PCB DESIGN AND ASSEMBLY FOR POWER SUPPLIES

Power supplies come in large varieties, can have different topologies, and feature numerous safeguards. Design of printed circuit boards (PCBs) for powers supplies can therefore, have infinite possibilities. Despite the huge variations involved, designers need to follow certain rules when designing PCBs for power supplies.

In general, a power supply draws in power, processes it, and provides a specified output that feeds a certain circuit connected to the power supply as load. We typically only use two types of power sources, AC or Alternating Current, and DC or Direct Current. The function of the power supply is to take in power at a certain voltage and current, and output nearly the same power but at a different voltage and current level. Apart from generators, a broad classification of power supplies divides them into inverter and converter types.

INVERTER VS. CONVERTER POWER SUPPLIES

Both inverter and converter type power supplies will change the voltage they take in to a different type at their output. An inverter type power supply will change the input DC voltage to an AC voltage at its output, whereas converters will take in AC or DC voltage and change it to a DC at its output. Both types of power supplies may output a fixed voltage or a variable voltage, multiple fixed voltages, or a combination of both fixed and variable voltages. They may have their current outputs limited in different ways to prevent burnout/damage from very low loads or shorts at the output.

The topology of the power supply determines the manner of conversion from the voltage at its input to the voltage it produces at the output. Broadly, the power supply industry uses either a linear mode or a switched mode for the purpose. While the switched mode power supply works at a much higher efficiency as compared to the linear mode, the former has a noisier footprint.

Other than the above, power supplies may have additional circuit modules with special functions. These can be rectifier blocks, power factor control blocks, input filter circuit blocks, control and feedback circuits, output regulator circuits, output filter circuit blocks, and overvoltage and overcurrent protection blocks, to name the essential ones.

DESIGN CONSIDERATIONS FOR POWER SUPPLY PCBS

Most of the rules related to design of PCBs are applicable to both types of power supplies, linear and switched, although their principle of operation is different. This is because they both achieve the same goal, even though they go about it differently.

When it comes to designing power supplies, the importance of a well-laid out printed circuit board cannot be overstated. Furthermore, the designer has to understand the dynamics behind the operation of the power supply for making the effort a success. Even when CAD software is used to design PCBs, the use of an auto-router for automatically routing the traces on a PCB for a power supply circuit usually causes failures. This is because the auto-router only connects nodes of the same signal name stated in the netlist. It disregards the length of the traces necessary to accomplish the connections. For the power supply designer to execute a good PCB layout, it also is necessary for him to know the different signals flowing between components.

Image of Zebra 77715P 77711 Z4M Plus & Z6M Plus Power Supply PCB Board

CURRENT LOOPS AND POWER SUPPLY LAYOUTS

The noise generation and operational performance of a power supply depends largely on current flow, and this takes place in loops. For the linear power supply, there are two main loops—the input source loop and the output load loop. For the switched mode power supply, there are two more—the high current loop of the power switch, and the high current loop of the output rectifier.

The fundamental requirement of the designer is to keep the different current loops separate and allow them to pass through as short a conductor as possible. Although the currents in the loops are largely DC, they do contain some AC components, which actually make up the conducted EMI. By keeping the conductor length short, the designer allows only a small part of the AC energy to radiate into the environment.

Most of the current loops in the power switch and output rectifier of a switched mode power supply carry high peak pulsating DC currents with trapezoidal waveforms and sharp edges. The designer should lay out these loops such that they enclose a very small area and use traces of considerable width.

As the inductance and resistance exhibited by the trace vary in inverse proportion to their width, narrow traces have higher resistance and show higher inductance. Therefore, the width of the traces making up these loops dictate the voltage drops around the loops. High peak pulsating DC currents, when passing through the high inductance of thin traces, also create RF radiation. Loops with wide traces reduce this tendency. Additionally, wide traces provide better heat removal from the power switch and rectifier.

GROUNDING IN POWER SUPPLY LAYOUTS

The high current loops discussed above require separate grounding to prevent them from influencing each other. This is because grounds represent return paths with the lowest potential for the currents. The ground represents the reference potential from which designers measure the potential of all other signals.

It is necessary for designers to consider sections of the ground system separately, as the ground carries both AC and DC signals from various points in the circuit. Improper interconnection of these grounds can make the power supply unstable.

Broadly, the designer must distinguish between the high-current input ground, the high-current output ground, and the low-level control ground, while keeping them separated from each other. Usually, the three grounds meet at a star point near the input return.

Some power supply circuits have analog sections, power sections, and digital sections on the same PCB. Designers must route the three sections separately, and ground them to the return side of the current sensing resistor. They must keep all traces to and from the current sense resistor both short and wide, or use Kelvin connections.

High current traces often cause EMI. Designers reduce the radiation by placing ground planes on both side of the traces, and on opposite sides of the PCB, thereby effectively enclosing the high current traces with ground. The large ground conductor areas behave as electrostatic shields, trapping the radiated energy in the form of eddy currents, which dissipates as heat.

