Low-cost Laser Cutter and PCB exposure

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***Abstract*— Downward trend in laser technology price and increase of the accuracy achieved has allowed it to acquire a new dimension in recent times. This paper proposes, with a practical approach, focusing on the RF field, the use of an innovative low-cost laser technology as part of the practical syllabus of an Advanced Electronics Prototyping Techniques course or similar. It provides with conceptual understanding on industrial manufacturing limitations while studying different materials engraving, professional software suites and PCB Exposure, in contrast with the expensive CNC milling methods typically used, an alternative cheaper laser engraving technique for RF is exposed.".**

Keywords*— *cutter; electronics education; engraving; Gerber; laser; low-power laser; Radio-Frequency PCB; stencil; SVG format.

I. Introduction

Currently, laser cutting is increasingly being used thanks to the advantages that it offers. One of the most important factors is the reduced price of the low-power laser cutting machine, which allows any user or company to easily acquire it. The reduction of the production costs and the increase of the quality of results are also a significant factor. That is why small businesses and universities are including this technology in the manufacturing process of their devices and R&D laboratories.

In a laser cutting machine the material melts or burns depending on the power of the incident laser, obtaining a very good quality surface finish. Particularly, this paper will deal with low-power laser technology. It uses less energy than other relevant cutting methods, such as plasma cutting, which needs powers around 3 kW to get similar results. Also, it is a technology that allows cutting easily without the help of advanced tools since the laser cutting machine is easy to acquire and control. This control is easy because the low-power laser cutting machine is a CNC (Computer Numerical Control) machine, i.e., the computer controls the position and speed of the motor that drives the axes of the machine [1].

Another advantage of a low-power laser cutting machine is that the laser beam does not wear during the cutting process, as well as their safety, since it does not include sharp elements, typical of mechanical machines. This prevents users from suffering accidents or the need of pieces replacement [2]. Additionally, low-power laser cutting technology allows cutting small objects or small diameter pieces in detail with high quality having a very low level of contamination on the work piece compared to traditional mechanical cutting techniques [3]. For these reason, the accuracy and quality of the results are better than the ones obtained by traditional methods of cutting.

However, like any other technology, it has some disadvantages. Low-power laser cutting technology cannot cut all kinds of materials. For example, copper, high thicknesses materials, metals and most transparent materials (such as glass) are impossible or too difficult to cut with a low-power laser beam because they reflect too much light or they are too thick. The following table describes the materials in which it is possible to engrave or cut.

TABLE I. ENGRAVING AND CUTTING MATERIALS FOR LOW-POWER LASER CUTTING MACHINE

Material	Can it be engraved?	Can it be cut?
Wood and bamboo	Yes, in any thickness	Only small thicknesses
Plastic and paper	Yes, in any thickness	Yes, in any thickness
Leather	Yes, in any thickness	Only thin leather
Bank card	Yes, in any thickness	Only thin bankcard
Rubber	Yes, in any thickness	Only thin rubber
Foam and felt	Yes, in any thickness	Yes, in any thickness
Horn	Yes, in any thickness	No
Metal and copper	No	No
Stone and shell	No	No
Transparent and translucent material	No	No
Reflective material	No	No
Ceramic	No	No
Jewelry	No	No
Silver	No	No

When the target are high thicknesses materials, laser power must be higher, so the energy required to keep the device in operation is very high. Certain materials, especially plastics, produce quite toxic fumes in cutting process, so the cutting machine should be placed in well ventilated places. The speed depends on the type of laser and the type (and thickness) of the material to be cut. Nowadays this technology is being fast developed to solve these drawbacks as it is expected to play an important role within cutting techniques.

A. Description of the used laser cutter

A low-power EleksMaker Laser-A3 Pro 2.5 W laser cutter is purchased, with a price of 209.00 €. It is made of stainless steel and acrylic and has a size of 60 x 45 x 25 cm. The low-power laser cutting machine allows engraving and cutting the materials mentioned above (Table I) with A3 format as maximum size (30 x 40 cm).

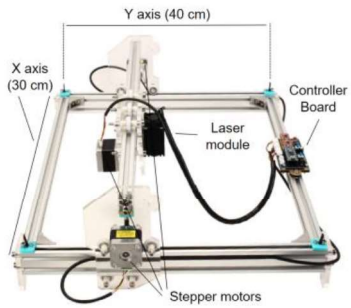


Fig. 1. Laser Cutter EleksMaker Laser-A3 Pro 2.5 W. It is formed by: a laser module, a controller board, three stepper motors, four stainless steel blocks that form the working area of the machine and another stainless-steel block to hold the laser module and allow its movement in two dimensions [4].

It has a laser diode of 2.5 W of power and it works with a wavelength of 445 nm. The laser light is violet and, also features a low positioning light. The controller board is EleksMaker Mana SE and it allows the control of the X and Y axes at the same time in a single movement. It communicates with the computer through the mini USB port. The controller board has three connection ports, one for each stepper motor. Also, it has two more connection ports, one to connect an optional 12 V power supply and another to connect the laser module.

