The Design Process of Commercial Circuit Design

Dante Rosalina
University of Southern California
Los Angeles, United States
rosalina@usc.edu

Nic-Alexander Strutz
University of Southern California
Los Angeles, United States
nstrutz@usc.edu

Ashleigh Sincock
University of Southern California
Los Angeles, United States
asincock@usc.edu

Anthony Romo
University of Southern California
Los Angeles, United States
aromo868@usc.edu

Avantika Saxena
University of Southern California
Los Angeles, United States
saxenaav@usc.edu

***Abstract*– This report explores the main process of designing a commercial circuit design. It details what steps have to be taken to produce a PCB (Printed Circuit Board), which is the commercial standard for circuit design. First developed in the 1930s, PCBs have improved greatly in the last 90 years, and combine conductive and insulating materials to provide connections between components. The history of the first PCBs and the advancements that helped improve them is mentioned alongside the individual components of a circuit. Resistors, capacitors and relays, etc. as well as their purpose and function in a circuit are explained. Additionally, the manufacturing process of a PCB is explored, explaining how different sheets of materials are etched and engraved to build the layers of the circuit board. It is also explored how this topic links to the week 3 project of building a circuit to monitor coronavirus symptoms in vulnerable members of the population.**

***Keywords*– Design process, PCB, circuit, components, LED, resistor, capacitor**

I. Introduction

There are multiple ways of creating a circuit, such as using a breadboard, however the common commercial process is to create a PCB. This stands for printed circuit board, which consists of a combination of conductive and insulating materials to create reliable connections between different components of the circuit. This reduces the space needed for wires and simplifies the manufacturing, as electronic components can be soldered directly onto the board. A PCB is usually a green color, but can come in any other color as well. PCBs are made specifically for the product they are intended for as there is no modularity or customizability, that would make it usable in any other scenario.

II. History of Circuit Design

The first PCBs, as seen today, were created and developed in the 1930s. Australian inventor Paul Eisler first made a PCB for a radio system, the technology of which was adopted quickly by the US military. The first concept of a PCB was created in 1925, when conductive materials were stenciled onto a wooden board [6]. The concept of etching copper foil onto non-conductive material was released to the public in 1948. Over the following decades this technology kept evolving until it became the commercial PCB that is commonly used today. These advancements include things like photo imageable polymer coating, which is used during the copper etching process. An addition to this is surface mount technology, which allowed components to be soldered onto the PCB without the need for a hole or wire lead [6]. All of these helped to make PCBs even more condense and efficient.

III. Design Stages

The design process of a commercial circuit can be split up into several categories. Firstly, the parameters of the electronics have to be known. This includes the voltages required for and the maximum current of components. Most commercial designers will be aware of the benefits and limitations of the parts that will be used, but may have to do additional research on specific elements that have not been used previously.

Next the pin diagram for the PCB has to be created, which shows the connections between chips and switches, as well as the other wiring that is required. This can then be transferred into a circuit designer software, such as Digi-Key PCB Builder or CircuitLab. The software will display how the circuit board will work, so a prototype does not have to be created to test each design. Additionally, it has to be considered how the PCB will be stacked up, as this can impact the efficiency [3].

At this stage the IPC requirements and parameters should also have been considered. IPC, standing for Institute of Printed Circuits, aims to create international standards for the assembly and production of electronic components. Therefore, these requirements should be met with each created PCB, which ensures it will be compatible with other aspects of the electronics [3]. Furthermore, the placement of the different components also has to be decided carefully. Some may produce electrical noise in the circuit, which although it does not have a large impact on the power or ground wires, can become a problem if it influences signal wires [4]. Therefore, different components may not be placed close to each other, although most experienced PCB designers will know how to place parts properly. Mounting holes also need to be placed onto the PCB, based on the application and location of the board. Different types of mounting holes, such as countersink holes, can be used for different purposes.

The final step of the design process is to add labels and identifiers to the board, indicating where each of the separate parts will be soldered on during the assembly. This not only saves time, but also makes the organization better in case repairs have to be done in the future.

