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A Guide to Microwave Diode Package Styles and Their Performance

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This article provides a review of microwave diode packages, with attention to the electrical and thermal performance characteristics that affect each type's suitability for particular applications

Few subjects cause more problems and confusion for users of microwave diodes than the effects of the diode package. Although they are required for most applications, packages always limit the performance of the circuit design, sometimes in unexpected ways. This paper will discuss the different types of packages available, the attributes of each and the effects one might expect when used in some common circuit applications.

Packages are a necessary evil. In a perfect world, all designs would make use of the unpackaged die, installed eutecticly and wire bonded into the circuit. However, microwave diode packages afford protection for the die, ease of handling and a means of efficient automated circuit assembly. Any discussion of microwave diode packages must start with an understanding of the detrimental attributes that packages bring.

Package Parasitics

Parasitics are unwanted electrical and mechanical attributes that result from the physical construction of the package. Package types have various combinations of parasitics, which limit circuit performance in different ways. The right choice of packages is always a compromise, often the lesser of several evils. Let's examine the different microwave diode package parasitics:

Series Inductance (Lp): Because any diode package has exterior terminations that must be connected to the die inside, there will always be an inductance associated with the wire or conductor used to accomplish this. The best high frequency microwave packages will have values as low as 150 pH. The worst can have over 2,000 pH, which is like putting a large value of inductive reactance in the worst possible place in your circuit—directly in series with the diode!

Shunt Capacitance (Cp): All packages are constructed using conductive metals and insulating materials with a particular dielectric constant. As we know, conductors separated by dielectric material create a capacitor. Values for a package's parasitic capacitance vary from under 100 fF to over 1,000 fF. This capacitor is also in the worst possible place in your circuit—directly across the terminals of the diode!

Series Resistance (Rs): The conductors used to connect the die to the exterior of the package are usually gold wire or at least gold plated. Although gold is a very good conductor, even small magnitudes of resistance can affect microwave circuit performance. A 0.1 ohm value of resistance in series with the device can result in measurable reduction in switch isolation or an increase in VCO phase noise.

Thermal Resistance (θj): Devices that handle power, such as PIN diodes or SRDs (step recovery diodes), need to have a thermal shunt to ground in order to dissipate excess power in the form of heat. If power cannot be dissipated, the junction temperature of the device can rise to the point of destruction. Some packages are designed to have excellent thermal properties with thermal resistance values as low as 10 degrees C/W. Others have values as high as hundreds of degrees C/W.

Pkg. Type	Lp	Cp	Rs	θj	Cost	Max Freq.	Hermetic	Comments
Ceramic	Excellent	Excellent	Excellent	Excellent	High	18 GHz	Yes	All products available
MELF	Good	Fair	Excellent	Very Good	Moderate	2 GHz	Yes	Only select PIN diodes available
MMSM	Very Good	Very Good	Good	Very Good	Low	8 GHz	No	Only select PINs and varactors
EPSM	Good	Good	Good	Good	Moderate	6 GHz	No	All products available
Glass Axial	Fair	Good	Good	Poor	Moderate	1.5 GHz	Yes	Many products available
Plastic	Poor	Fair	Fair	Poor	Low	2 GHz	No	Only select PINs, varactors & Schottkys
Stripline	Good	Good	Good	Fair	Moderate	8 GHz	Yes or No	All products available

Table 1 · Microwave diode package comparisons.