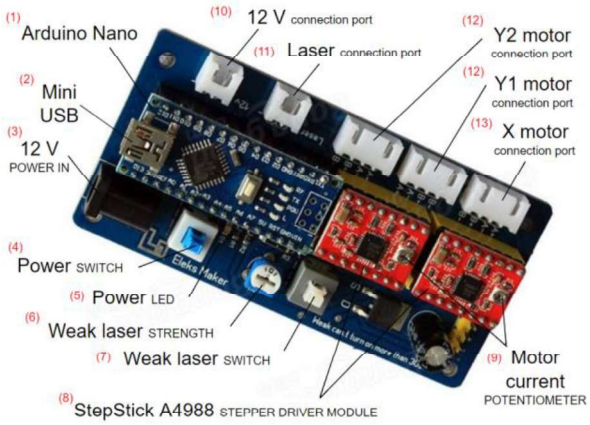


Fig. 2. Controller board. (1) Arduino Nano. (2) Mini USB of Arduino Nano board. (3) 12 V power input. (4) Power switch. (5) Power LED. (6) Weak laser strength. (7) Weak laser switch. (8) StepStick A4988 Stepper Driver Module. (9) Motor current potentiometer. (10) 12 V connection port. (11) Laser connection port. (12) Y motor connection ports. (13) X motor connection port [4].

The controller board has an Arduino Nano board and two carrier board for Allegro's A4988ET DMOS Microstepping Driver with Translator and Overcurrent Protection [5]. Also, a heat sink needs to be attached to the A4988ET. This driver allows controlling one bipolar stepper motor at up to 2 A output current per coil. However, the manufacturer EleksMaker indicates that the stepper motors employed are 1.3 A [4][6].

The machine has three stepper motors for X and Y axes, so it can engrave and cut in 2D. It uses two motors to control X axis movement and the third stepper motor for the Y axis.

B. Description of control software

Low-power laser cutting machine supports different applications: EleksCam, Candle, Benbox, Grbl controller, LiteFire or LaserWeb. LaserWeb is the most used because it is a free software that allows controlling printers, engravers and laser cutters. It supports different firmwares: Grbl, Marlin, Smoothieware and LasaurGrbl. Currently, version 4 is the latest, available at the GitHub project repository [7]. It is based on Node.js [8] and it is supported by most platforms: Windows, Linux, Mac, Raspberry Pi and Vagrant. To use this software in the laser cutter, the hardware of the machine must be slightly modified. Specifically, S header must be shorted with V0.9.

This machine works correctly for a maximum continuous working time of 2 hours [6]. Then it is necessary to wait 30 minutes, a time in which the laser module cools down. The equipment requires a working voltage of 12 V and a current of 2.5 A [1]. The desktop low-power laser cutter is delivered disassembled. The distributor provides a video tutorial ("*How to Assemble for A3 30x40 cm DIY Violet Laser Engraving Machine*"). This activity may be also useful from the teaching point of view, to be proposed for students as a medium complexity assembly of a real product.

II. Low- power laser cutter basic application

The most basic application of the laser machine is to cut the materials mentioned above (Table I). To engrave or cut the objects with greater or less intensity, the parameters are modified at the control software. The most important parameters are: the percentage of used power, the number of passes over the same line and the engraving speed. In this application, the low-power laser cutter plays a very important role among all the technologies used. It allows cutting very detailed pieces of an easy and precise form with a very low production cost when compared other techniques [9]. The result varies depending on how the object is designed; in our case, as a first approximation, it will be used AutoCAD® [10]. For this reason, we will evaluate the results obtained for different design formats of the object in this software, as well as describing the procedure needed.

A. Cutting and engraving process

In this section, we describe the cutting and engraving process with the low-power laser cutter. The following software are needed to cut objects with this machine: AutoCAD® [10], Inkscape [11] and LaserWeb [7]. AutoCAD® [10] is a paid tool from Autodesk. However, there is an educational version, which would allow its use for the practical syllabus period. Inkscape [11] is an open source vector graphics editing software. LaserWeb [7] is the CNC control software described before. Fig. 3 shows the flow chart of the processes that must be followed to carry out the cutting of an object with the low-power laser cutting machine.

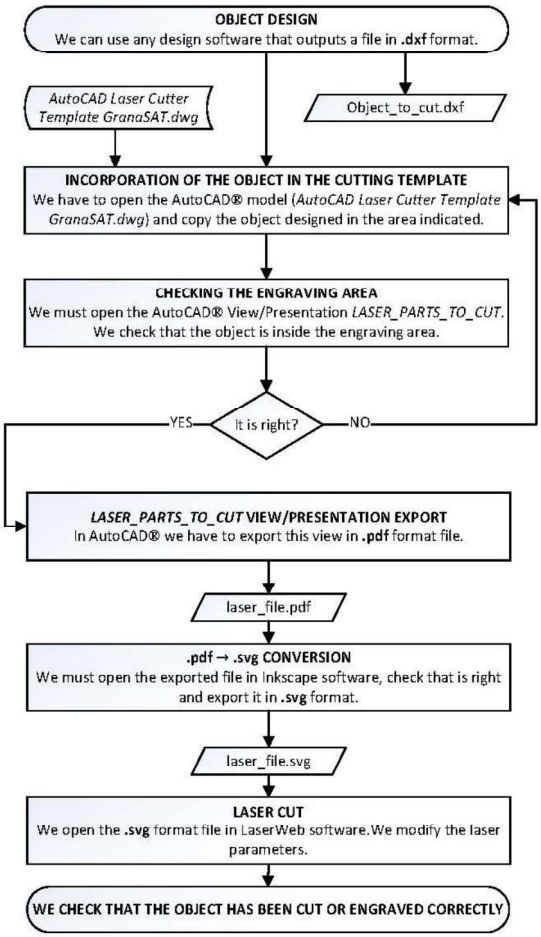


Fig. 3. Flow chart of the processes that must be followed to carry out the cutting of an object with the low-power laser cutting machine.