LAYOUT FOR PARALLELING CAPACITORS

The equivalent series resistance and equivalent series inductance of filter capacitors at the output of a power supply contribute to internal heating of the capacitor and the level of ripple current in the output. Therefore, designers try to lower the ESR and ESL by using several capacitors in parallel.

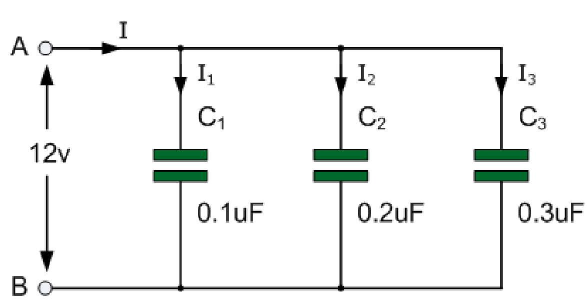


Image courtesy of electronics-tutorials.ws

As the current sharing between the capacitors is dependent on the PC board layout between these components, the designer must use capacitors of similar rating and keep the layout between each of them identical as well to promote equal sharing of current. By keeping the traces between the components wide and short, the designer avoids parasitic impedance that could isolate a capacitor from the loop. Therefore, any high frequency current pulses remain outside the loop, preventing creation of conducted EMI.

USE OF EMI FILTERS

Any time power leads enter or leave the enclosure of a power supply, they have the potential of radiating EMI. Regulatory bodies expect the power supply to maintain its EMI levels below the maximum level they have specified in the frequency range. Therefore, designers use EMI filters to reduce the radiation levels—it is not possible to eliminate the radiation completely.

The design of an EMI filter allows it to block the high frequency noise from the PWM switching the power supply uses, and return the noise to the ground. It is important the designer lay out the components of the filter circuit properly, to prevent some switching energy from the components to couple into the traces connecting them and escaping into the environment.

ASSEMBLY OF POWER SUPPLY PCBS

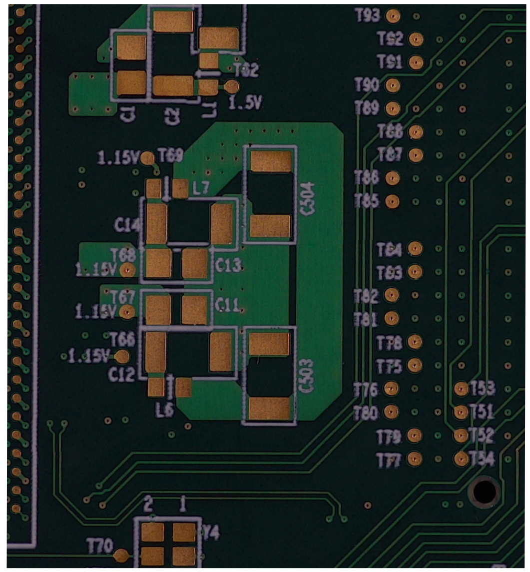
As with other applications, OEMs tend to use Surface Mount Technology (SMT) components for their power supplies. While this is adequate for power supplies with low voltage and current ratings, others may require the use of through-hole components, improved insulation, and heavy copper tracks for supplying high voltages and currents.

Most components for high voltage and high current power supplies tend to be large and heavy, even when they are SMD types. This is mostly true for inductors, capacitors, and high power resistors.

Assembly of such large components on the PCB requires careful handling when soldering them using reflow machines. In the reflow machine, the PCB assembly with all components on board passes through preheating zones before the actual soldering takes place. After the soldering is over, the assembly must cool down.

The temperature at which soldering takes place for lead-free solder is higher than that required for leaded solder. Therefore, the PCB assembly must undergo preheating to a higher temperature as well. However, the presence of components with large volume and mass presents a problem with preheating.

Large components take more time to heat up as they have a larger mass. Until they have adequately heated up, other components around them are starved of heat. The shadow effect thus created by a large component does not allow the neighboring small components to heat up adequately, resulting in improper soldering.



Heavy copper tracks present much the same problem as above. The mass being higher, the copper requires more heat to reach the required temperature before soldering. If the heavy copper tracks do not reach the necessary preheat temperature, the solder on their pads will not melt properly, and components will not adhere to them

Engineers need to adjust the thermal profile for such assemblies passing through the reflow machine to allow them to heat up sufficiently before they reach the soldering zone. This may require fitting thermocouples on specific points on the PCB assembly, especially near the larger components and on the heavy copper traces to assess the nature of the change in temperature they undergo during their passage through the reflow machine. Proper assembly of power supply PCBs with heavy copper and large components may require some expertise, but it is possible to achieve success.

CONCLUSION

Although designing PCBs and assembling them for power supplies is not a simple task, it is no black magic either. Following the best practices evolved after long hours or trial and error, reaching the final design that works effectively and efficiently is not a difficult task. Likewise, proper assembly of power supply PCBs with heavy copper and large components may require some expertise, but it is possible to achieve success.

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