Base Plate Tempurature for Ferrite Isolator/Circulators Application Note

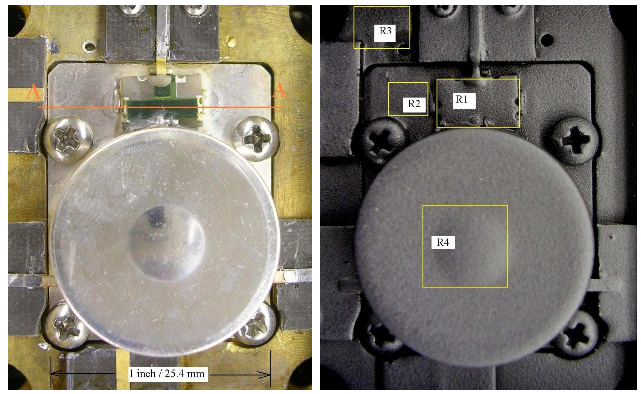
Introduction: This application note defines "base-plate temperature" for M/A-COM's circulator/isolator product lines. The choice for base-plate materials and their impact on the power handling capability are also discussed.

Chip resistor and base plate: High power **chip resistors** are commonly used in stripline-junction ferrite isolators as isolated-port terminations. Some circulators also utilize chip attenuators at the isolated port. The main function for such terminations/attenuators is to dissipate the reflected RF power in the event of gross mismatch at the output port thus protecting other parts in the system. The chip suppliers typically specify the power handling capabilities of the chips with the criterion that the base-plate is kept below a certain temperature. Otherwise a de-rating factor must be used.

"**Base plate**" is usually defined (by the chip manufacturers) as the heat-sink that directly attaches to the chips, i.e. right underneath the chip (see [1] for an example). This may be different from where M/A-COM's customers monitor/maintain the system temperatures. M/A-COM defines the "base-plate temperature" to be that of the area **on the bottom side of the housing assembly** beneath the high power termination/attenuator. In most cases, close approximation of this temperature can be obtained by observing the area next to the chip.

Fig. 1(a) show a 1 inch by 1.25 inch drop-in circulator (MAFRIN0472), which has a 20dB chip attenuator, mounted in a brass test fixture (M/A-COM part#: SVP08280). The area of interest was then painted black (Fig. 1(b)) to facilitate infrared thermal imaging. The test fixture itself was bolted onto a 1.26cm thick aluminum plate (size: 17.5cm by 17.5cm) which serves as additional heat-sink. Thermal joint compound was applied between base-plate and fixture, and also between fixture and heat-sink. Ambient temperature was 22^{o}C. No extra cooling was provided. Fig. 2 shows simulated temperature at "AA" cross-section under 100 watts DC power dissipation.

Thermal images (Fig. 3) were taken while the chip attenuator dissipated the DC power. The chip resistor was checked for its DC resistance value and RF matching characteristics in the circulator, both before and after the test.



(a) Mounted (b) Painted

Figure 1: MAFRIN0472.

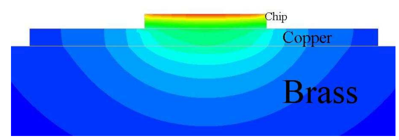


Figure 2: Simulated temperature at crosss-section "AA" in 1(a). Temperature gradient between lines is about 12^{o}C.

Four areas around the chip attenuator labeled R1 through R4 were monitored for surface temperature with different DC power inputs. (R1: top of the chip, R2: next to the chip, R3: test fixture, and R4: top of the housing.) The results are tabulated in Table 1. Please note that temperatures are NOT uniform within individual areas, so both the minimum and the maximum are listed. The important temperature, concerning the power-handling capability of the chip, is the area **next to the chip** i.e. R2. If the part is expected to survive large reflected power for an extended period of time, it is crucial to provide proper heat-sink for the chip resistors to lower the temperature at R2.

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Table 1: Surface temperatures.

Power level	Surface Temperature min./max (^oC)			
	R1	R2	R3	R4
5 W	25.4/33.0	26.2/27.6	25.4/26.2	25.1/25.9
20 W	29.2/51.2	32.4/35.3	29.2/30.3	29.2/30.0
50 W	43.8/115.6	53.8/61.4	43.1/45.6	43.2/44.1
72 W	55.1/160.8	73.6/83.7	57.2/60.9	58.2/59.2
98 W	65.5/223.6	101.0/114.5	75.4/79.9	76.2/77.6

The measured (and simulated[2]) temperatures were plotted in Fig. 4. The same plot also shows the specification (of the chip attenuator) with proper de-rating factor. When large power is being dissipated, the temperature outside the base-plate is not a good indication of the chip-resistor environment (relevant to the health of the chip resistors). This situation is different from the normal operation, when the fixture temperature may be a good estimation of the junction temperature (relevant to the proper operation of the circulators/isolators). Thermal grease underneath base-plate can reduce the temperature in R2 area by as much as 15^{o}C in the case of 98 watts dissipated power.

Base-plate Material: Thermal images and simulations confirm that the temperature difference between R2 (area next to the chip) and R3 (fixture) can be substantial; even though both copper and brass are good heat conductors. (MAFRIN0472 uses a copper base-plate, M/A-COM part#: 1000010333-0008). For parts that use base-plates made from material with poor thermal conductivity (such as steel), the heat will be "trapped" around the chip. This results in even greater temperature differences between region R2 and R3. Table 2 lists thermal conductivities for a few materials.

