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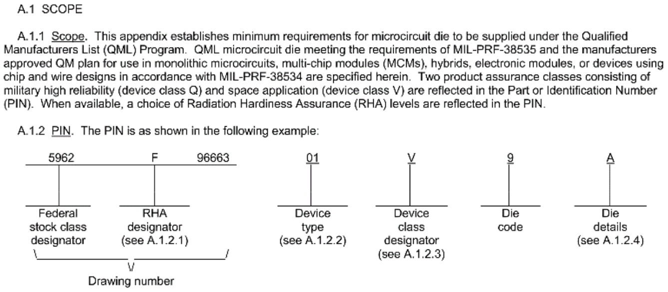
Known Good Die

There are many use cases for which engineers and designers elect to purchase bare die for their applications. They might integrate the die into a multichip module (MCM), or use it directly as a chip-on-board (COB), in order to meet size, cost, and mass constraints. In some special radio frequency (RF) applications a COB solution might be required to minimize the inductance and capacitance of integrated circuits leads. Furthermore, many manufacturers purchase bare die from other providers and integrate it into their packaged parts. The term "known good die" (KGD) is commonly used when referring to these die purchases; however, it is not well defined and might have different meanings depending on the manufacturer or specific use cases. In this bulletin, we describe what KGD might refer to and some of the detailed flows that KGD go through at different manufacturers.

"QML Die" in MIL-PRF-38535

Under MIL-PRF-38535, "QML die" can have several different meanings. The first is Qualified Manufacturers List (QML) die that is covered by Appendix A in the Standard Microcircuit Drawing (SMD) of the part that is offered in die form. This is commonly referred to as "SMD die" and is assigned a die code of "9" in the QML part number's case outline position. **Figure 1** shows an example of such a part (5962-96663). It is important to note that the manufacturers that offer the SMD die are also expected to offer the fully packaged part (per the SMD) on the QML listing.



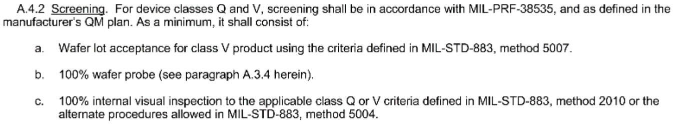
A.1 SCOPE

A.1.1 Scope. This appendix establishes minimum requirements for microcircuit die to be supplied under the Qualified Manufacturers List (QML) Program. QML microcircuit die meeting the requirements of MIL-PRF-38535 and the manufacturers approved QM plan for use in monolithic microcircuits, multi-chip modules (MCMs), hybrids, electronic modules, or devices using chip and wire designs in accordance with MIL-PRF-38534 are specified herein. Two product assurance classes consisting of military high reliability (device class Q) and space application (device class V) are reflected in the Part or Identification Number (PIN). When available, a choice of Radiation Hardiness Assurance (RHA) levels are reflected in the PIN.

A.1.2 PIN. The PIN is as shown in the following example:

Figure 1. SMD die example showing the die code.

For QML die products, the minimum screening steps are listed in the SMD (Section A.4.2). Some manufacturers might elect to do more testing than the minimum requirements, shown in **Figure 2** (from 5962-96663).



A.4.2 Screening. For device classes Q and V, screening shall be in accordance with MIL-PRF-38535, and as defined in the manufacturer's QM plan. As a minimum, it shall consist of:

a. Wafer lot acceptance for class V product using the criteria defined in MIL-STD-883, method 5007.

b. 100% wafer probe (see paragraph A.3.4 herein).

c. 100% internal visual inspection to the applicable class Q or V criteria defined in MIL-STD-883, method 2010 or the alternate procedures allowed in MIL-STD-883, method 5004.

Figure 2. SMD die minimum screening required.

The 100% wafer probe includes functional and parametric testing sufficient to make the packaged die capable of meeting the electrical performance requirements listed in the electrical characteristics table of the SMD, which lists parameters throughout the part's rated temperature range. It is important to note that QML die is not required to go through temperature cycling or burn-in at the die level. However, as specified in MIL-PRF-38535, Section 4.2, all QML integrated circuits shall meet the requirements of the screens specified in Tables 1A and 1B of the specification whether or not the actual testing has been performed. The manufacturer might elect to eliminate or modify a screen based on supporting data that indicates that for the QML technology, the change is justified. For example, many manufacturers have optimized their wafer probe process and in agreement with the Defense Logistics Agency (DLA) perform it only at 25°C. If such a change is implemented, the manufacturer is still responsible for providing product that meets all of the performance, quality, and reliability requirements of MIL-PRF-38535.

