Abstract—This paper presents a technique to combine high currents and microelectronic control in a single system for power train and power supply applications. The combination is achieved by incorporation of busbars and other massive copper bars into a printed circuit board (PCB) to obtain high current load capability as well as heat sink for components with considerable power dissipation. Typical applications of automotive industry or avionics handle currents in the order of up to 1000 Ampere.

Index Terms — Printed Circuits, Power Supply, Power Train, Power Control

I. INTRODUCTION

Actual power trains and power supplies target at intelligent functions to control, monitor and maintain the performance of corresponding systems. To close the gap between power conductors on the one hand and electronic components on the other hand, you usually need special interposer, cables and mounting material, especially if surface mount devices are provided.

On the electronics side, discrete power components and modules connected to separated control units can often be found. Increased currents and power loss at control unit components result in change of PCB technology from standard copper thicknesses of 35 micrometer to 70, 140, 210 or even 400 micrometer copper planes and conductors, typically.

Some special PCB techniques have been described to combine copper cross sections for higher currents with standard copper foils. One method is to pre-etch thick copper foils down to a standard thickness only at areas where the fine-pitch layout requires limited copper thickness [1]. Another method is to include copper wires in PCB to enhance conductor cross section selectively [2].

Even with 400 micrometer copper foils, the total copper cross sections are limited, for insulation plies between single copper layers. So standard PCBs are not applicable e.g. for devices which control currents of electrical power train directly.

The main motivation of system integration of busbars from copper of 1 to 3 millimeters height into PCBs is to save mounting space, effort, material and time when building up power systems which contain microelectronic controls.

Key part of the system is a patented PCB [3] where massive copper bars are integrated to enhance current load as well as heat spreading structures.

II. CONSTRUCTION OF HIGH CURRENT PCBs

Incorporation of massive copper parts into PCBs is carried out by separate preparation of the copper parts at first. This can be done by etching, milling or punching copper plates. The way of copper preparation depends on form factor, size and number of the parts needed. Minimum width of the thick conductor parts should be in the range of 2 mm.

In the second step the insulation material around the massive copper parts is structured by milling PCB base material of the same height as the copper inlays. Minimum insulation gap between copper parts should also be in the range of 2 mm.

After merging the copper parts and the surrounding insulation material, the whole PCB can be formed by a usual multilayer lamination process followed by standard PCB manufacturing processes like drilling, plating, and patterning of conductor layout.

There are some variations of the technology described which use the whole potential of embedded busbars.

First of all the busbar can be formed in a way that it protrudes up to the surface of the PCB as shown in Fig. 1. In this manner, the surface of the PCB will remains completely flat to allow a standard SMD assembly process with stencil printing, placement of components and soldering. Also IGBT modules and cable terminals will be easier to mount directly onto the board.

![Fig. 1. Cross section of a high current PCB with protruded areas for SMD components. Hatched areas show the central copper bar and conductors.](image-url)
Another version is obtained by forming peripheral leads sticking out of the edges of the PCBs. These constructions can be used to directly build connectors or busbar-like terminals.

If the copper inlays are limited to a small area of the PCB, they act as thermal inlays, leading the heat from components at the top side down to the bottom side. This is an alternative to the copper coins fit into milled holes after PCB production. The embedded copper parts distinguish itself in being more reliable, providing the opportunity of various shapes as well as connecting inner layers. In contrast to conventional heat sink inlays, embedded parts are not exerting mechanical stress on the PCB.

To safe weight of systems containing massive copper tracks some user replace the heavy metal by aluminum. Though electric conductivity of this light metal is reduced by 40% compared to copper, aluminum is interesting anyway, because its specific weight is only 30% of the corresponding copper value.

The latest variation of the high current PCB is a single layer design where protruded areas on a copper plate reach through notches of a single sided PCB up to the surface to provide solderable heat sink pads. This stack-up is particularly used for cooling components with high power dissipation, e.g. LEDs with up to 10 watts per component.

### III. ADVANTAGES OF HIGH CURRENT PCBs

The method of forming PCBs for currents up to some 100 amperes is advantageous especially if units are built which not only replace common lead frame or busbar structures. The technology shown best suits especially applications with complex electronic circuits placed on PCBs.

In detail there are advantageous points as follows:

#### A. Copper Cross Section

In contrast to standard thick copper stack-ups, these busbar PCBs handle typical busbar currents even with SMD-components, wire bonds or screwed contacts while contacting the entire cross section of the conductor. Bottlenecks in copper cross section between components and conductors by plated vias made for conventional PCBs are eliminated.

#### B. SMD assembling process

You can use standard SMD production processes to assemble power components as well as other microelectronic components in one run within an adapted soldering process. Connectors and special terminals could be added simultaneously. So you reduce mounting effort, material and time.

Drying and preheating steps have to be adapted to obtain good soldering results. In addition, soldering processes with good heat transfer to and from the assembly have to be chosen, e.g. reflow soldering by vapor phase soldering or using well controlled convection ovens.

#### C. Layout with high Degree of Freedom

Compared to standard busbars, the high current PCB technology provides a high degree of freedom for electronic design. The geometry and location of conductors can be defined with few constrains to maximize component density as well as thermal and functional performance.

#### D. Cooling of Components

The direct attach of components to the busbars also allows heat flow and consequently cooling of components. So the copper bars act as conductors and as heat sink simultaneously.

### IV. APPLICATIONS

Automotive control units of electric and hybrid car applications are the prominent applications of high current PCBs. As well power train control units as other operating places e.g. steering controls are known. Driving force for the use of these PCBs are the low mounting effort and compact design of corresponding systems leading to increased reliability compared to conventional systems. Other applications are power supplies, intelligent power converter, rail drive systems and planar transformers in general.

### REFERENCES