# THERMAL INFLUENCES ON ELECTRONIC COMPONENTS FROM THE MANUFACTURING STAGE TO SYSTEM INTEGRATION

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**Abstract: The present work investigates the process of thermal management for individual components used for electronic systems, from their manufacturing stage to the assembly of the final product. Two stages of development were studied, firstly, the manual soldering process was investigated and how the thermal phenomena can affect different ICs, depending on their form, during soldering and secondly the effect of the IC package on heat dissipation was investigated. The manual soldering process was studied for the smallest of the surface-mount devices because the assembling technique involves direct contact with the soldering iron. DIP-28, TQFP-32 and MLF-32 package models have been implemented in SolidWorks 2013 and their efficiency in evacuating heat has been evaluated and compared. Natural cooling was investigated in an open environment and investigations in closed spaces and with forced cooling applied were also made. The research focuses on accurately modelling electronic packages for ICs.**

***Keywords:*** *thermal, model, soldering, SolidWorks, packages.*

## I. INTRODUCTION

Thermal management of electronic devices, especially embedded ones, has become a challenge over the recent years [1]. The process of thermal management for the physical components starts as soon as they leave the production line [5] and ends with the final product being released to the consumer. A component is subjected to high temperatures during the soldering process [4], whether it is wave or flow soldered, or manually soldered, on the end of the line rework stations.

For manual soldering, using an instrument with excessive temperature can be damaging to sensitive components [3]. The aim of the both studies presented in this paper is to create well-defined models for simulations in order to reduce the time needed for thermal design of electronic systems and to avoid any unnecessary thermal stress of the manual soldered components, as well as to predict the heat dissipation of the modelled components during the functioning stage [2].

The first study focuses on the impact manual soldering has on frequently used surface-mount devices, especially very small packaged ones. Three types of such packages were studied: DIP-28, TQFP-32 and MLF-32. The research was done through simulations in SolidWorks as well as through experimental measurements, using in one case a thermocouple to measure the temperature each package reaches after 10s of exposure to a soldering iron.

Secondly, the next step is to determine the effect of the IC packages on heat dissipation, and also to study the effect of the PCB on eliminating heat from an electronic system into the environment. An analysis is performed on the type of cooling that suits better each package of the integrated component. Thermal simulations of DIP-28, TQFP-32 and MLF-32 packages were carried out, varying the type of cooling between natural convection and forced convection. For each type of package a model in SolidWorks was developed and simulations were implemented to see which type of package dissipates heat better, studying also the scenario where the device is mounted on a PCB in an enclosed space.

## II. SIMULATION AND EXPERIMENTAL SETUPS

Firstly, simulations were defined in SolidWorks, for the manual soldering process before any experiment was done. The simulation setup contains each package mounted on a PCB, on which the corresponding footprint was designed. A solder iron was created and mated with the pads. For each package a simulation of 10s was defined in Flow Simulation tool, time that corresponds with the maximum allowed time for soldering a pin of the component to its pads. Figure 1 shows the simulation setup for the component encapsulated in DIP package, and Figure 2 for TQFP package.

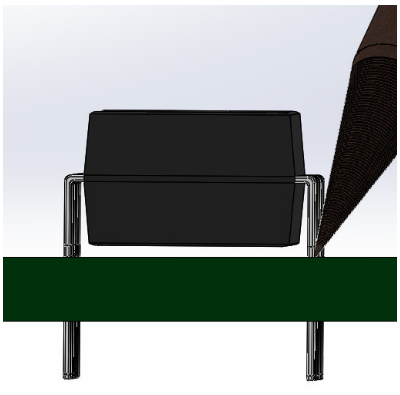

*Figure 1. Simulation assembly for the soldering process experiment – DIP-28*

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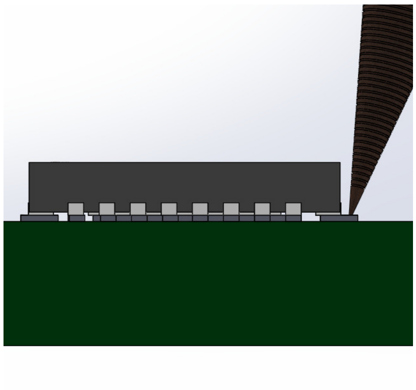

*Figure 2. Simulation assembly for the soldering process experiment – MLF-32*

For the manual soldering the study was also done experimentally, using a thermocouple placed on top of each component during the soldering process.