Lot qualification of die parts is performed on packaged units, per the device's quality level. Furthermore, MIL-PRF-38535 lists that for devices to be delivered as die, burn-in of packaged samples from the wafer lot shall be performed to a quantity accept level of 10(0).

The second type of QML die is one that comes from a wafer fabrication (fab) facility/line/process that has been audited by DLA and is covered under a QML-38535 certification. In this case, QML die sales are not listed in the QML listing. The Certificate of Conformance (CoC) supplied by the QML-approved fab would exempt the QML manufacturers from performing a site audit of the fab. Some examples of this type of QML die are: National Semiconductor, Motorola, Texas Instruments (TI), or Cypress Semiconductor, selling their wafer/die from their certified wafer foundries/facilities/lines/processes to other QML manufacturers.

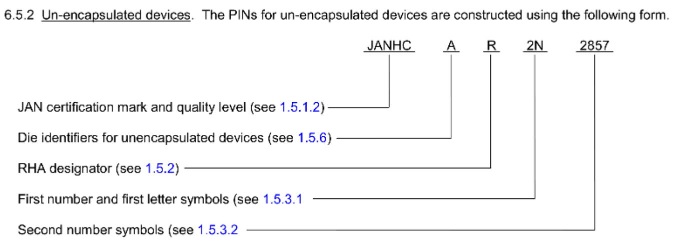
In both cases described above, the term "KGD" is not used. KGD has various meanings for different stakeholders and different products. Currently, MIL-PRF-38535 does not define KGD.

It should be noted that MIL-PRF-38534 defines KGD as "a bare die of the same quality and reliability level as an equivalent packaged die."

"QPL Die" in MIL-PRF-19500

In the MIL-PRF-19500 Qualified Products List (QPL), die is offered in two quality levels, JANHC and JANKC, which are covered in Appendix G of the standard. Military-qualified die is classified as MIL-PRF-19500 JANHC die, and space-qualified die is classified as MIL-PRF-19500 JANKC die. JANKC die can be manufactured and sourced only by a wafer fabrication facility that has been used to qualify a JANS product on the QPL. Manufacturers of QPL die for use in QPL products can be either in-house or contracted suppliers and must be audited and qualified by DLA in both instances. See **Figure 3** for an example specification of a MIL-PRF-19500 die (JANHCAR2N2857).

MIL-PRF-19500 Appendix G specifies the screening and qualification requirements for JANHC and JANKC die. The screening and sample size requirements are congruent with MIL-PRF-38534 element evaluation requirements.



6.5.2 Un-encapsulated devices. The PINs for un-encapsulated devices are constructed using the following form.

JANHC A R 2N 2857

JAN certification mark and quality level (see 1.5.1.2)

Die identifiers for unencapsulated devices (see 1.5.6)

RHA designator (see 1.5.2)

First number and first letter symbols (see 1.5.3.1

Second number symbols (see 1.5.3.2

Figure 3. Example specification of a JANHC die.

JANHC and JANKC QPL die are electrically probed for key electrical parameters, and defective die are identified during this process. Wafer screening requirements are specified in Paragraphs G.5.2 through G.5.2.7. Screening consists of 100 percent electrical test, 100 percent visual inspection of die, and then additional screening of sample die assembled into packages. The minimum sample size is 10 die for each JANHC wafer inspection lot and 22 die for each JANKC wafer inspection lot. The QPL sample die will be assembled into the appropriate package by the QPL manufacturer prior to going through the screening process steps 4–7 listed in Appendix G, Table II, of MIL-PRF-19500. These include temperature cycling, mechanical shock or constant acceleration (JANKC die only), electrical test (read/record), high-temperature reverse bias (HTRB), electrical test read/record, burn-in, electrical test read/record, steady-state life (JANKC die only), electrical test read/record, wire-bond evaluation, die-shear evaluation, scanning electron microscope (JANKC die only), and radiation-hardness assurance. Appendix G, Paragraph G.5.4 specifies that die shall be stored in dry nitrogen or another inert atmosphere. All MIL-PRF-19500 QPL die are manufactured on a DLA-audited and -certified manufacturer's wafer fabrication processing facility/line. To ensure traceability, the DLA-qualified manufacturer will provide a CoC for the die manufacturer, as required per MIL-PRF-19500, Paragraph 3.7.

