# Optimization of the Robotic Soldering Process: A Focus on Solder Spread and Spattering

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## Introduction

Robotic soldering is a growing market within the PCB assembly industry and interest in robotic soldering equipment and applications is increasing every year. This method is more efficient than hand soldering and will aid in alleviating human error. The robotic soldering process is more controlled and repeatable than a selective soldering fountain, and it can increase productivity and profitability. As the industry grows, we've found that there is not enough published data regarding this soldering technique. In this paper, we will present how cored wires with different flux percentages will affect robotic soldering performance. All wires used in this project were SAC305 alloy with a 0.020" diameter and 3%, 3.5%, 4%, or 4.5% flux.

## Reasons for Adoption

It is the evolution of manufacturing and production processes that have led electronics assemblers and assemblers in other industries to the wide use of robotic soldering. In the overall evolution of manufacturing, what started as physical work moved to mechanical work, and later progressed to assembly line work. Gradually, the evolution towards computer-assisted work continued until it reached the point where we currently stand—the availability of programmable, fully automated processes. Robotic soldering machines, as we know them, appeared in the early 1980s and have advanced since then into the efficient and reliable equipment that is commonly found today.

There are multiple reasons for adopting an automated soldering system into the PCB assembly process. First, and possibly most importantly, is the consistently accurate and repeatable application of solder to the desired joint. The robot, once programmed, will apply the same amount of solder and heat to the desired solder joint location for the same amount of time, every time. Increased repeatability allows for reductions in manufacturing costs such as those associated with personnel and with the amount of rework needed.

Regarding personnel, many skilled hand soldering experts have been leaving the workforce due to reasons such as retirement, leaving the next generation of operators lacking the skills required to meet IPC's standards. This deficiency in new skilled operators brings assemblers to a crossroads: one direction leads to training new operators and anticipating that they will remain with the company long enough to see a return on their investment, or investing in an automated soldering system and relying on the equipment manufacturing and engineering teams to install a highly reliable soldering process.

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Robert has more than five years of experience in the manufacturing industry. He earned his bachelor's degree in Economics from the State University of New York (SUNY) at Cortland, NY, and his master's degree in Technology Management from SUNY Polytechnic University (SUNY Poly) in Utica, NY. Robert resides in Newport, NY.

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## Benefits

Efficiency and versatility are among the advantages of including an automated soldering machine within the assembly process. Due to increased consistency and reliability, there will be less need for reworking a board, saving users both time and labor costs. Once fully optimized, the equipment purchaser will be able to see a measurable return on investment through improved throughput.

## Applications

An assembler would consider using robotic soldering where it is impossible or unreliable to use mass soldering (wave soldering or solder paste) and where human soldering is too unreliable or too costly. There may be instances where defects happen frequently with mass reflow techniques or where human hand soldering needs to be eliminated. It could also be that the component being assembled is heat sensitive and requires that only the joint area be exposed to heat and not the entire component. Another possible application would be adding a large component that would make the mass reflow profile too difficult or too slow.

Applications where robotic soldering would not be ideal are those where it is too costly or time consuming to solder each joint individually. For instance, mass soldering techniques, such as wave soldering, would have the ability to bond many joints more quickly. Another situation where robotic soldering may not be the best assembly technique would be where a human decision is required; human operators have the ability to adjust more quickly, if needed.

Applications where robotic soldering can be found include:

- Circuit boards
- Wires
- Flex circuits

In industries such as:

- Automotive
- Aerospace
- Medical
- Consumer electronics

## Flux-Cored Solder Wire's Role

### What makes a good cored wire, according to a robotic soldering *equipment supplier?*

During the course of our experiment, there was extensive discussion regarding the features that would allow robotic soldering to work most efficiently. To summarize that discussion, three primary attributes were found to be desired by robotic soldering equipment manufacturers and their customers.

First, it is important that the solder **feeds well** into the machine and to the solder joint. From a solder supplier's perspective, this means that the solder wire should be evenly wound in order to prevent kinks in the machine. It is important that there is enough tension placed on the wire as it leaves the spool and enters the machine's feeding mechanism; this helps prevent kinking or too much slack in the wire, both of which can cause the wire to break if pulled with enough force. Feeding well also means that the wire should be void-free, meaning that there should not be any gaps in the wire containing an empty core. Voids in the wire will likely result in poor wetting and subsequent downtime once realized.

The next noted characteristic is that the solder **flows well**. Solder that flows well will pre-tin the iron fully and then, once applied at the joint, will flow effortlessly to create the desired joint. Achieving effortless flow will require fine-tuning of factors, such as wire diameter, flux formula, flux percentage, tip temperature, and dwell time.

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Miloš joined Indium Corporation in 2018. He attended the University of Nis, School of Electronics Engineering, where he received his Master's degree in Electronics Engineering and Bachelor's degree in Electrical Engineering. Miloš is a founder of the non-profit organization, "Urban Youth Forum," which successfully encourages students to plan, develop, and execute projects involving environmental protection through the recycling of electronic waste. Miloš is fluent in English, Serbian, Croatian, and Bosnian.

