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Assembly and packaging for extreme environments

Microwave and RF microcircuit assembly, packaging and test require attention to detail for reliable operation in extreme military and aerospace environments.

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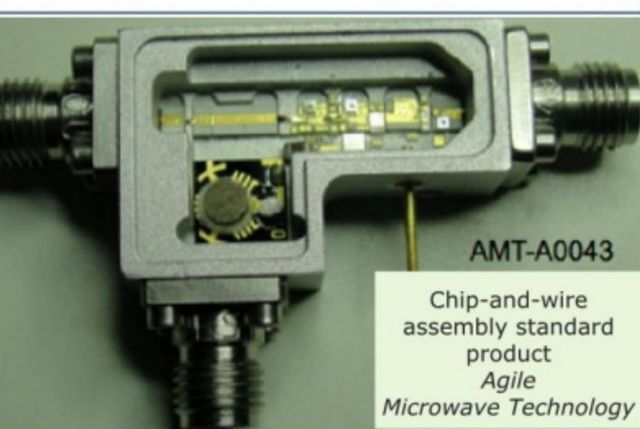

Chip-and-wire assembly standard product
Agile Microwave Technology

Critical issues

Design issues, component sourcing, substrate selection, process selections and material trade-offs are critical due to their high frequency characteristics.

In addition, new semiconductor device technology, transitioning from commercial markets (COTS) such as gallium arsenide(GaAs); gallium nitride (GaN) on silicon/silicon carbide substrates; silicon germanium (SiGe) and indium phosphide (InP) are now available for high reliability applications.

Also driving RF and microwave technology is the industry's investment and advancements in miniaturizing smartphones, drones, small satellites, phased-array technology, 5G and the Internet of Things (IoT).

Unique processes

RF and Microwave hybrids are complex assemblies (figure at left) and require many unique processes.

Typical processes are shown in the table below. The need for extreme quality control has evolved over the years from unique customer requirements to standardized control meeting MIL-PRF-38534.

TYPICAL RF AND MICROWAVE HYBRID PROCESSES[1]

- *Gold Wire Bonding (ball and wedge)*
- *Aluminum wedge bonding*
- *Ribbon Bonding (gold 3 mils x 0.5 mils thick)*
- *Surface mounting of components using screen-printed solder paste.*
- *RF Connector Installation (solder or mechanical)*
- *Hermetic sealing using seam welding of Kovar packages*
- *Hermetic sealing using Laser welding of aluminum package*
- *Hermetic sealing using Gold-Tin soldering of Kovar package*
- *Hand Soldering*
- *Eutectic Die Attach (gold tin or solder)*
- *Epoxy Sealing of microwave packages*
- *Epoxy die and component attach*
- *Coil Tacking or Winding via wire bonding, welding or soldering*
- *Board Installation (epoxy, solder, mechanical)*
- *Beam-lead diode attachment*
- *RF Tuning*
- *RF/Microwave electrical testing and calibration of "golden units"*

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Primer (from 3)

RF and Microwave hybrids (also called multi-chip monolithic microwave integrated circuit (MMIC) modules, multi-chip RF modules) must comply to the requirements of MIL-PRF-38534: GENERAL SPECIFICATION FOR HYBRID MICROCIRCUITS to supply product to the hi-reliability military and space markets.

Commercial, off-the-shelf
The "PRF" in the specification number means it is a performance specification. This dates back to a 1994 memo[2] written by U.S. Secretary of Defense William Perry to use commercial off-the-shelf (COTS) components in military systems.

The Department of Defense (DOD) responded by generating performance specifications as a way to reduce cost and enable the introduction of COTS components by not requiring ridged military specifications.

The end user can now specify the requirements in the "detailed procurement specification". All testing is performed in accordance with MIL-STD-883 Test Method and Procedures as listed:

- ☐ ***1001 to 1999 Environmental tests***
- ☐ ***2001 to 2999 Mechanical tests***
- ☐ ***3001 to 4999 Electrical tests (Digital Microcircuits)***
- ☐ ***5001 to 5999 Test procedures (Linear Microcircuits)***

Performance specifications
Performance specifications use a qualified manufacturers/materials list (QML) philosophy where each process and material that is used to build the device is qualified and certified instead of a Qualified Parts List (QPL) where each device must be qualified and certified.