Firstly, the cutting template must be designed in AutoCAD® software [10]. It defines the engraving area of 300 mm x 400 mm and shows, the different working modes to make the design efficient. Three layers have been defined: the layer to be cut (red color), the layer to rasterize (white color) and the layer to not cut or rasterize (blue color).

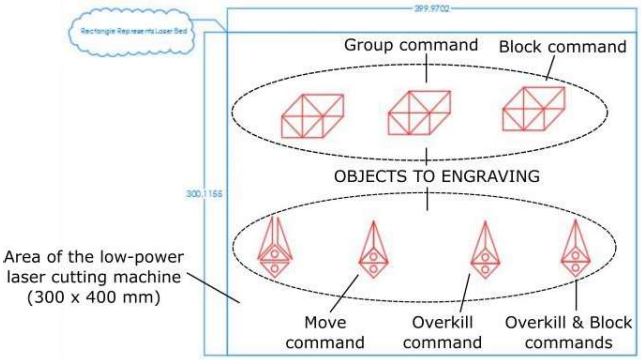


Fig. 4. Template designed in AutoCAD®. It shows the area of the low-power laser cutter (300 x 400 mm) and two types of objects designed with different AutoCAD® commands.

The AutoCAD® [10] project consists of a model and two views: LASER_PARTS_TO_CUT and LASER_EXAMPLE. The model includes both the low-power laser cutting machine area and an example of use. Two views have been made on this, one in the engraving area and another in the example. LASER_PARTS_TO_CUT view shows the objects to be engraved. In this way, we can check if the objects are within the area of the low-power laser cutter. Also, we can see how the lines defined in blue color have disappeared since this layer should not be engrave. On the other hand, in the view LASER_EXAMPLE is shown an example of use in which different AutoCAD® [10] commands have been applied for the same object.

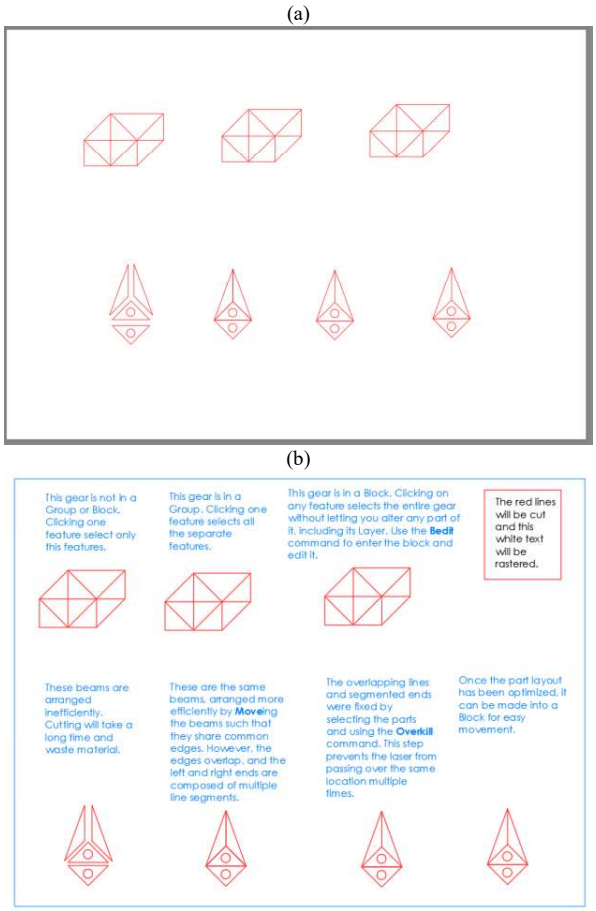


Fig. 5. AutoCAD® project. (a) LASER_PARTS_TO_CUT view. (b) LASER_EXAMPLE view.

B. *Example of use*

In AutoCAD® [10] there are different commands that optimize the design of an object. The example of Fig. 4 demonstrates the advantages of these commands. For this example, we used a sheet of cardboard with a thickness of 2.28 mm. The laser module works at 80 % of its maximum power, 800 rpm [12] and a cutting speed of 1 mm/s. A single pass has been defined to only engrave the object in the material.

If no commands are applied the object is designed line by line. Two commands for grouping the lines that form the object

are compared: GROUP and BLOCK [13]. Using the GROUP command of AutoCAD® [10] and selecting the objects to be grouped [13] improves the efficiency of the object. Now all the items have been grouped and when any of them are selected they will all be selected automatically. Another option is to create a block with all lines. The main difference with the groups is that once created, each time a block is inserted what is done is a reference to the block created so that the AutoCAD® [10] file reduces its size and if it is a block is modified all inserted in the model (Table II). To do this, we use the AutoCAD® [10] BLOCK command [13].