In a separate experiment, chip attenuators were mounted onto steel base-plates (Fig. 5). The temperatures monitored in the R2 area were substantially higher compared to the previous experiment (copper base-plate). Consequently, no resistor survived dissipated power greater than 30 watts for more than 60 seconds unless the unit was placed on a cold plate set to temperature lower than -10^{o}C.

Table 2: Thermal Conductivities.

Material	$K(\frac{W}{M \cdot {}^oK})$
Cold Rolled Steel (CRS1010)	49.8
Free-Cutting Brass (C36000)	116
Aluminum Alloy (6061-T6)	167
Tough Pitch Copper (C11100)	388

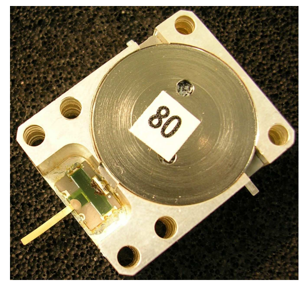

Figure 5: A M/A-COM circulator with steel machined housing.

Conclusion: In this application note, M/A-COM defines the "base-plate temperature" (the area **on the bottom side of the housing assembly** beneath the chip termination/attenuator), based on the experimental and simulated results. The operating temperature is considered to be the same as the base plate temperature unless otherwise specified. For applications where the circulators/isolators are expected to sustain large ($> 30W$) dissipated power, M/A-COM recommends using **copper** (or other material with good heat-conducting property) for the base-plate material to assist the heat removal. Thermal grease underneath the base plate is also highly recommended.

References

[1] *Product Catalog 2004-006*, Barry Industry, Inc. 60 Walton St. Attleboro, Massachusetts, 02703, U.S.A.

[2] *IcePak, Version: 4.1.12*, Fluent Inc., 10 Cavendish Court, Centerra Park, Lebanon, New Hampshire 03766, U.S.A.

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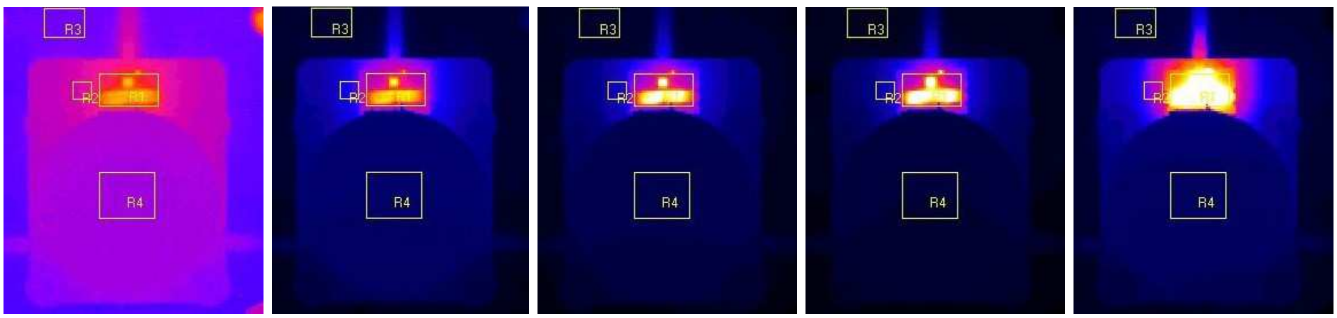

(a) 5W (b) 20W (c) 50W (d) 72W (e) 98W

Figure 3: Thermal images of MAFRIN0472 while dissipating DC power.

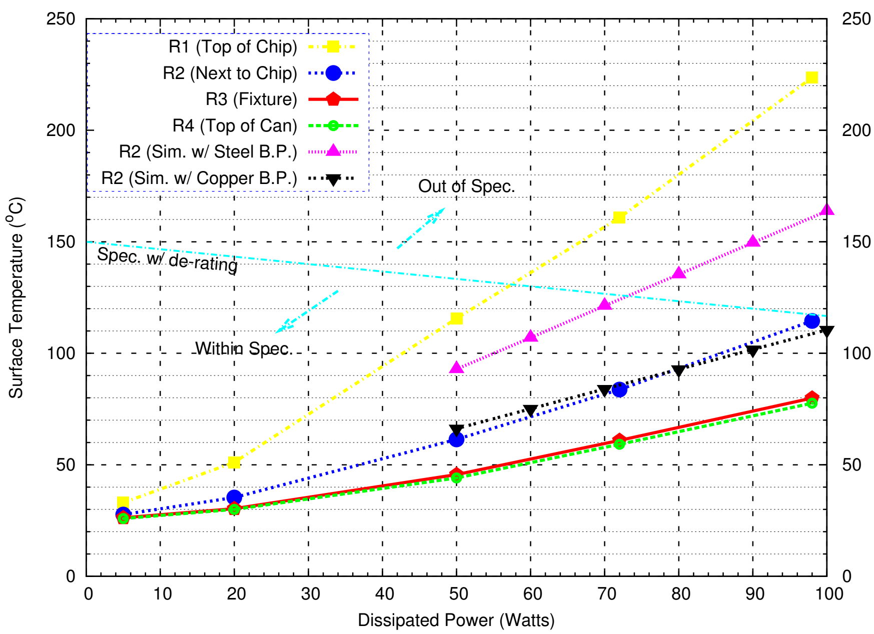

Figure 4: Base-Plate Temeratures versus Power Dissipation.

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