For the thermocouple measurements, both cases were considered, with solder flow and without solder flow. The solder was composed of 60% Sn and 40% Pb. Also, two positions of the solder iron were considered, perpendicular on the pads and at a 30˚ angle to the pads.

For the second of simulations three IC package models were built in SolidWorks: DIP-28, TQFP-32 and MLF-32, as seen in Figure 1.

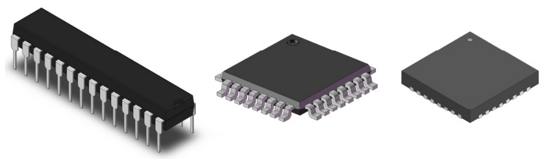


*Figure 3. SolidWorks IC packaging models (size are not to scale between components).*

For these packages different simulation methodologies were employed during the investigations. Each package was placed inside a box with 20cm x 20cm x 20cm dimensions, which has a number of 16 ventilation holes and a fan opening. The box simulates the case where a system is placed, for different applications.

The cooling methods chosen for the simulation were natural convection and forced convection. Convective heat transfer uses the movement of a fluid or a gas to transfer thermal energy from one place to another, in our case the gas being air.

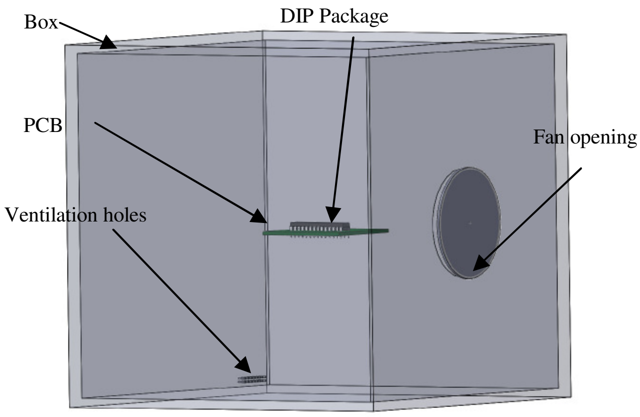


*Figure 4. SolidWorks model for DIP-28 package mounted on PCB*

The initial temperature condition for each package was set to 100℃ corresponding to a maximum usage of the devices' capabilities. The initial temperatures for air and for the box were set to 25℃.
Table 1 shows all the simulation configurations done for this research.

*Table 1. Package and cooling technique configurations for the simulations.*

| **Package** | ***DIP-28*** | ***MLF-32*** | ***TQFP-32*** |
|---|---|---|---|
| **Cooling Technique** | Forced cooling | Forced cooling | Forced cooling |
| | Natural cooling | Natural cooling | Natural cooling |

## III. SIMULATIONS RESULTS

SolidWorks, the tool used to develop these studies uses the Finite Element Method for calculating the heat transfer.

For the study regarding the manual soldering process, the simulation results can be found in figures 5, 6 and 7. Results show that for the configuration with DIP-28, the package reaches a temperature of 120 °C after 10s, which is within normal range of temperatures for the component.

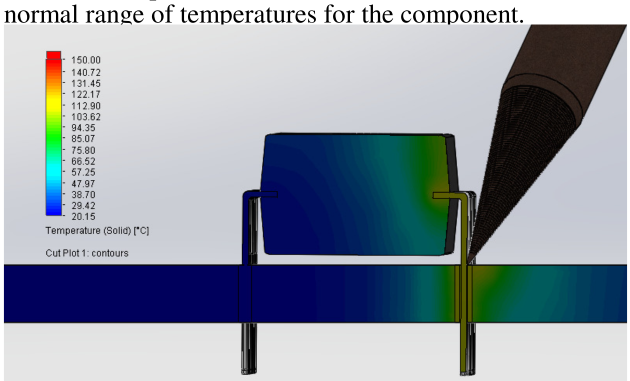


Fig. 5. Cut plot of the results for the DIP-28 package – temperature distribution.

