DESIGN SOLUTIONS
AUTOMOTIVE

Add Even More USB Ports to Your Car—In Less Space

Introduction

The interior of modern cars is populated with multiple USB ports—placed in the head unit, glove compartment, armrests and rear seats—for charging portable electronics (Figure 1). These ports connect to the USB host charger/adapter in the radio head unit via captive cables. Depending on the location, the cable lengths can reach several feet, which creates Ohmic voltage drop and EMI radiation problems in the automobile. The high number of USB ports creates a heavy load for the USB charger, which may generate excessive heat in the radio head unit, affecting system reliability. In this article, we'll discuss the shortcomings of existing automotive USB host solutions. We'll present a new, highly integrated solution that easily supports the growing number of USB ports while requiring minimal space and significantly reducing heat generation.

Figure 1. Modern Car Console with USB Plugs for Passengers

Existing Solutions

The typical car USB adapter delivers a 5V power source to the portable device (PD) after a successful handshake has been established between the portable device and the charger/adapter. Some charger/adapter solutions require multiple chips which take up precious space and require cable compensation that is difficult to implement. Other solutions implement the 5V voltage source with nonsynchronous switching regulators, resulting in excessive power dissipation. A space-inefficient and lossy solution is costly and ultimately less reliable. Such solutions will not support the next generation of architectures that are needed for the growing trend of packing more USB ports in an automobile. The amount of space available for automotive electronics is continually shrinking. Many solutions also do not include spread-spectrum frequency modulation, which minimizes EMI-radiated emissions from the switching regulator modulation frequency.

The Ideal Solution

The ideal adapter/charger solution would incorporate all the necessary features into a single chip to provide ease of design and space savings. The solution shown in Figure 2 (USB ADAPTER IC) incorporates a synchronous-rectification buck converter (SR BUCK) for optimal efficiency and a sensing amplifier to measure the load current. A feedback loop raises the output V_{SENSP} in proportion to the load current and the cable's resistance, exactly canceling the USB cable voltage drop and delivering 5V to the device independent of the load current. High-current capability is a must to support the growing number of USB ports in the modern car. In Figure 2, the data lines (HVD-, HVD+, D-, D+) implement the communication between host and client devices for the initial handshake before charging.

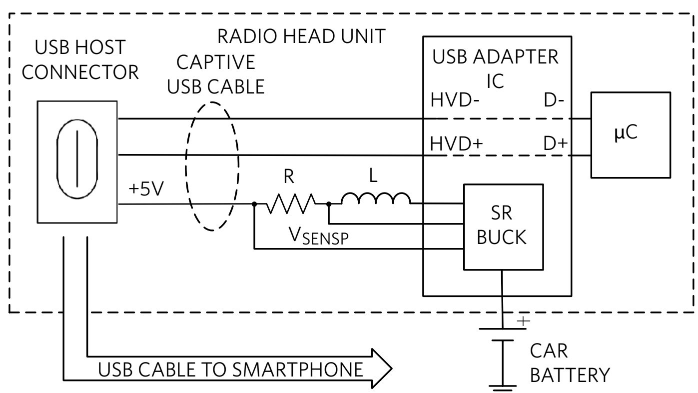

Figure 2. Car USB 5V Adapter Schematic

These features can be found in the MAX20037/MAX20038 automotive high-current step-down converters with USB protection and host charger/adapter emulation. The ICs combine a 3.5A automotive-grade step-down converter, a USB host charger/adapter emulator, and USB protection switches for automotive USB host applications. The high-current capability facilitates many USB ports.

Small Size

Operation at 2.2MHz allows for reduced output ripple and smaller external components, which, in combination with a small (5mm × 5mm) 28-pin TQFN IC package, result in minimum PCB space occupation.

