An Evolution in PCB Design Costs

Quiet Power

Feature Column by Istvan Novak, SAMTEC

In this column, I want to cover my experiences, particularly where costs are concerned, with printed circuit boards from the 1960s to the present day. I grew up in an apartment building in downtown Budapest, where I began doing hobby projects building circuits at our kitchen table. Now, I'm lecturing about the most recent advances in signal integrity at Oxford. We've come a long way. Over the decades, new technologies allowed users to have more layers, lower-loss dielectrics, fine-pitch surface connections, blind and buried vias, and HDI and HDI+ board constructions that allow us to design higher performing systems. I expect this trend to continue.

Today, to connect multiple components into a compact circuit, we mount the components on a printed circuit board. But in the late 19th and early 20th centuries, people would hammer nails into a wooden board and then wrap the leads of multiple components around them (the original breadboard). Household electronics, like vacuum-tube radios, amplifiers, and record players, all used a similar concept. The connection between components was done with wires, which were easy to replace if needed, and allowed connections in any direction. However, finding a particular wire in a chaotic three-dimensional wire blob was a real challenge.

As the number of connections increased, so did the possibility of mis-wiring something and manufacturing also became time-consuming. The printed circuit board technology gradually emerged. (If you are interested in the history of printed circuit boards, see references 2 and 3.) In the 1960s and '70s, the main cost driver was the number of layers.

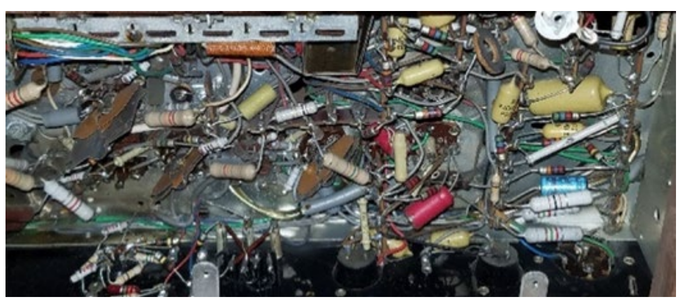

Figure 1: A Philips B5X21A vacuum-tube radio with discrete wiring. You can see the front, middle (with the back removed), and back (with the cover removed and a jumble of wires and component leads). Fun fact: This radio still works even though it was manufactured in 1963[1].

PCBs on Layers

In the early days, PCBs had one or two connecting layers, which required only a single dielectric sheet with a conducting layer on one or both sides. As a child, electronics fascinated me, and as soon as I could read, I turned to hobby magazines. Some described the new technology: Instead of discrete wires, they could draw connections of electronic circuits on copper-clad dielectric, and then etch away the copper where the connection wasn’t needed.

Later, I made little gadgets with transistors that I had purchased from a local hobby shop that sold materials, tools, and components for radio amateurs and hobbyists. With the non-market economy in those days, a transistor cost about the same as six pounds of bread.

I built small portable radios on homemade printed circuits. The first attempts failed miserably. The hand-drawn pattern of ink that had to be baked before etching often peeled off too early. Once I discovered the correct temperature, length of baking over the kitchen gas range flame, and the proper etching time, the boards became more reliable. An example is shown in Figure 2. It is the audio amplifier of a battery-powered portable radio I built in the late ’60s[4].

By the late 1990s, glass-reinforced epoxy had replaced Paper Bakelite, and etching and plating had become carefully optimized and automated processes. The circuit complexity required several routing layers, plated through-holes, and blind and buried vias (which had recently become available). Instead of manually drawing the pattern with ink, engineers used CAD software to perform the routing. The CPU module in Figure 3 (reproduced from Slide 12[5]) had a 20" x 8.5" 24-layer PCB. The board did not have blind or buried vias and used only standard low-cost FR-4 laminates, but it had selective gold plating. The price of the prototype bare boards in small quantities was around $600.

As production ramped up, prices came down. In the 2000s, the cost of bare PCBs with standard laminate materials, no blind or buried

Figure 3: CPU module of SUN Microsystems V880/V890.