Circuit Implications of Parasitics

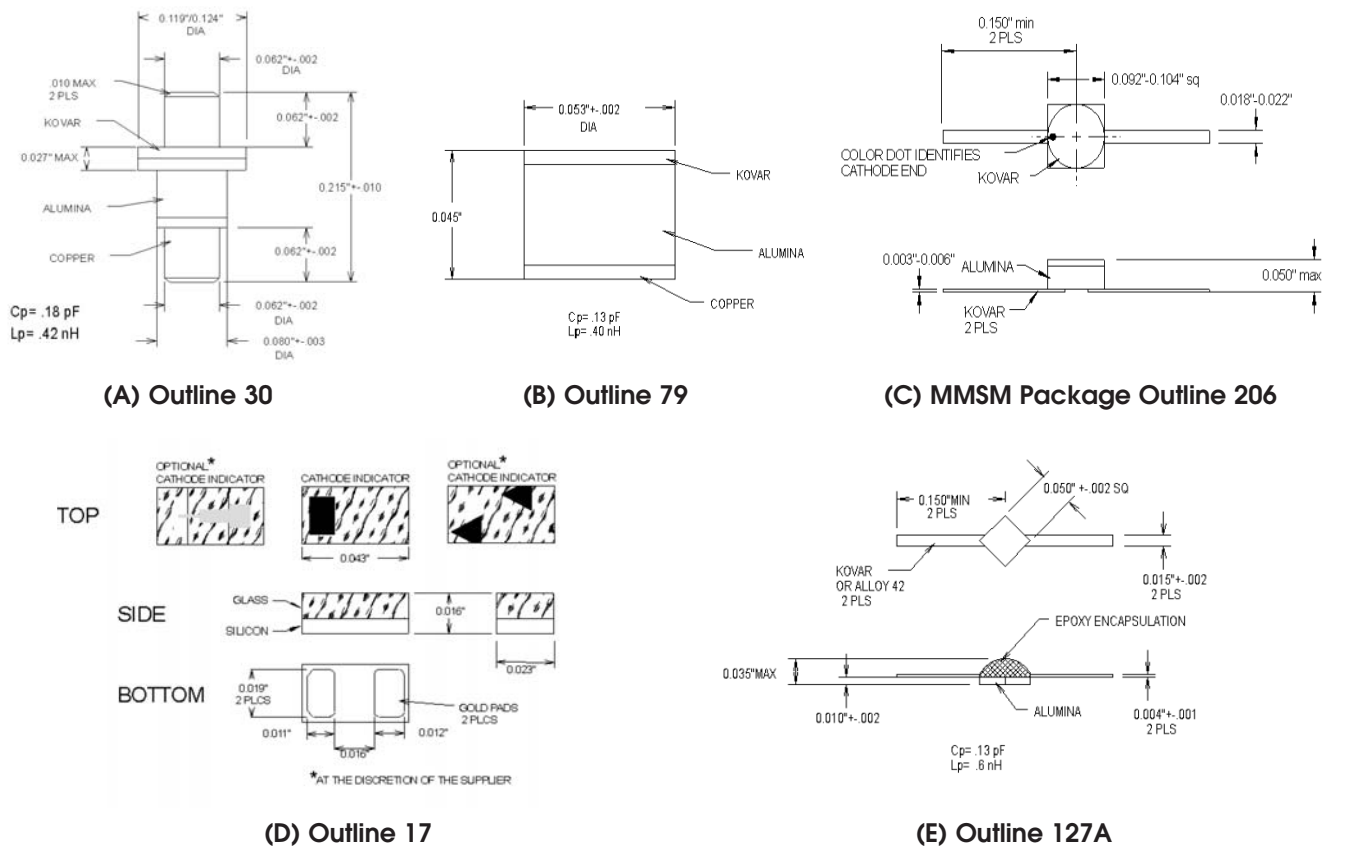
As a general rule PIN diode switch applications demand the lowest possible parasitic capacitance. This value directly limits the isolation that can be achieved in a series design. Additionally, low values of thermal resistance are highly desirable in order not to compromise the power handling characteristics of the device.

PIN diode limiters also require packages which have low thermal resistance, but it is also imperative to limit parasitic inductance.

Schottky diodes used as mixers or detectors usually do not have to dissipate much power, so package thermal resistance is not usually a concern. Minimizing parasitic inductance and capacitance are important, but not critical as in PIN diode applications.

Varactor diodes used in voltage controlled oscillators (VCOs) demand the lowest package parasitic inductance. This value will directly affect the maximum frequency which can be achieved. Package parasitic capacitance will limit the bandwidth (tuning range) and tuning linearity of the VCO. Because VCOs do not require power to be dissipated in the varactor, package thermal resistance is usually not important.

Comb generators and harmonic generators using SRDs and VGVs (harmonic generator varactors)



(A) Outline 30 **(B) Outline 79** **(C) MMSM Package Outline 206**

(D) Outline 17 **(E) Outline 127A**

Figure 1 · Microwave packages.