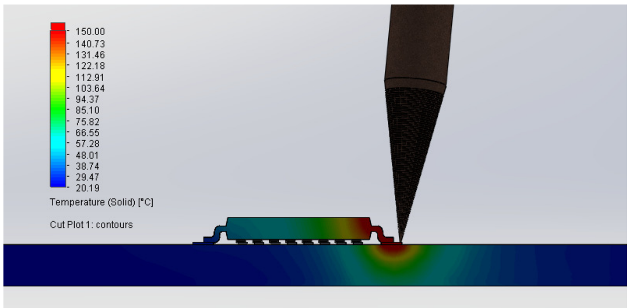


Fig. 6. Cut plot of the results for TQFP-32 package – temperature distribution.

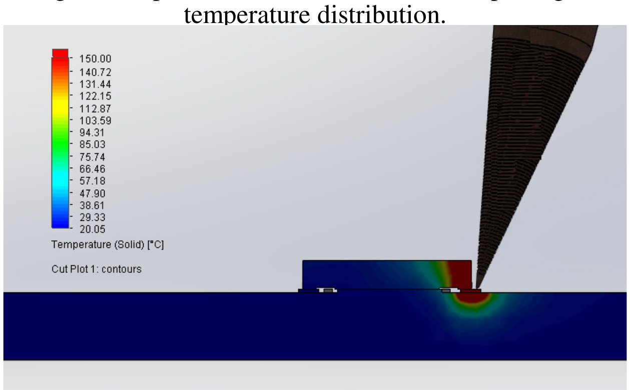


Fig. 7. Cut plot of the results for the MLF-32 package – temperature distribution.

For TQFP-32 and MLF-32 packages, in simulations it can be observed that the temperature the devices reach are 130℃ and 150℃, respectively.

It can be observed that the temperature decreases with the increase of packages dimensions, which is an expected result: larger components are heated slower than the smaller ones.

Also, in the simulations it can be seen that the transfer of heat is made only through the contact point between the solder iron and the pad, the heat radiated by the solder iron was inhibited in the simulation results.

When measuring the packages' temperature with a high precision thermocouple, the results in tables 2 and 3 were obtained:

*Table 2. Thermocouple measurement results – without solder flow*

| Package | Solder Iron Position | |
|---|---|---|
| | 90 ˚angle | 30 ˚angle |
| DIP-28 | 113℃ | 91℃ |
| TQFP-32 | 137℃ | 124℃ |
| MLF-32 | 159℃ | 136℃ |

*Table 2. Thermocouple measurement results – with solder flow*

| Package | Solder Iron Position | |
|---|---|---|
| | 90 ˚angle | 30 ˚angle |
| DIP-28 | 125℃ | 106℃ |
| TQFP-32 | 143℃ | 126℃ |
| MLF-32 | 205℃ | 188℃ |

As it can be seen in the tables above, package dimensions as well as the solder alloy and the position of the solder iron can influence the temperature the component reaches at the end of soldering cycle. It can also be observed that when the iron is held at a 90˚angle of the PCB, the temperature the component is submitted to increases, due to the thermal radiations around the soldering iron. It can be concluded that holding the soldering iron at a 30˚angle can be safer for the component, thus avoiding the risk damaging the component during soldering.

Also, the fact that the temperature of each component decreases with size is observable when measuring the temperature with a thermocouple. For the second study, the results are divided into two different parts, depending on the type of chosen cooling technique and were analyzed in order to discover which the best package to use in an application is.

### *A. Results obtained when using natural convection*

Figure 8 presents the result obtained when comparing heat dissipation of each package. The results were studied regarding the duration the packages reaching the ambient temperature.

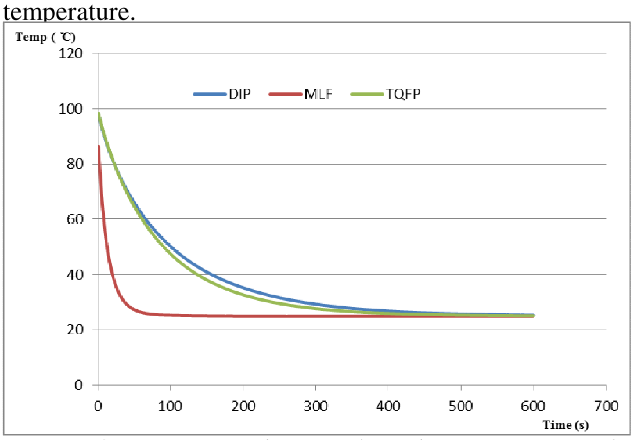


*Figure 8. Comparison between heat dissipation rates of DIP, MLF and TQFP packages, natural convection*

As it can be observed in the graph above, that there is an obvious influence of the package the IC is encapsulated in on the quantity of heat dissipated by a device in open air. MLF-32 package has the highest efficiency in evacuating the heat build-up. That is because it not only dissipates heat through its pins, which are made from a thermal conductive material, and its insulator plastic surface area, but also it contains a thermal pad that increases the IC's ability to dissipate heat.