TABLE II. THEORETICAL COMPARISON OF THE DIFFERENT COMMANDS FOR GROUPING OBJECTS

Command	Object View	Theoretical Laser Working Time
No command	Set of lines	Low
GROUP	Set of lines	Medium
BLOCK	A single line	High

When we do not apply any command, the laser engraves each line separately and the working time is reduced but the laser does not work continuously. In the second case, the GROUP command [13] is applied, the route is optimized and the laser "ON" time is higher. The BLOCK command [13] defines the set of lines as a single object. While cutting, the laser stays "ON" all the time so the laser module follows a longer path.

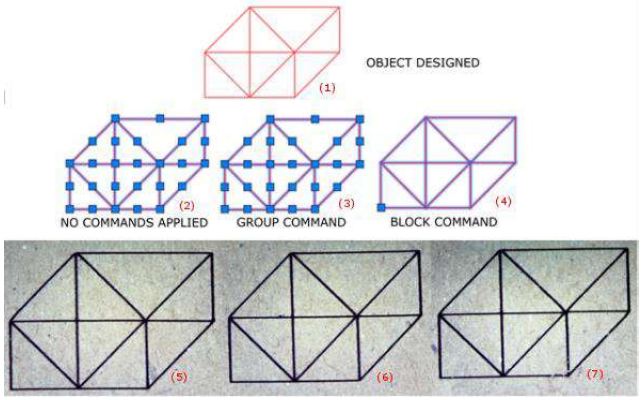


Fig. 6. Comparison of the definition and results of the same object to which different AutoCAD® commands have been applied. (1) Object designed. Definition of the object (2) without applying any commands, (3) by applying the GROUP command and (4) by applying the BLOCK command. (5) (6) (7) Result of the engraving seen from the electron microscope.

Pictures 5, 6 and 7 of Fig. 6 show that the only differences between the different AutoCAD® commands applied are working time of the laser and the path that it follows.

Next, a new object is created to evaluate the effect of having to engrave several objects, depending on whether they overlap or not. For this, two commands are used: MOVE and OVERKILL [14]. First, the geometric shapes are separated from each other by a small distance of 4 mm. This design will not be very efficient since it engraves each geometric shape separately and wastes material. Applying the MOVE command, the shapes are not engraved separately but in cases where the lines are shared in several ways they overlap, with a thicker line in these areas. To solve that problem it is used the OVERKILL command [14]. This function eliminates the duplicated geometry in the selected objects.

TABLE III. THEORETICAL COMPARISON OF THE DIFFERENT COMMANDS TO INCREASE THE EFFICIENCY OF THE DESIGN

Command	Maximum line width	Theoretical Laser Working Time
No command	Width set	Very high
MOVE	More than the defined width	High
MOVE & OVERKILL	Width set	Low
MOVE & OVERKILL& BLOCK	Width set	Medium

When any command is applied, the working time of the laser will be higher (Table III) and it is possible that if the forms are too close the material will burn. Applying the MOVE command, the working time of the laser has been reduced (Table III) but there are some overlapping lines by which the laser passes more than once and the material can burn. MOVE and OVERKILL [14] commands offers a shorter working time (Table III) and a higher quality result since all lines have the same thickness. Finally, the object has been converted in block with BLOCK command [13].

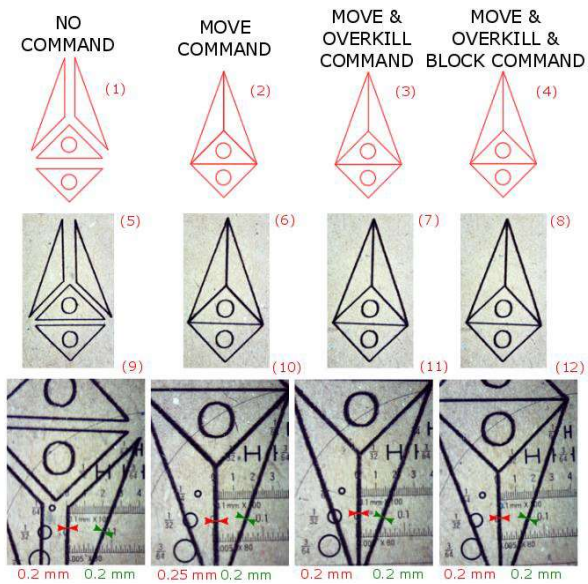


Fig. 7. Comparison of the definition and results of the same object to which different AutoCAD® commands have been applied. Definition of the object (1) without applying any commands, (2) by applying MOVE command, (3) by applying MOVE and OVERKILL commands and (4) by applying MOVE, OVERKILL and BLOCK commands. From (9) to (12) Result of the engraving seen from the electron microscope and measurement of the line width.

For the first case (pictures 1 and 5 of Fig. 7), the forms are separated a certain distance. With the MOVE command (pictures 2 and 6 of Fig. 7) the laser passes more than once through those lines shared by the geometric shapes. The third defined object (picture 3 of Fig. 7) applies the MOVE and

OVERKILL commands [14]. The latter is responsible for all lines have the same thickness: 0.2 mm (pictures 7 and 11 of Fig. 7).

C. Comparative results

Below is a comparison of the results for the different design formats (Table IV). It includes the working time of the laser and the thickness of the line engraved by the laser.

