensions, mainly on the length and width due to the currently available high temperature connectors. If miniature high temperature connectors are

Table 6.4 Target and actual dimensions for prototype HIGHTECS module

Dimension	Target mm	Actual mm
Length (inc connectors)	90	157.60
Width	40	64
Height	60	38.20

Table 6.5 Target and actual current power consumption for prototype HIGHTECS module

Consumption	Unit	Target	Actual
Power	W	10	2
Current	A	1	0.2

developed, there is scope for size reduction. Internally, the derated resistors for high temperature operation have the largest dimensions. As miniaturised high temperature resistors become more widely available, these resistors could be incorporated in the hybrid circuit.

6.2.2 Module Power Consumption

The target and actual power consumption of the prototype HIGHTECS module are presented in Table 6.5.

6.3 Summary

The HIGHTECS ASIC, hybrid circuit and module have been designed and manufactured. The HIGHTECS ASIC has successfully demonstrated dual output of ARINC 429 messages; however, problems have been encountered in achieving a consistent linear output in the Analogue to Digital Conversion (ADC) transfer function. The hybrid circuit and module has also produced ARINC 429 messages, but the output has been inconsistent, which again is believed to be related to the ADC transfer function. The ADC, which was supplied to the project as an existing IP block, is sensitive to its supply voltages and does not meet its published specification. The transfer function of the ADC has discontinuities present. The discontinuities reduce as the analogue supply voltage is increased above the digital supply voltage and as the temperature is increased above ambient. The voltages needed to eliminate the discontinuities are above those recommended for the SOI ASIC process. A small number of devices were identified which had a functioning ADC at a digital voltage of 5 V and analogue voltage of 5.5 V and these devices have been assembled into the HIGHTECS hybrid circuit and module. The results show that the

HIGHTECS module can function between $-40°C$ and $+225°C$, with linearity of output improving as the temperature increases. A re-spin of the ASIC design was carried out to address the issues of the inconsistent ADC functionality by bringing out separate voltage references and improving the connections around and to the ADC block. The results on the 2nd version of the HIGHTECS ASIC show the analogue sensor conditioning and frequency measurements functions in line with specification on the ASIC over the temperature range $-40°C$ up to $250°C$ with operation up to $275°C$. However the ADC output is not linear at 5 V, which is the recommended voltage for the SOI process and further work will be required outside the scope of this project to develop an improved ADC IP block which can function at 5 V.