

Beat the Heat: Build a Compact, Multi-Standard Dual USB Charger

USB ports are pervasive in automobiles. With the intermediation of the proper cable, a number of portable devices, smartphones, and tablet PCs can be charged on the go using an automotive USB charger. The electronic modules that implement these functions must fit inside small spaces without overheating.

The problem is exacerbated in the case of dual-port dedicated USB charging solutions (Figure 1), which must support two connectors without increasing component count and solution size. The dual USB charger must support up to 3A charging at 5V per connector and must be AEC-Q100 qualified and comply with Apple® and USB specifications. In addition to size and temperature challenges, the solution must include dual legacy USB enumeration technologies, emit minimal EMI radiation, withstand 40V load dump, and have protection to prevent automotive field returns.

This design solution reviews the shortcomings of the typical approach and proposes a novel solution to overcome these challenges.



Figure 1. Car with Dual USB Socket

The Heat Problem

The thermal specification of a USB charger module is straightforward: its temperature cannot exceed 40°C above ambient.

Let's look at a typical solution in which the 5V charger in a flip-chip package has a junction-to-ambient thermal resistance $\Theta_{J-A} = 20^{\circ}\text{C}/\text{W}$, which draws power from the 14V car battery, charging a portable device with 6A at 91% efficiency. The output power is:

$$P_{\text{OUT}} = 5\text{V} \times 6\text{A} = 30\text{W}$$

With an efficiency of 91%, the input power is:

$$P_{\text{IN}} = P_{\text{OUT}}/\eta = 30/0.91 = 32.92\text{W}$$

And the power loss is:

$$P_{\text{D}} = P_{\text{IN}} - P_{\text{OUT}} = 32.92 - 30 = 2.92\text{W}$$

Accordingly, the temperature rise inside the IC is:

$$\Delta T = \Theta_{J-A} \times P_{\text{D}} = 20 \times 2.92 = 58.4^{\circ}\text{C}$$

This exceeds the specified limit. Clearly the factors at play here are the charger efficiency and its thermal resistance.

Adding up the ΔT of 58.4°C to the ambient 25°C temperature leads to a peak temperature of 83.4°C as shown in Figure 2.

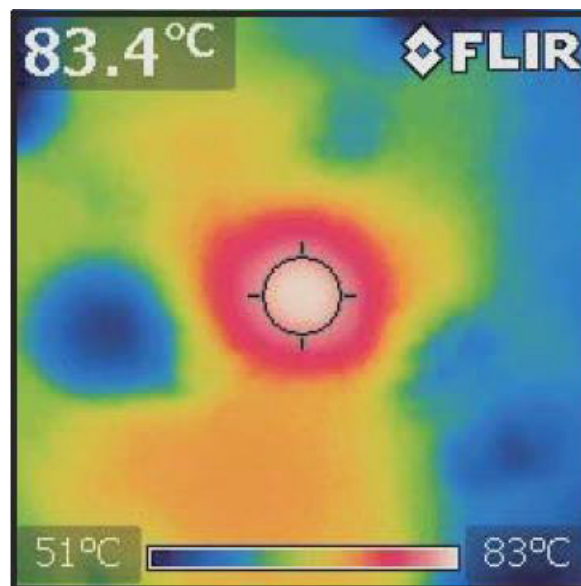


Figure 2. Peak Temperature of a Typical USB Solution

The Size Problem

The key to small size is a high level of integration. Figure 3 shows a typical solution which, while integrating the charger control and a power train, still requires a couple of external TVS to protect from the short to battery and short to V_{BUS} . Accordingly, while the charger IC occupies an area of only 25mm^2 , the total active area occupied rises to 45mm^2 once the TVS areas are added.

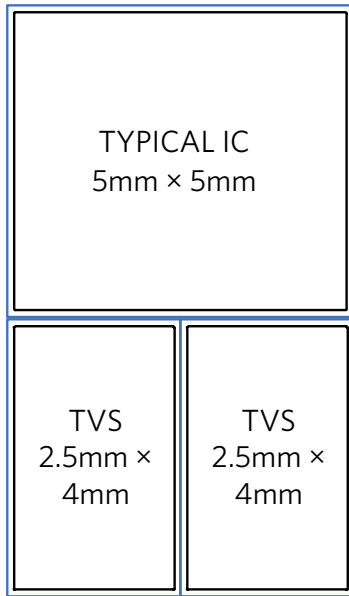


Figure 3. Charger and Protection ICs in a Typical Charger

When adding the rest of the passives, the PCB side occupancy reaches 333mm^2 . Clearly a higher level of integration is necessary to minimize the PCB size.

Highly Integrated Solution

As an example, the **MAX20047** (Figure 4) is an automotive-grade, small-footprint dual-port charger IC designed for automotive charging applications. It combines a fully synchronous 6A step-down buck converter with integrated high-side and low-side FETs that can operate with input voltages from 3.5V to 36V and deliver a 5.2V output voltage. The IC features integrated iPod®/iPhone® 1.0A, iPad® 2.1A and iPad® 2.4A dedicated charging modes. It also supports an automatic transition between multiple modes such as Apple®, USB-IF DCP, China YD/T 1591-2009, and Samsung® 1.2V to enable fast charging on all devices.

Short-to-ground protection and overcurrent protection are also provided on the protected HVBUS outputs to protect the internal BUS power rail from an overcurrent fault. The IC offers short-to-battery protection up to +18V and can also be ordered with spread-spectrum operation to reduce EMI. The buck converter switching frequency is programmable from 0.4MHz to 2.2MHz. The IC is tested to ISO 10605 and IEC 61000-4-2 ESD standards.