TABLE IV. COMPARISON OF THE RESULTS OF THE TWO OBJETCS DESIGNED

Object	Command	Line Width	Laser Working Time (HH:MM:SS)
Object of Fig. 6	No command	0.2 mm	00:01: 44.32
	GROUP		00:01:54.20
	BLOCK		00:01:54.70
Object of Fig. 7	No command	0.2 mm	00:01:41.14
	MOVE	0.25 mm in overlapping lines and 0.2 mm in rest	00:01:39.91
	MOVE & OVERKILL	0.2 mm	00:01:23.34
	MOVE & OVERKILL & BLOCK		00:01:24.03

Creating a group from the objects would be the optimal option because the working time of the laser is minimal. On the other hand, use OVERKILL command [14] reduces the working time of the laser and ensures that all lines have the same thickness and there are no overlapping objects.

III. PCB EXPOSURE

PCB manufacturing is a complex matter. Although manufacturing cost of standard PCB has been dramatically reduced over the last years, it is still expensive and harder to find when RF substrates are required. Different techniques and technologies are used in industry for mass production and prototyping. An innovative low-cost method is exposed in this paper, making use of the laser engraving technique introduced before, which will allow students to study manufacturing techniques in a practical manner, while realizing of the issues which may arise in an industrial process. Again, this process is intentionally followed using professional software suites widely extended in industry, allowing students a first contact with them.

A. Design Files treatment

The first issue to deal with is the treatment of the files which contain the PCB layout; Gerber® format is usually used in industry to manufacture PCB. However, the controller software used, LaserWeb, does not admit Gerber files. Therefore, an adequate conversion must be performed. Block diagram of Fig. 8 shows a way to perform the conversion process.

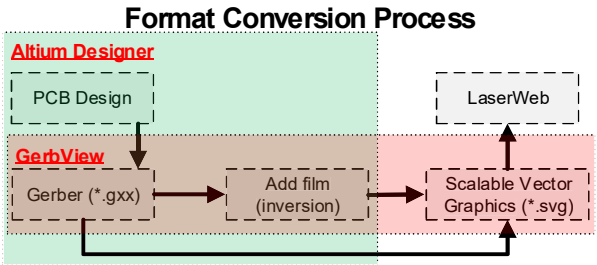


Fig. 8. Film Wizard Menu

This process uses Altium Designer®, one of most extended software for PCB design, and then shows two possibilities: either adding the film directly in Altium Designer®, and convert it to *.svg with GerbView® or make the inversion and convert it to *.svg format all at once using GerbView®. There are, of course, more software and ways to perform this process, however, this will be the one considered in this paper. In case of using Altium Designer®, the first step deserves to be remarked; for the sake of simplicity, instead of a real PCB design, a simple template will be used. In addition, this template will be useful for students to characterize and determine the limitations of the hardware used, which are vital skills when working with rapid prototyping.

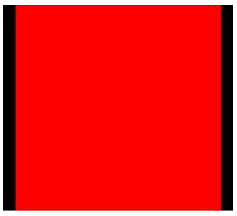


Fig. 9. Gerber Template used

In this case, as it can be appreciated in Fig. 9, it is a simple square; however, the process is the same regardless of the complexity of the design. Once Gerber files (in this case, for the Top Layer) are generated, the steps to follow if using Altium Designer are:

1. Generate *film*. It is the step which inverts the colors of the layout. In Altium Designer® it is created from the menu "Tools→Film Wizard".

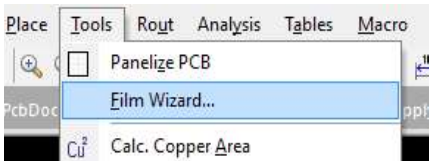


Fig. 10. Film Wizard Menu.

2. It is necessary to set-up the *film*. Fig, 11 shows that the *film* must be configured according to the size of the PCB, (1), the number of them (for panelization), (2), and negative/mirror options, (3). The size must be adjusted according to the case, as well as the panelization; for simplicity, no array will be considered. Finally, negative option must be selected for the layers to be engraved, (4). Regarding film size, if using Altium

Designer®, only entire lengths in inches are accepted. This fact will gain importance later.

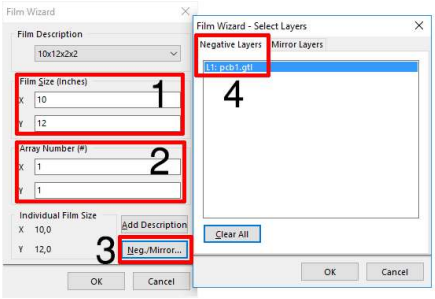


Fig. 11. Film Wizard Menu

When generated, the result looks like Fig. 12.

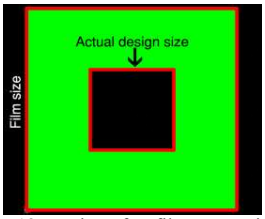


Fig. 12. Design after film generation.

Inversion has produced that the original square has been replaced by an empty space of equivalent size, and has been surrounded with a region whose size corresponds with the specified in **(1)**. It means that the *usable area* of the whole engraving area will be only the black square, while the rest is wasted. Therefore, to minimize wasted material, it is recommended, when using this method to generate the film, to try to make designs whose size is the closest possible to entire units of inches. Of course, as said before, there are other ways to produce the inversion necessary without that constraint; this one is exposed for the extended use of Altium Designer in PCB Design field. Once the film is generated, it can be converted to *.svg format, for instance, using the GerbView software mentioned.

B. *Manufacturing and Testing*

Once the files derived from the design have been adequately treated, a *.svg format file should have been obtained. To perform the manufacturing of the design, that *.svg file must be loaded at LaserWeb.