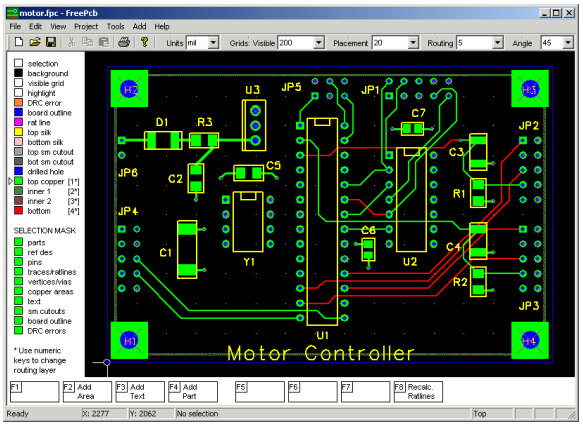

Fig. 1. FreePCB software used to design PCB layouts [1]

IV. Components of an Electronic Circuit

Electronic circuits are made up of many different components, which are connected through copper strips or wires to complete a function. They can range from simple circuits like turning on a LED to more complex circuits that take multiple inputs from sensors and switches to control several LEDs or other outputs.

Components are commonly separated into 6 categories: capacitors, resistors, diodes, transistors, inductors and relays [5]. Capacitors are similar to batteries in the aspect that they store energy, however unlike batteries, capacitors charge and discharge in fractions of a second. The main function of them is power factor correction, which is required to provide sufficient starting torque to motors. Resistors consist of thin copper wires that are wrapped around a ceramic core, which causes higher resistance in the wire, as the more turns and the thinner the wire is, the higher the resistance is [5]. They are separated into different resistances, shown by the markings on the ceramic rod. Most PCBs include resistors built in, which bypasses the need for separate resistors in commercial applications. They are mostly used to manage current and voltage in a circuit, giving the maker more control. Additionally, if the current is too high, it can cause components to overheat, such as LEDs, which are prone to overheating at high current. It can also dampen the voltage in case some microcontrollers require a lower voltage.

There are two different types of diodes: vacuum and semiconductor. A vacuum diode uses an electron

cloud in a vacuum to prevent current from flowing from the anode to the cathode, instead only flowing in one direction. A semiconductor diode uses p- and n-type semiconductors to achieve the same effect of only allowing current to flow in one direction [5]. Another component that is used in circuits is a transistor. They work similarly to relays, however without using any moving parts. Again, there are different types of transistors that achieve different functions, in this case turning on based on a negative or positive voltage. They also amplify electric signals, such as in hearing aids, where the sound waves are amplified to be louder when reaching the speaker. Consisting of coiled copper wire, the purpose of inductors is to convert AC power to DC, by preventing the AC from going through, while the DC can. They also are used in transformers and proximity sensors, as they produce a magnetic field. A relay is an electronic switch, which opens or closes when current flows through it. This is done through the use of electromagnets, which pull together or push apart two conductive plates. They are used in most complex electronics since they can control a high current using a low current signal [5]. All of these components make up the majority of circuits and are included in most PCBs.

V. Manufacturing

Most PCBs are machined, although some may also be made by hand. The main non-conductive material used is usually a glass fiber based board called FR4 [7]. For certain applications different materials, like PTFE based boards, are used instead, however they are harder to work with. The actual connections are made using thin copper sheets, which bonds together with the FR4. The most common form of etching the copper sheets is using Ferric chloride (FeCl3) [7]. Acid resistant sheet is placed over the copper and then the tracks are printed onto this layer using light. The remaining copper gets etched, leaving only the necessary paths.

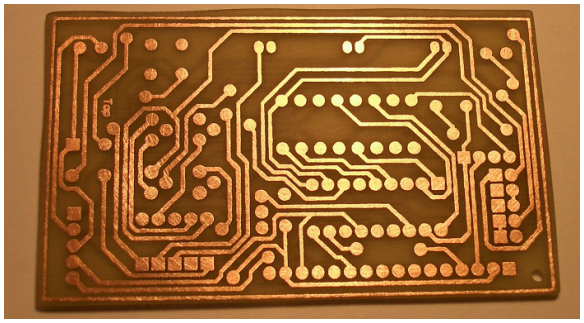

Fig. 2. Acid etched copper sheet [2]

Multiple conductive and non-conductive sheets are bonded together to create the full PCB, to which the other components of the circuit are then soldered to.

VI. Relation to Week 3 Project

The design process of commercial circuit design relates to the week 3 project, as it was a system for coronavirus monitoring, using AND and OR gates to light different color LEDs, based on how many symptoms the patient has. Although a PCB was not made, breadboards were used to create a circuit, by connecting different chips and gates to each other, following a logic diagram. This connects to the project, as a non-commercial circuit board was designed and created, following a similar process to the design of a commercial circuit board.

Resources

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