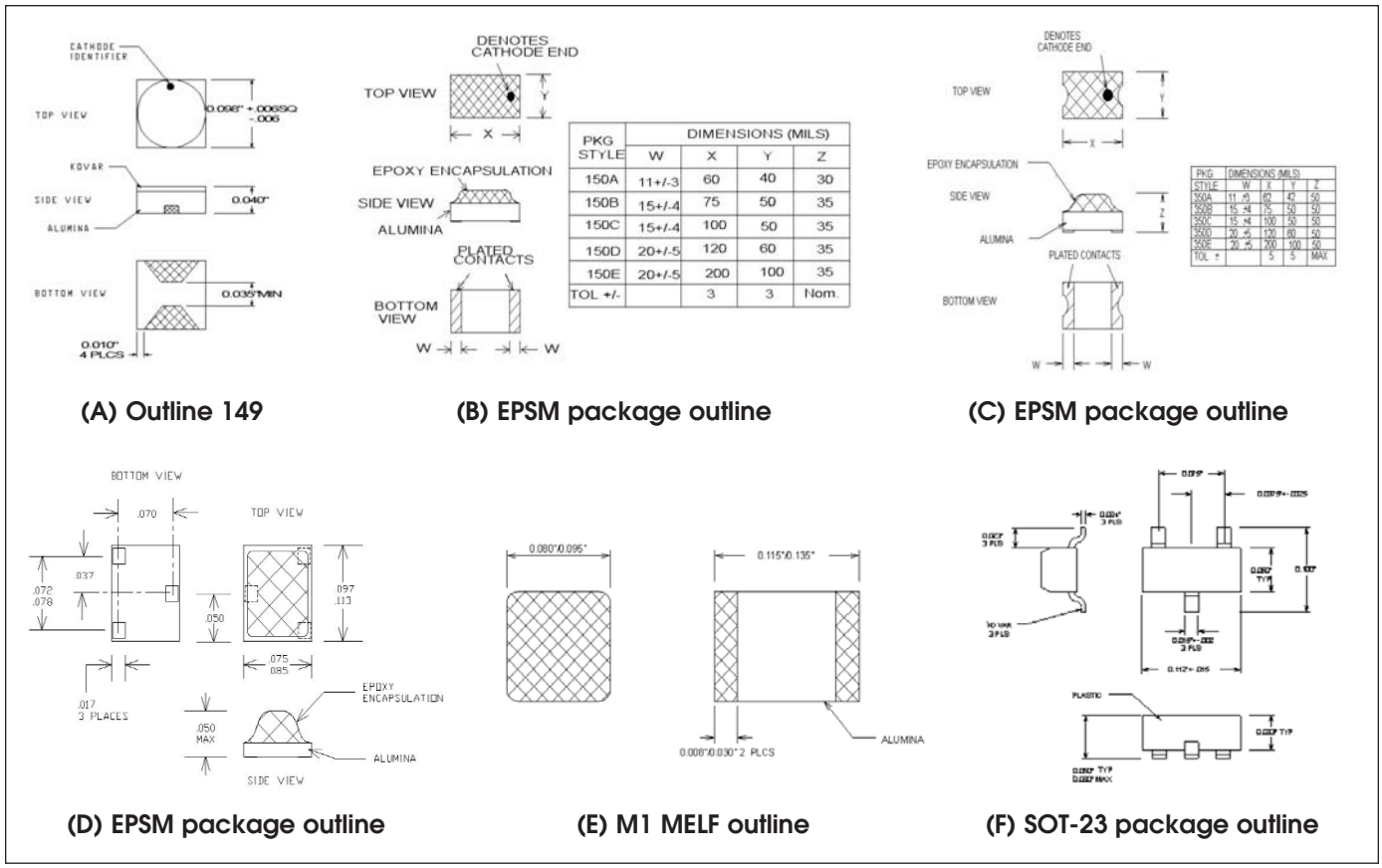


Figure 2 · Surface mount packages.

demand the lowest possible package thermal resistance due to the large power dissipations in these applications. Package parasitic inductance and capacitance can often be tuned out provided the magnitude is not too great.

Package Categories

In general terms, packages can be grouped broadly into three categories: Microwave, Surface Mount and Through-Hole. Some package types such as Microwave Monolithic Surface Mount (MMSM™) belong in more than one category. Let's discuss each category and look at some examples. Refer to Table 1 for some comparisons between package types.

Microwave Packages

There are three package types which can be used at microwave frequencies above 6 GHz.