Fig. 13 shows the main interface of LaserWeb Software. Block 1 is used to load the *.svg files while Block 2 allows setting the options of the process. Particularly, blue boxes have been placed at the three relevant ones; the first one determines the technique used to engrave, in this case, *Laser Fill Path*. The second blue box, *Line Distance*, establish the distance between every round, and it is constraint by the minimum line width that the Laser is able to perform; after testing, for this EleksMaker Laser-A3 that distance was found to be 0.01 mm. The third blue box contains the options regarding *Cut Rate* and

Fig. 13. LaserWeb Main Interface

Passes. Finally, after setting the desired parameters, Block 3 allows generating the corresponding GCODE.

Engraving directly removing the copper from the laminate is a hard task which requires expensive high-power Laser System. In order to be able to engrave the substrate using a low-cost technique, it is painted with Standard Black Synthetic Spray Paint. Once applied, the laminate is let to dry. It allows a low-power laser like this EleksMaker Laser-A3 to degrade the paint layer instead of the copper. It must be remarked the importance of this step: trying to directly remove the copper with a Laser System which is not specifically designed for it may result in severe damage of the Laser because of reflections. Once everything is adequately set, the engraving is started from the menu Control, shown in figure 14.

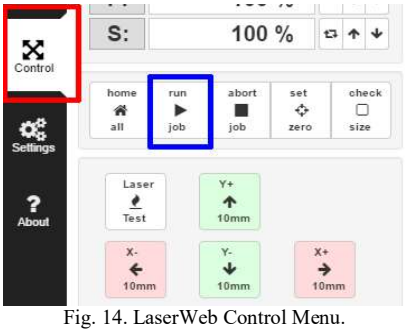


Fig. 14. LaserWeb Control Menu.

After engraving, to remove the paint layer, a chemical attack Technique based on Ferric Chloride is used. Although this is not directly related to the topic of the paper, it is common technique, which in our opinion, students must practice during their academic training; in addition, it reinforces rapid prototyping techniques, extensively requested today. This chemical reaction is composed of Hydrogen Peroxide and it is given by this equation.

$$Cu + 2HCl + H_2O_2 \rightarrow CuCl_2 + 2H_2O \quad (1)$$

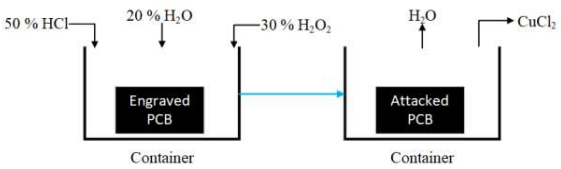


Fig. 15. Chemical Reaction.

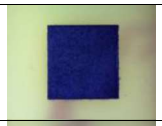
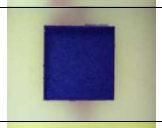
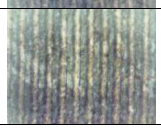
As shown in figure 15, on the left side, the elements which produce the reaction, the copper from the substrate, Ferric Chloride and Hydrogen Peroxide. To control the speediness of the reaction, water is also added to dilute the acid. The proportion used is 50 % HCl, 30 % H_2O_2 and 20 % H_2O. The reaction produces Copper(II) chloride and water. Following this process an experimental comparative is made, with the parameters listed in Table V.

TABLE V. COMPARISON OF THE RESULTS OF THE TWO OBJETCS DESIGNED

Parameter	Value
Laminate Used	FR4. 1.6 mm thickness, 1 oz.
Paint Used	Standard Black Synthetic Paint (Spray)
Artwork dimensions	147.26 x 101.54 mm
Line Distance	0.01 mm
Technique Used	Laser Fill Path
Passes	1
Paint Layers	1
Cut Rate	Variable

Cut Rate defines how fast the laser movement will be. With the parameters stated at table V, the template shown in Fig. 9 is manufactured using different *Cut Rates*, to determine the influence of these parameters in the result.

TABLE VI. COMPARISON OF THE RESULTS

Cut Rate (mm/s)	Before chemical Attack	After Chemical Attack	Engraving Time (HH:MM:SS)
200			2:19:16
500			1:00:29
1000			00:36:56
2000			00:29:40
10000			00:29:12

Regarding results, before chemical attack, lines are more defined when the cut rate is lower, with larger engraving times. After chemical attack, results are quite similar regardless of how fast cut rate is configured, which implies that slow cut rates are not specifically needed to obtain acceptable results. Malformation appreciable at the 2000 mm/s test are probably due to an excessively acid solution.

The faster the cut rate is set, the shorter engraving time. However, this acceleration is not linear at all, although cut rate is increased up to 10000 mm/s, the cutting machine is not able to maintain the engraving time in the same proportion. 2000 mm/s seems to be limit given by this hardware. Fig. 16 shows this relation. The curve obtained can be characterized with an acceptable reliability (R^2 = 0.75) using a non-linear regression given by the equation:

$$y=726.93\ x^{-0.385} \quad (2)$$

With 'y' parameter in minutes and 'x' parameter in mm/s.