Although the packages TQFP-32 and DIP-28 are very

different in structure and size, their behavior regarding heat dissipation is similar, with a small advantage for TQFP-32, which reaches the ambient temperature of 25℃ 10 seconds faster than DIP-28.
Figure 9 shows the internal temperatures of the packages, 5 seconds into the simulation.

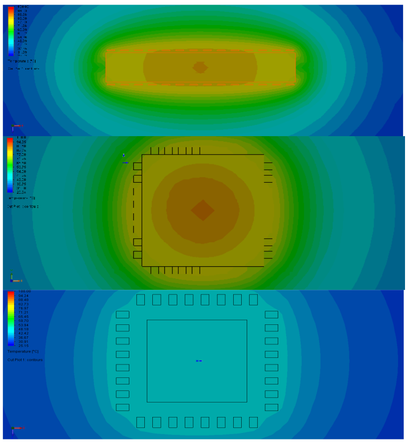


*Figure 9. Cut plots of the three tested packaging types during cooling*

### *B. Results obtained when using forced convection*

Figure 10 presents the result obtained when comparing heat dissipation of each package, when forced convection is used. The fan is an axial Papst 412, predefined in SolidWorks, which has a turbulence intensity of 2%. The results were studied regarding the duration the packages reaching ambient temperature.

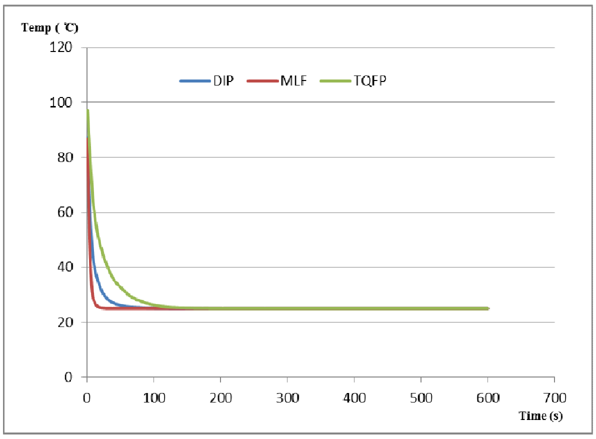


*Figure 10. Comparison between heat dissipation rates of DIP, MLF and TQFP packages, forced convection*

In the graph above it can be seen that the tendency heat dissipation has, depending on the package, maintains in the presence of the fan. MLF-32 package cools fastest, the difference appears between DIP-28 and TQFP-32 packages, the latter being cooled the slowest. This is explained by the fact that the DIP-28 package has a bigger surface exposed in the direction of the air flow.

## IV. CONCLUSIONS

The first research focuses on how the manual soldering process affects the component. All simulations and measurements were done in a time interval of 10s.

The conclusions that can be drawn are that for simulations, the only point through which the heat is transferred is the contact point between the solder iron and the pads and when the contact surface increases, so does the heat transferred to the component. Also, temperature of the component decreases with its size.

The conclusions that can be drawn from the thermocouple measurement are that solder flow increases the temperature the component is submitted to. Also, the angle the soldering iron is held can help to overcome possible damages to the component during soldering, thus a 30° angle between the solder iron and the pad is not harmful for the component

The purpose of the second research was to investigate how IC packages dissipate heat, depending on the structure. In the simulations we have taken into account the material for each type of package. These investigations were made with the intent of identifying which package suits better the integration in a more complex system.

As a result of the simulations it can be concluded that the package that dissipates most heat is MLF-32, which is equipped with a thermal pad, this being suited for applications which deal with high temperature environments, when forced convection is not an option, due to space limitations.

When forced convection is applied, all three IC packages have similar behaviors, the MLF-32 package keeping its tendency of dissipating heat fastest.

## ACKNOWLEDGEMENT

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