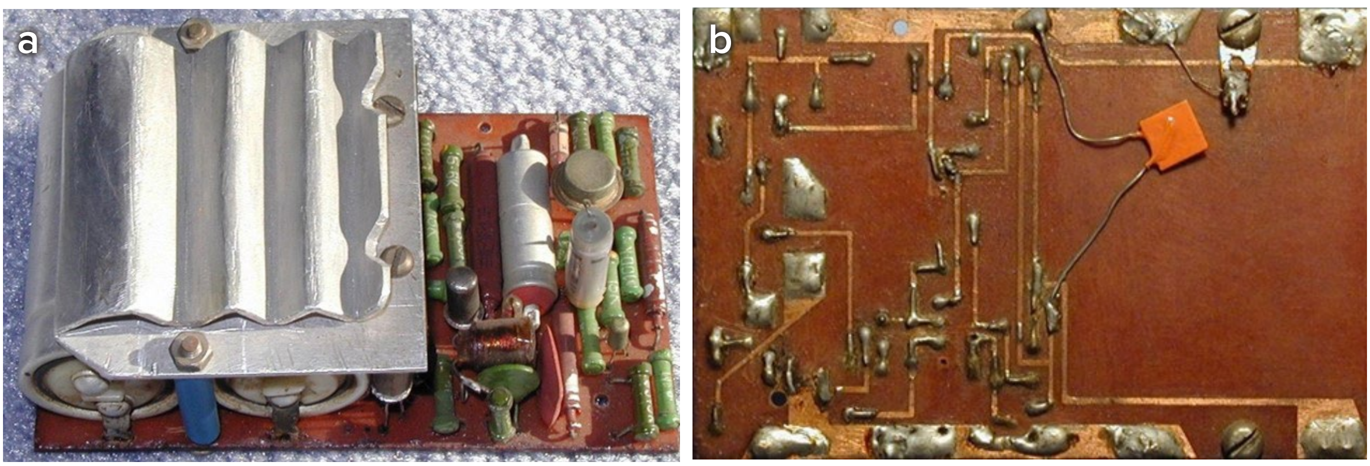

Figure 2: Homemade printed circuit board from the late 1960s. Figure 2a shows the top view of the single-layer PCB with the components. Figure 2b is the back side of the board with the copper traces. There was no need for vertical connections or plated through-holes, so the cost of the driver was simply the cost of the laminate. The color of the bare dielectric reveals this was an early Paper Bakelite board laminate. I recall the cost was probably around the price of a couple of scoops of ice cream at the time.


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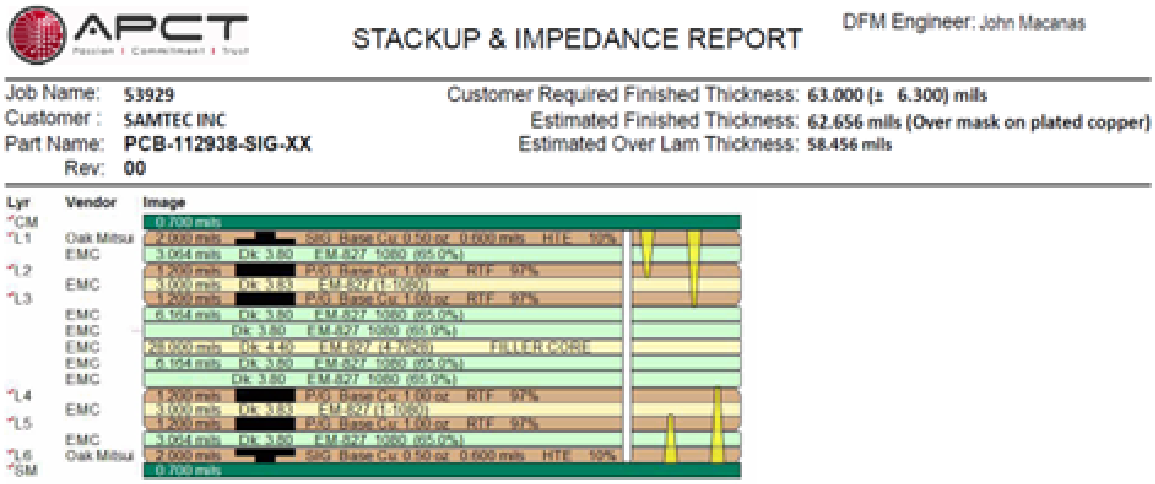

Start Layer	End Layer	Drill Type	Plate Type	Via Fill	Stacked Via	Min Drill Size (mils)	Drill Depth (mils)	Pad Size (mils)	Hole Qnty	Do Not Hit Layer	Related Process
1	6	Mechanical	PTH	----	----	0.000	58.5	0.000	0	----	Final Assembly - 1/6
1	2	Laser	Micro Via	Copper Fill	No	6.000	3.7	0.000	0	----	Final Assembly - 1/6
6	5	Laser	Micro Via	Copper Fill	No	6.000	3.7	0.000	0	----	Final Assembly - 1/6
1	3	Laser	Micro Via	Copper Fill	No	10.000	7.9	0.000	0	----	Final Assembly - 1/6
6	4	Laser	Micro Via	Copper Fill	No	10.000	7.9	0.000	0	----	Final Assembly - 1/6

	Plating Type	Panel Size	Grain Direction
Final Assembly - 1/6	Pattern Plate	18 x 24	18

Figure 4: Six-layer board stackup and material definition.

vias or special finishes, could be calculated by multiplying the board's square footage by three times the number of metal layers. As an example, consider a board of 12" x 8" with 10 layers and no special technology. This board size means a 0.8 square foot area. As each processed metal layer was estimated having a cost of $3, the estimated cost become 0.8 x 10 x 3, or $24.

Now, we've reached the 2020s. In another article I wrote[6], I describe a simple six-layer board designed and built in 2023. The board was built with regular FR-4-like laminates and had four blind-via layers: two on the top and two on the bottom. The blind vias were copper-filled, but not planarized. Exposed copper was gold-plated. Due to the usually fixed setup costs commonly called non-recurrent expenses (NRE), the cost was a strong function of the number of boards in small quantities. The price of these boards was around $400 each.

As PCBs have evolved over the past 60 years, so have their associated costs. Now, with more efficient manufacturing, new technologies (such as 3D printing), and more automation, I expect to see even more changes in the costs of PCBs that will make them more efficient to produce, thus helping both the manufacturers and the consumers. **DESIGN007**

References

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