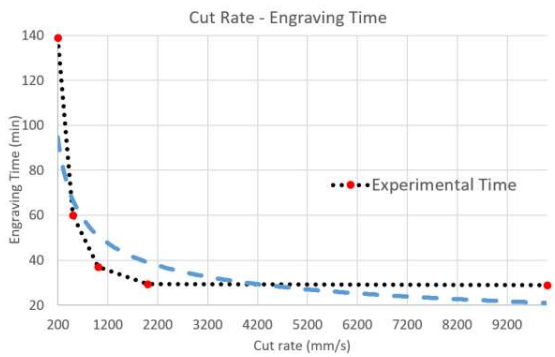


Fig. 16. Cut Rate – Engraving Time curve.

Once the hardware has been adequately characterized and its limitations are known, it is proposed as activity for students to manufacture an actual RF PCB design, particularly a LNA

design, from [18]. It is based on the LNA Mini-Circuits PSA-4 5043 and Top Layer layout is shown in figure X. The design is quite simple because PSA-4 5043 is internally matched to 50 Ω and there is no need to perform any matching network or similar. Figure 17 shows how the result should look like after the processing and before to be manufactured.

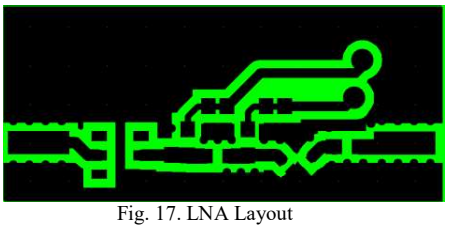


Fig. 17. LNA Layout

C. *Stencils manufacturing*

Once the circuit is engraved on the PCB board, it is necessary to solder the corresponding components. Currently, the most common method to do this is surface mount technology (SMT). It consists in mounting each component, active and passive, on the surface of the printed circuit. Each of the surface mount devices (SMD) is soldered independently on the board. It is tedious and slow when the number of components is high or you want to make a large amount of PCB. Stencils allow soldering the majority of components at once. Solder paste is deposited on the entire board. That is why the solder paste templates are necessary, so that the solder paste is only deposited in the pads indicated in the design of the circuit.

A board with a row of SMD resistors of different sizes placed one after the other has been designed. This makes it possible to evaluate from what SMD component size laser technology can be used for the manufacture of solder paste templates with Stencils. It is interesting to export the surface layer or Cream Layer or solder paste layer (Fig. 18). Solder paste layer contains the pads where the SMD components will be soldered. The size of the pads is slightly lower than designed because the Stencil layer of the design tool is being exported. This is necessary to compensate for the inevitable melting of the Stencil caused by the laser heat. Other way, the pads will be too large and bridges would be created.

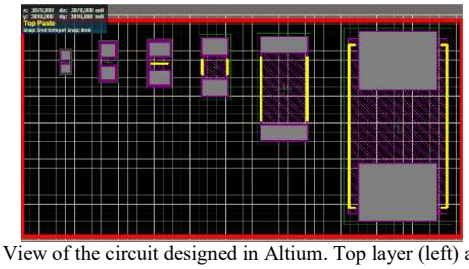


Fig. 18. View of the circuit designed in Altium. Top layer (left) and solder paste layer (right). The colored areas in red (left) and grey (right) are the pads where the SMD components will be welded.

Finally, the file is opened in LaserWeb. The configuration profile of the low power laser cutting machine is loaded and the "*Laser Cut*" cutting mode is set to cut only the contour of each pad. To perform a practical demonstration, a Stencil with a thickness of 0.07 mm has been chosen. LaserWeb allows trying different laser power, cut rate or the number of passes to obtain different results. For the material chosen, the laser starts cutting at 83 % power (830 rpm [12]) and it is recommended to define a speed lower than 100 mm/s for low power and around 1000 mm/s for high power. The higher the power of the laser, the higher the cutting speed must be so that it does not burn the material and vice versa. If cutting speed is too high, the result is less accurate. Increasing the number of passes is useful when the laser power is low, and cutting the material is desired.

This hardware allows manufacturing stencils with a laser power lower than 85 % and cut rate around 300 mm/s. Higher values yield to burnt pads unless cut rate is increased. When manufacturing this this Stencil, a laser power of 83% (830 rpm [12]) has been set, with a cut rate of 1 mm/s and 2 passes.

The Stencil is inspected with the microscope to evaluate if the cut is precise and clean (Fig. 19). The edges of the pads are slightly melted, due to the combustion of the plastic. However, this does not affect the larger pads. With the microscope and the scope of the microscope it is determined which size of pads marks the limit to use laser technology. This pad size is defined as one in which the edges of the plastic form a 90° angle.

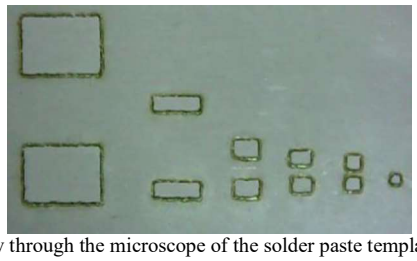
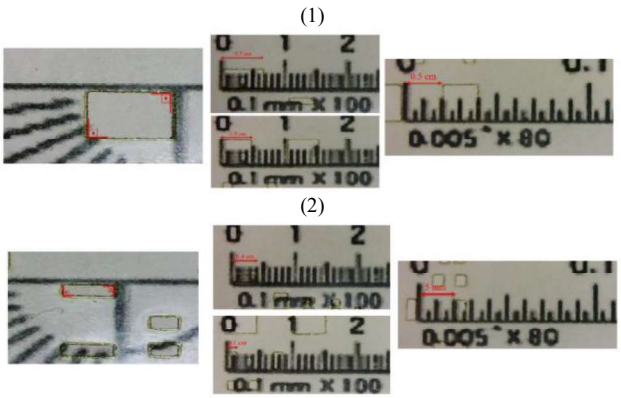


Fig. 19. View through the microscope of the solder paste template of the row of SMD resistors of different sizes. Stencil 0.07 mm thickness.

