MCM & Hybrid Reliability

MCM/Hybrid Performance

Defining performance for today's military systems is extremely critical. Historically, the military overspecified performance of MCMs/Hybrids used in military applications. In addition, the military mandated the use of military-qualified parts. Today, non-military and military parts are often used together. This presents a potential risk to the application and makes defining satisfactory operation more difficult than in the past. To assist in developing performance criteria for MCMs/Hybrids, performance specification MIL-PRF-38534 should be used.

MCM/Hybrid Time

MCM/Hybrids, qualified to MIL-PRF-38534 and listed in QML-38534, are designed to last up to 20 years. On the other hand, non-military parts are designed to last from 12 months up to 5 years. The part's package has a significant effect on the part's life. Packages that dissipate heat effectively and/or protect the internal circuitry from the environment last longer. The environmental categories detailed in the Scope section of this document/database establish timed-based requirements for part usage.

MCM/Hybrid Operating Conditions

With the inclusion of non-military parts in military applications, operating conditions have become more critical than in the past. The environmental categories detailed in the Scope section of this document/database establish operating condition requirements for product usage.

Reliability

Typical failure rates for deposited circuit elements are shown in Table 1.

Because Hybrids and MCMs typically are significantly higher in unit cost than standard components, an alternative to lengthy testing of many devices is to perform a product assessment. RELTECH Assessment Guidelines are a viable alternative to the expensive testing used in the past, as it requires only a relatively few devices, with testing tailored to the expected application, and for the specific product technology.

When passive structures are used in microwave applications, the primary reliability issues associated with transmission lines are electromigration and adhesion of the metal to the substrate. Electromigration is the movement of metal atoms along a metallic strip, due to momentum exchange with electrons. The metal atoms that migrate along the line tend to accumulate at grain boundaries. The accumulation of metal can create fingers of metal that can short the device. In the other possible scenario, failure of the metal strip to adhere properly to the substrate can cause the line to break, creating an "open" circuit. It could also cause the line to break off connection with an active component in the device circuit.

Element	Temperature (°C)				
	15	60	76	110	136
Thick-film resistor	0.0005	0.001	0.0015	0.002	0.0025
Chip Connector	0.001	0.0015	0.0025	0.006	0.025
Wire Bonds					
Au-Al Ball	0.000005	0.00002	0.0001	0.001	0.006
Al-Al	0.00001	0.00001	0.00001	0.00001	0.00005
Au-Au	0.00001	0.00001	0.00001	0.00001	0.00001
Crossovers	0.000005	0.000005	0.000006	0.000008	0.00001
Transistor Chips					
Low Power	0.0001	0.0003	0.0009	0.0027	0.007
Power	0.005	0.01	0.03	0.09	0.27
Diode Chips	0.0001	0.0003	0.0009	0.0027	0.007
Microcircuits					
Quadgate or equivalent	0.002	0.0036	0.018	0.082	0.24
Dual flip-flop or op amp equivalent	0.004	0.0072	0.036	0.164	0.48
SSI (25 gates)	0.0125	0.0225	0.1125	0.512	1.5
MSI (50 gates)	0.025	0.0459	0.225	1.02	3.0
LSI (100 gates)	0.050	0.09	0.45	2.04	6.0
VLSI (1,000 gates)	0.1	0.2	1.2	3.5	15
VLSI (10,000 gates)					

Table 1. MCM Circuit Element Base Failure Rates (%/1000 hr.) [2]

Single crystal gallium arsenide (GaAs) has the following properties that are relevant to transmission line design:

Dielectric constant	12.8
Loss tangent	0.00006 (high resistivity GaAs)
Surface roughness	1/40 micron

Thermal conductivity 32 watts/m-^{0}K

Power dissipation in vias is minimal and therefore, does not limit device performance. Active components, and in some cases thin film resistors, tend to be the elements that require power derating.

Air bridges, designed to limit the current density to less than $5x10^5$ A/cm^2 , show no degradation at 175^{0}C. Mechanical tests of air bridges have shown no failures at stress levels up to 30,000 g's (centrifuge test) and under temperature cycling tests from –65 to +150^0 C.[3]

[2]Failure rates are taken from IPC-MC-790, "Guidelines for Multichip Module Technology Utilization"; August, 1992.

[3]A. Fraser and D. Ogbannah, "Reliability Investigation of GaAs IC Components", 1985 GaAs IC Symposium Technical Digest, Nov. 1985, pp 161-164.