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The third characteristic to mention is that the solder wire **does not damage the soldering iron tips**. The soldering iron is one of the most important pieces of the robotic soldering machine and of the robotic soldering process; it is not an aspect that can be overlooked. The soldering iron must be able to repeatedly provide a consistent supply of heat to the solder joint. The type of formula used or the ingredients in a core flux formula can have dramatic effects on the speed of degradation of a soldering iron. It is also vital that the correct type and size of tip be used based on the application to fully optimize the soldering process.

### According to a robotic soldering equipment *user*, what makes a good cored wire?

Once installed, the soldering wire that is used will likely be determined either by the in-house engineering team or by a recommendation from the equipment supplier. In either instance, the solder wire characteristics listed by the equipment supplier also apply for the customer. Solder that feeds well and flows well are desired attributes for the assembler. A wire that feeds and flows well allows for consistency and accuracy in the process, while improving the overall cycle time of completing the board, thus reducing the need for extra rework. Soldering iron tip degradation needs to be taken into consideration when determining what flux formula to use. Excessive need for re-installing soldering iron tips reduces the overall cycle time, as well as increasing the overall cost of assembly.

An attribute not mentioned previously concerns the cosmetics of the board post-soldering as some flux formulas are prone to spatter more than others. This has become such an important characteristic for this part of the electronics assembly industry that solder wire suppliers are now releasing “low-spatter” formulas to improve post-soldering cleanliness and aesthetics (Figure 1).

## Spatter Matters

What is Spatter? Spatter refers to the explosive spray of materials (flux and possibly solder) that “spit out” from the wire after heat has been applied. It is often caused by the out-gassing of the flux during the soldering process.

*Figure 1. Excellent spattering performance (3%).*

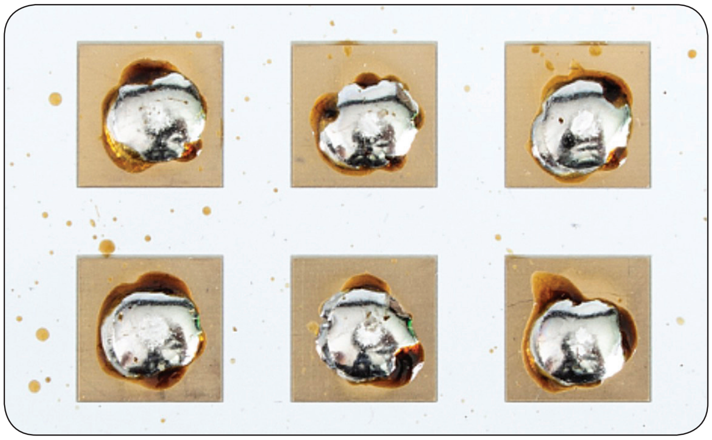

*Figure 2. Poor spattering performance (3%).*

### Critical Side Effects To Be Avoided

During automated and manual soldering, spatter is not only cosmetically unappealing, but it also increases cleanup time, wasted material, and could, in theory, impact the processing performance of sensitive components (Figure 2). It can also cause an exposure burn to the operator who is soldering manually.

Spattering in robotic soldering applications can also have an undesired effect on the soldering machine’s visual inspection system. A visual inspection lens covered with spattered flux will not be able to detect the defects that it is programmed for as effectively as a clean visual inspection lens. This can later lead to issues on the production line, such as needing more rework, disposing of the boards, and even affecting the finished good’s life cycle if the issues are not caught prior to shipment.

## Measuring Spatter and Our Test

### Test Parameters

- Tip
  - Size: 3mm
  - Temperature: 400°C (752°F)

    *Note: 425°C saw more spatter with 4.5% flux core*
- Board: Aluminum-clad, preheated @ 160°C (325°F)
- Wire
  - Diameter: 0.020" (0.50mm)
  - Formula type: No-clean
  - Flux percentages: 3%, 3.5%, 4%, or 4.5%

### What Are We Testing?

- Flux percentage effect on spattering
- Flux formula effect on spattering

## Main Conclusions

### Spattering Is Influenced by Formula More Than Flux Percentage

In a robotic soldering assembly process, forming the solder joint does not involve direct human interaction. Therefore, it is generally accepted that the assembler will want to use as much flux as possible to ensure that wetting occurs and the ensuing solder joint is adequate. When the flux percentage was increased from 3% incrementally to 4.5% using the same core flux formula, some improvements were shown in the rate of wetting and the spread of the solder. While this may be attractive when considering cycle times and overall production output, there is another factor that should be considered: spatter. In our study, we found that spattering is influenced by formula more than flux percentage. As seen in our formula control group, the spattering performance of each board is relatively similar using flux percentages ranging from 3–4.5% (Figure 3).


*Figure 3. Control group.*

## Other Conclusions

### ROL0 < ROL1 < ROM1

The results showed that not all flux percentages and activity levels were created equal. As was expected, the activity level of the flux at 3% of the core improved congruently with the appearance of spread and wettability, meaning that testing done with J-STD-004A ROL0 did not perform as well as J-STD-004A ROL1, and both performed inferior to J-STD-004A ROM1. However, in regard to spattering, it should be noted that as the activity level went from "L" to "M," there was a tendency for decreased spattering performance, as shown in Figure 4.


*Figure 4. ROL0 < ROL1 < ROM1.*

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