Fig. 20 shows that pads of the three largest packages the corners form perfect 90º angles and therefore the lines that form it are straight. As the size of the pad is reduced the edges become rounded because the surface is smaller and the plastic melts with the passage of the laser. In this way, laser technology is useful for manufacturing stencils with SMD components with a minimum size of 0.3 x 0.1 cm. It is observed for SMD resistances of 0.2 cm x 0.1 cm that the pad begins to be rounded, curving the lines that form it. The separation between the pads is also important. A large gap will help the pads to be perfect rectangles.



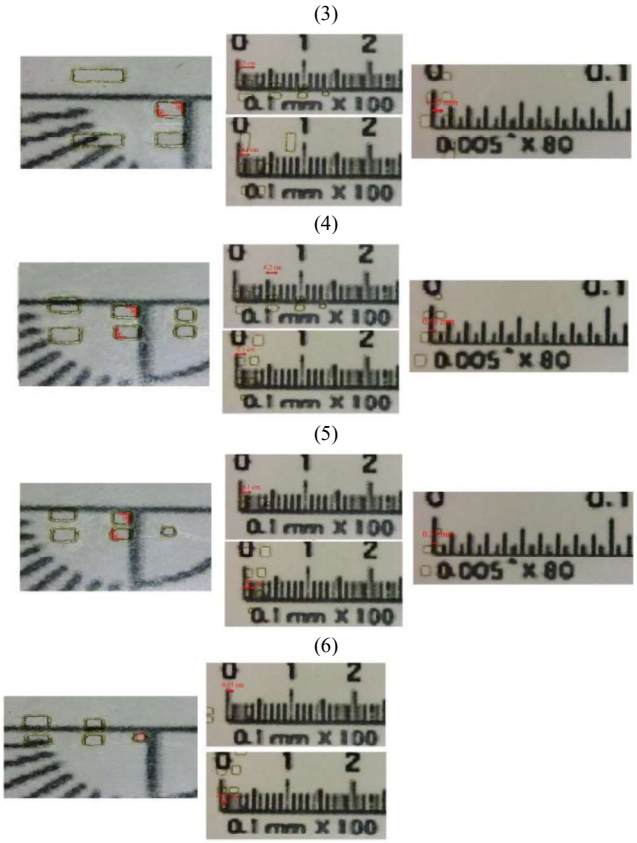


Fig. 20. View through the microscope of the pad of (1) 0.7 x 0.5 cm, (2) 0.4 x 0.1 cm, (3) 0.3 x 0.1 cm, (4) 0.2 x 0.1 cm, (5) 0.1 x 0.1 cm and (6) 0.05 x 0.05 cm. The corner angle of the pad is shown in the image on the left. In red, an angle of 90º has been indicated. The dimensions of the pad (width and height) are shown in the two central images. The separation between the pads is shown in the image on the right.

After that, the Stencil template is placed on the board very well aligned. This stage of the PCB manufacturing process is very important since a minimum error when placing the stencil has great consequences. If the misalignment is noticeable, the board is likely to lose its electrical functions. In addition, ideally the template is stretched and flat on the board. This done, the solder paste is dragged on the entire board. To continue, the stencil template is separated from the plate and the solder paste remains in the circuit pads. Finally, the devices are placed carefully in their correct place. It is crucial that the placement of the SMD components is very accurate. Once all the components are in place, the board is heated to reflow the paste and all the devices are soldered simultaneously.

The board is inspected with the microscope to verify that the components are correctly soldered. It is likely that when placing the solder paste some pins of the devices have a bridge of paste between them. This can occur due to breaks in the template during the placement of the solder paste or because of the short distance between pins and the amount of paste placed. The jumpers and jumpers are solved with solder.

IV. Conclusion

The use of a low-power laser cutting machine to engrave or cut objects is useful because of prize when compared to other machines. It is advantageous since the result of cutting and engraving is very precise. In addition, as indicated in Table I, the low-power laser cutter can cut and engrave materials with different thicknesses in a very low laser working time. Because low-power laser techniques are expected to be increasingly present in manufacturing processes, this article has described in detail the different stages of it (Fig. 3). From an educational perspective, we strongly believe that this topic can offer students their first experience at a variety of fields, from PCB design, to low cost PCB engraving and manufacturing techniques, which makes this content vital in every Master related.

The thickness and opening of the stencil controls the amount of solder paste deposited on the PCB. It is important to have a stencil with the proper thickness and that the opening of the template is optimal so the amount of paste is not excessive as it compromises the electrical functionality of the PCB. For this, it is necessary to have an optimal cutting speed so that the stencil is accurate. On the other hand, the laser slightly melts the edges of the pads, especially the smaller ones. It is proposed as a solution to this problem to cut the template using two superimposed Stencils. In this way, the laser will melt the upper part and when separating the two Stencils, the lower part will be perfectly cut with no edges melted.

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