Customer requirements
Conversion of Customer Requirements is the engineering and quality process that reviews the customer specification or standard product data sheet and insures the end product meets all the requirements of MIL-PRF-38534.

It verifies that the design meets the electrical performance and that the process/materials are qualified, the level of testing (class level) is correct, and all required deliverables (data, traveler, etc.) are delineated.

Avionics, military systems and spacecraft demand components that can survive the strain of severe environments, such as the first stage rocket booster of the Artemis. (NASA)

What Does QML control?

- *Processes and Materials qualified*
- *Design and Manufacturing Process Controlled*
- *Materials verified prior to assembly*
- *100% Testing on each device (Screening) Group A conformance "Shake and Bake" test)*
- *Sample Testing (Periodic Inspection) Group B, C, and D)*
- *Quality Management System audited by DLA*
- *Radiation levels delineated and Radiation testing certified.*

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Primer (from 5)

MIL-PRF-38534 has several quality assurance levels, shown from highest to lowest below:

- *Class K - Highest reliability level, specified for space*
- *Class H - Standard Military Quality Level*
- *Class D - Vendor Specified Quality Level*
- *Class E - Devices based on class K, H or G with exceptions to the class requirements.*
- *Class G - Lower version of the Military quality level*
- *Class L - Class L is the highest quality class for non-hermetic devices*
- *Class F - Class F is the standard quality class for non-hermetic devices*

Path to cost reduction
As part of the DOD drive to reduce cost, increase device reliability and to implement new technology, there is a Technology Review Board (TRB) option in the MIL-PRF-38534 specification.

Alternative prevention methods
TRB under DLA approval allows a manufacturer to generate alternative prevention methods.

These include statistical process control (SPC), periodic process capability certification, design analysis, design robustness, and off-line reliability assessment or to eliminate non-value added tests or excessive MIL-PRF-38534 requirements.

MIL-PRF-38534 Appendix D Performance Varifications for Non-Hermetic Device Technologies specifies two quality levels. These are *Class L non-hermetic devices,*

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Primer (from 6)

which will be specified over the temperature range of -55°C to +125°C or as specified in the device specification.

The second quality level is *Class F* nonhermetic devices. These devices are specified over the temperature range of -40°C to +85°C or a wider range.

Conclusion

The *MIL-PRF-38534* specification undergoes constant updating via the JEDEC 13.5 (Hybrid Manufacturers) and G12 (Component Users) groups within the Industry/Government Solid State Devices.

This document has evolved and become more valuable to the industry for over 30 years since its introduction.

References

1. T.J. Green, *Microwave Hybrid Design for Manufacturability (DFM)* course, *https://www.tjgreenllc.com/in-plant-training/*
2. Dr. William Perry, memo, "Specifications & Standards—A New Way of Doing Business," *https://www.sae.org/standardsdev/military/milperry.htm*

The Author

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Global economy headed for recession—IHS Markit

LONDON—Disruptions to supply chains, demand, international trade flows and travel—along with lockdowns and collapsing stock prices resulting from the coronavirus disease 2019 (COVID-19) virus—have dealt a heavy blow to the global economy.

GDP growth revised downward

The United States, Europe, and Japan are headed for recession. The IHS Markit forecast for world real GDP growth in 2020 has been revised down to 0.7% in response to the spread of the virus.

Growth below 2.0% is classified as a global recession. The number of active world cases is assumed to top out by the third quarter.

Nevertheless, the result will be a U-shaped rather than V-shaped cycle, as a sharp reduction in near-term growth is followed by a slow recovery.

Forecast risks are overwhelmingly on the downside and depend crucially on how governments respond.

Central banks

Central banks have already taken emergency actions, but the fiscal response is more uncertain.

The recent sharp drop in oil prices will help energy consumers and hurt energy producers. The net effect on global growth is likely to be negative, but small.

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