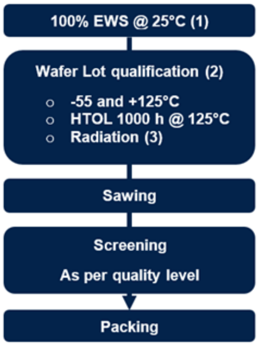
MIL-PRF-19500 does not define KGD, nor does it permit non-QPL die to be used in MIL-PRF-19500 qualified products.

Manufacturers' Die Offerings

Many manufacturers offer products in die form at various quality levels. For example, the following manufactures offer SMD die per MIL-PRF-38535 as described above: Analog Devices, Cobham, Honeywell, Mercury, Microchip, Micross, Renesas, STMicroelectronics (ST), and TI. Some examples of

MIL-PRF-19500 qualified manufacturers that sell QPL wafers/die from their certified wafer foundries/process lines are Infineon, Microchip, Semicoa, Sensitron, and VPT Components. In this section we'll describe a couple flows and die product levels offered by some MIL-PRF-38535 manufacturers to demonstrate a few available options.

ST offers most of its space-qualified products in die version as well. These die products are offered in two quality levels: Engineering Model (EM), and Flight Model (FM). Each one is offered in two different flows, depending on whether the packaged products are QML- or European Space Components Coordination (ESCC)–qualified. The general manufacturing flow for products in die form is shown in **Figure 4**.

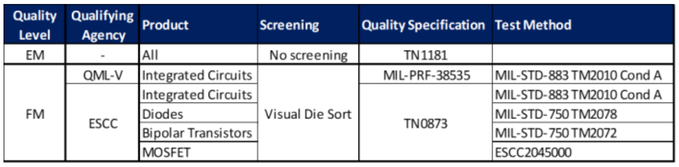


1. Dynamic Part Average Testing is as of today implemented for most diodes. For bipolar transistors and MOSFETs, both Part Average Testing and Geographical Part Average Testing are implemented. Electrical wafer sort (EWS) is done for 100% of die at 25°C.
2. The Wafer Lot Qualification is made by sampling on packaged parts. It is indeed performed on each wafer whenever the wafer-to-wafer variations are not marginal vs the part-to-part variations.
3. The radiation test is only performed on wafer lot used for the manufacturing of RHA guaranteed parts.

Figure 4. STMicroelectronics die flow.

ST space EM parts follow the Engineering Model Quality Level document (TN1181), whether they are QML or ESCC qualified. EMs in die form come from a qualified wafer lot and come with a CoC. The EMs are not submitted to additional screening or testing. ST space FM parts are listed in the product's SMD (they are SMD die as described above). The FM parts follow the Die Manufacturing and Quality Specification (TN0873)[1]. The screening step consists of a visual die sort that follows MIL-STD-883 TM2010 Condition A for QML-V die, and TN0873 for ESCC die. **Table 1** summarizes the EM and FM quality levels.

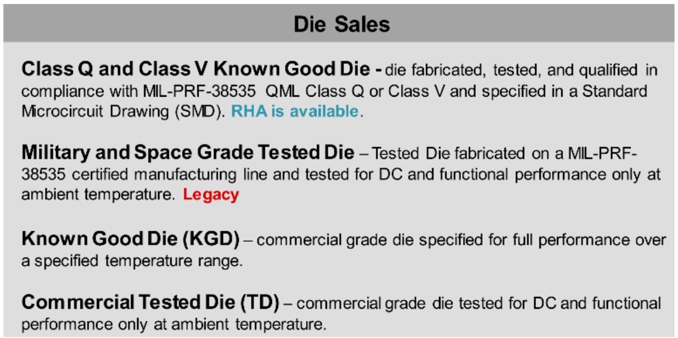
Table 1. STMicroelectronics EM and FM die.