Ceramic packages are the best performing microwave package styles available. They are hermetic and the type of choice for military and space applications. They are also the most expensive. They combine low parasitic inductance, low parasitic capacitance and can have superior thermal resistance characteristics as well. Most products are available in ceramic packages. Outline 30 and 79 are good examples (Figures 1A and 1B).

MMSM packages combine the attributes of excellent microwave performance, surface mount convenience and economy pricing, but only select products are available in this outline. Consult the factory for details. Figure 1C shows the MMSM package outline (206).

Stripline packages for microwave are usually also ceramic and can be completely hermetic or have epoxy encapsulation. They combine low parasitic inductance, low parasitic capacitance and are designed specifically for stripline or microstrip construction. They can, however, have high thermal resistance and are not the best choice for applications which will result in high device dissipation. Outline 17 (Figure 1D) is hermetic, and outline 127A (Figure 1E) is epoxy encapsulated.

Surface Mount

There are five types that can be used for surface mount applications. Once again some fall into more than one category: MMSM, ceramic, EPSM, MELF and plastic (SOT-23).

MMSM outline 206 was discussed under microwave packages above (Figure 1C).

Ceramic surface mount packages combine all the excellent attributes of ceramic microwave packages with the ease of surface mount assembly

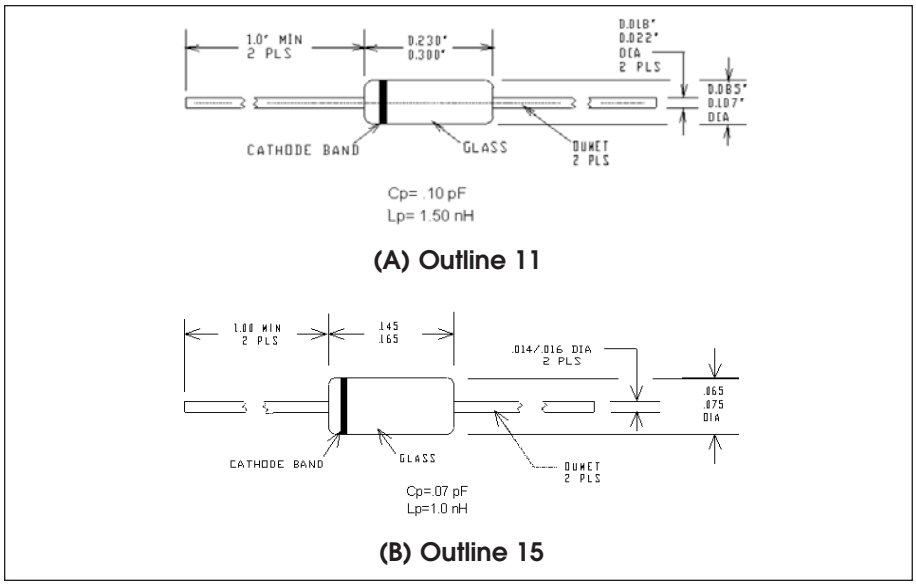


Figure 3 · Through-hole packages.

compatibility. Most products are available in this type. Figure 2A shows a good example/outline of 149.

Enhanced Performance Surface Mount (EPSM™) packages offer consistent performance for applications up to 6 GHz. Both parasitic inductance and parasitic capacitance are very low compared to conventional plastic injection molded surface mount packages. Thermal resistance is moderate but is also superior to plastic. Additionally there are a wide range of outlines from which to choose, and most products offered are available in EPSM. Figures 2B, 2C and 2D show some common EPSM outlines.

Metal Electrode Leadless Faced (MELF) packages are specially designed for PIN diodes. They have low values of parasitic inductance but high values of parasitic capacitance. They are suitable for frequencies under 2 GHz and have very low thermal resistance, making them suitable for power applications. Only select PIN diodes are available in MELF packages. Figure 2E shows the M1 MELF outline.

Plastic SOT-23 packaged devices are rugged economical packages suitable for low power applications with frequencies up to 2 GHz. They have moderately high levels of all parasitics but are ideal for less critical higher volume commercial use. Figure 2F shows the SOT-23 package.

Through-Hole

Glass axial packaged diodes have been around for many years and are still popular today for UHF frequencies and below. Their hermeticity and proven environmental design are favorites for military requirements. They have very high thermal resistance which makes them unsuitable for high power applications. Figure 3 shows two common glass axial package outlines.

Author Information

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