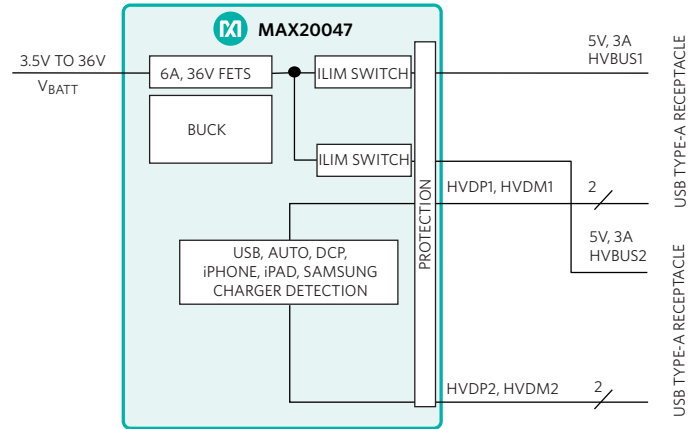


Figure 4. Highly Integrated Solution Block Diagram

The highly integrated IC succeeds in integrating the charger and protection in a mere 17.5mm^2 area, almost a third of the previous case (Figure 5).



Figure 5. Highly Integrated IC With Protections

When the rest of the passives are included, the total PCB area adds up to only 170mm^2 , about half of the previous case discussed.

Higher Efficiency

The IC delivers up to 3A of charging current with high efficiency per port (Figure 6) through integrated switches with programmable current limit and thermal foldback control.

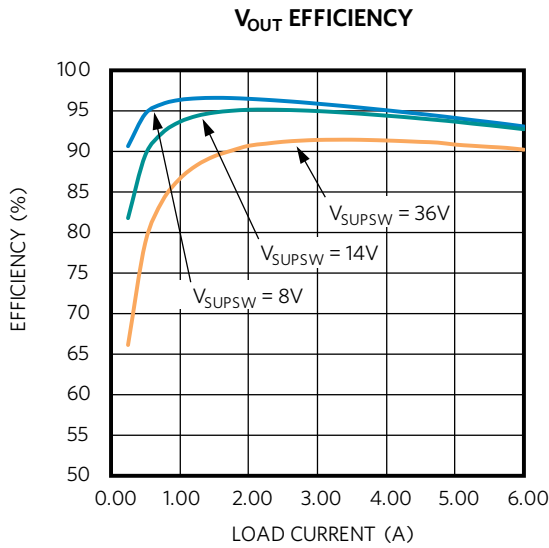


Figure 6. High Efficiency Curve

With 93% efficiency at 6A, this IC has a 2% efficiency advantage versus the typical case discussed earlier.

Thermally Enhanced Solution

Equally important, the thermally enhanced flip-chip package, in conjunction with an optimized PCB layout, utilizes four-layer 2oz/2oz copper and thermal vias (Figure 7). This yields a junction-to-ambient thermal resistance (Θ_{J-A}) of only 18°C/W. This is 2°C/W lower than the typical case discussed earlier.

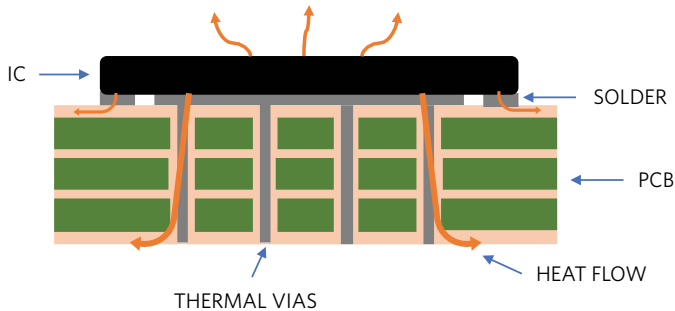


Figure 7. Thermally Enhanced PCB Illustration

Low Temperature Rise

The combined effect of a higher efficiency at 6A (+2%) and lower thermal resistance (-2°C/W) yields a temperature rise ΔT of only 39.6°C. This temperature rise is 32% lower than the previous case and is below the 40°C limit!

Adding up the ΔT of 39.6°C to the ambient 25°C temperature leads to the peak temperature of only 64.6°C shown in Figure 8.

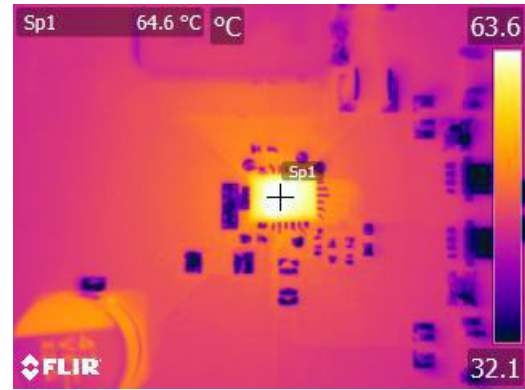


Figure 8. Integrated Solution's Reduced Peak Temperature

Conclusion

USB ports in automotive charging applications must fit inside small spaces without overheating. This is exacerbated in the case of dual-port dedicated charging solutions, which must support two connectors without increasing component count and solution size. We reviewed the shortcomings of a typical solution and showed how a novel automotive-grade, small-footprint dual-port USB charger IC overcomes the challenges of size and heat generation.

Learn more:

[MAX20047 Dual 3A USB DCP Charger](#)

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