Quality Level	Qualifying Agency	Product	Screening	Quality Specification	Test Method
EM	-	All	No screening	TN1181	
FM	QML-V	Integrated Circuits	Visual Die Sort	MIL-PRF-38535	MIL-STD-883 TM2010 Cond A
	ESCC	Integrated Circuits		TN0873	MIL-STD-883 TM2010 Cond A
		Diodes			MIL-STD-750 TM2078
		Bipolar Transistors			MIL-STD-750 TM2072
		MOSFET			ESCC2045000

As of today, ST has not identified interest from its customers for options such as burn-in or 100% high- and/or low-temperature test at electrical wafer sort (EWS), commonly referred to as KGD. ST's QML-V products are proposed in die form only when it can be agreed with DLA that an EWS at 25°C plus a wafer lot qualification test on 25 pieces at -55°C, +25°C and +125°C is sufficient to make the packaged die capable of meeting the electrical performance requirements of the SMD.

TI offers a wide variety of products in die form. TI defines KGD as "die tested to the same quality and reliability standards as their packaged equivalents" [2]. **Figure 5** shows TI's die parts categories.



Die Sales

Class Q and Class V Known Good Die - die fabricated, tested, and qualified in compliance with MIL-PRF-38535 QML Class Q or Class V and specified in a Standard Microcircuit Drawing (SMD). RHA is available.

Military and Space Grade Tested Die – Tested Die fabricated on a MIL-PRF-38535 certified manufacturing line and tested for DC and functional performance only at ambient temperature. Legacy

Known Good Die (KGD) – commercial grade die specified for full performance over a specified temperature range.

Commercial Tested Die (TD) – commercial grade die tested for DC and functional performance only at ambient temperature.

Figure 5. Texas Instruments die categories.

An example flow of a QML-V die is shown in **Figure 6**.

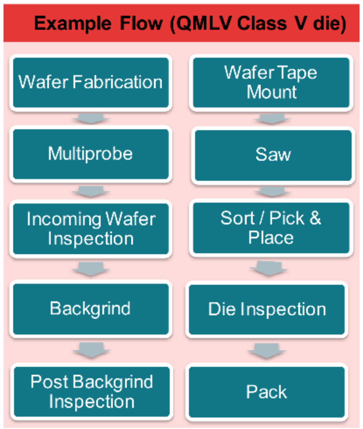


Figure 6. Texas Instruments example QML-V die flow.

TI's datapack available for QML die includes the data for Group C, wafer lot acceptance (Class V only), and Group E (radiation-hardness-assured only). However, the attributes (yield) and variables (read and record) are not available. TI does not offer catalog burned-in die at this time. TI does perform testing at multiprobe—for example, VBOX, GOI, and IDDQ—to ensure quality of the die. Wafer fabrication includes engineering parametric testing (test structures), wafer-level reliability testing (WLR), and outlier controls. During feasibility studies, a candidate for die sale is evaluated for packaged-device electrical-yield performance and operational life without burn-in. If either is deemed unsuitable, the device will not be released in die sale.

Conclusion

Die parts find many uses in today's space applications. Compared to packaged parts, bare die parts are smaller, lighter, have a lower cost, and might have improved electrical performance in specific applications such as RF. This makes KGD an attractive option to integrate into MCMs, or to use directly as COB.

In this bulletin we explained the different types of die available as part of the MIL-PRF-38535 and MIL-PRF-19500. We also described some of the manufacturing flows and different quality levels of die parts provided by a few manufacturers as part of their commercial, military, or space products. The term "known good die" is commonly used when referring to these die purchases; however, it is not well defined and might have different meanings depending on the manufacturer or use case. It is recommended to always inquire about the detailed manufacturing and test flows that KGD go through at the manufacturer that is providing the parts.

References

[1] STMicroelectronics, "DIE2HR/D2HR Manufacturing and Quality Specification," Technical Note TN073, DocID022757, Rev. 5, September 2017. Available: https://www.st.com/resource/en/technical_note/dm00047600-die2hr-d2hr-manufacturing-and-quality-specification-stmicroelectronics.pdf

[2] Texas Instruments, "Die and Wafer Services." Available: https://www.ti.com/die-wafer-services/overview.html

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