High Efficiency

The most common step-down switching architecture is the nonsynchronous buck converter. In this architecture, the low-side rectifier is a Schottky diode external to the IC. On the other hand, by utilizing a synchronous architecture the diode is replaced with an integrated, low-resistance, low-side MOSFET acting as a synchronous rectifier. We trade-off the high voltage drop across the diode with the small drop across the MOSFET transistor's $R_{DS(ON)}$. Synchronous rectification provides significantly higher efficiency than the nonsynchronous converters used by the typical solution. Thanks to synchronous rectification, the device achieves peak efficiencies well above 90% (Figure 3).

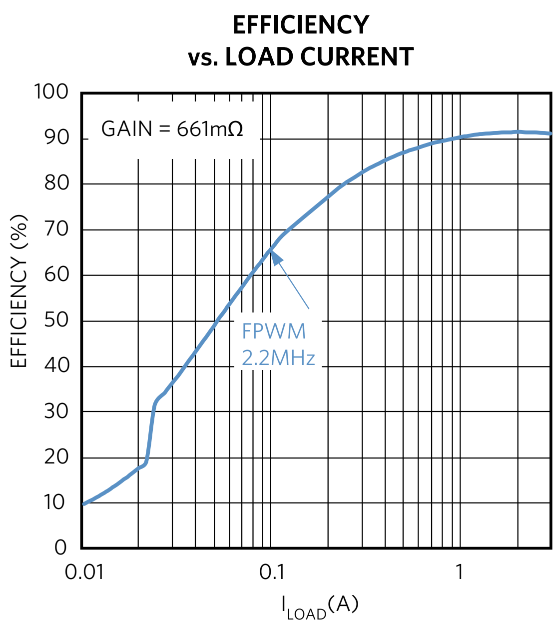

Figure 3. MAX20037/MAX20038 Efficiency

Cable Compensation

The device family includes a USB load current-sense amplifier and configurable feedback-adjustment circuit, designed to provide automatic USB voltage compensation for voltage drops in captive cables. Cable compensation and diagnostics can be easily implemented through the I^2C bus. External programming resistors are used as an alternative to the I^2C bus.

Low Noise

The ICs operate at constant frequency in forced PWM mode (FPWM). Optional spread-spectrum frequency modulation is designed to minimize EMI-radiated emissions due to the modulation frequency. In Figure 3, the device frequency is set at 2.2MHz, above the AM band, to reduce radio frequency interference.

Load Compliance

The ICs are compatible with both USB-compliant and non-compliant loads. A compliant USB device is not allowed to sink more than 30mA and must not present more than 10µF of capacitance when initially attached to the port. The device then begins its D+/D- connection and enumeration process. After completion of the "connect" process, the device can pull current (100mA for USB2.0, 150mA for USB3.0) and must not present a capacitance > 10µF.

ESD Protection

The devices feature low-voltage, high-bandwidth data switches (MAX20037) and high-voltage, high-ESD data switches (MAX20038). The MAX20037 offers data switch protection for up to 6V and high-ESD protection with an external ESD array. The MAX20038 offers data switch protection for up to 18V and high-ESD protection with internal ESD protection circuitry.

Conclusion

The interior of modern cars is populated with multiple USB ports for portable electronics charging, creating space and heat generation challenges for the charger/adapter. The cables connecting these ports to the USB host in the radio head unit create Ohmic voltage drop and EMI radiation challenges. We discussed the shortcomings of existing solutions and presented the MAX20037/MAX20038 highly integrated, automotive step-down converters that support a high number of ports with their high-current capability and minimal space occupation, noise, and heat generation. They easily compensate for cable Ohmic losses via an I^2C bus or through external programming resistors.

Glossary Tems

Enumeration: The process of identifying and assigning an address to a USB device connected to the USB host. If supported, the device is configured for charge.

Captive Cable: Connects an A-plug or USB Type-C™ port to a non-standard USB port.

Learn more:

MAX20037 Automotive High-Current Step-Down Converter with USB Protection/Host Charger Adapter Emulation

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