Application Brief

Fast Role Swap, Linear ORing with TPS25947 and LM73100 in USB Type-C systems

USB Type-C interface is quickly becoming one of the most popular ways of connecting electronic devices. From speakers to laptops, a single USB Type-C port can deliver power and offer high-speed data transfer. However, USB Type-C faces its own set of design challenges such as the process of Fast Role Swap (FRS). Its power-protection devices also need to qualify for the unique design specifications while protecting the port from overvoltage, short circuit, and reverse current. The TPS25947 efuse and LM73100 ideal diode can offer power protection while meeting the USB-Type C requirements for robust high power delivery, high-speed data transfer, and FRS.

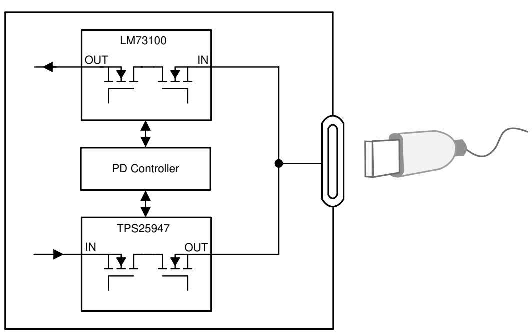

Figure 1. USB Type-C Power Protection Block

Figure 1-1 shows that two protections devices are needed per port to protect the system at all times especially during FRS.

Fast Role Swap (FRS) Explained

FRS describes the process when the device transitions from a power sink to a power source and vice versa. A laptop docking station, for example, requires robust FRS design and protection to ensure uninterrupted power supply to its accessories when external power disconnects. To further put FRS into perspective, imagine the setup in Figure 2-1: a laptop and its docking station connected through a single USB Type-C. The docking station initially charges the laptop and powers the other accessories through external power source. When the external power is removed, the laptop needs to quickly transition from a power sink to a power source to continuously supply power for its connected accessories. There are two major challenges in FRS:

1. The switching time must be less than 150 µs. Denoted by **tSrcFRSwap**, the time is defined to be from Vbus dropping below 5 V to the new source beginning to supply power at 5 V.
2. The Vbus voltage immediately before FRS is uncertain. With external power, the docking station charges the laptop at about 20 V. Once FRS begins, the system needs to promptly switch to the new source within the 5-V specification.

While meeting FRS requirements with fast charging and linear ORing, TPS25947 and LM73100 also feature adjustable overvoltage and undervoltage protection that ensures a smooth FRS within the 5-V specification.

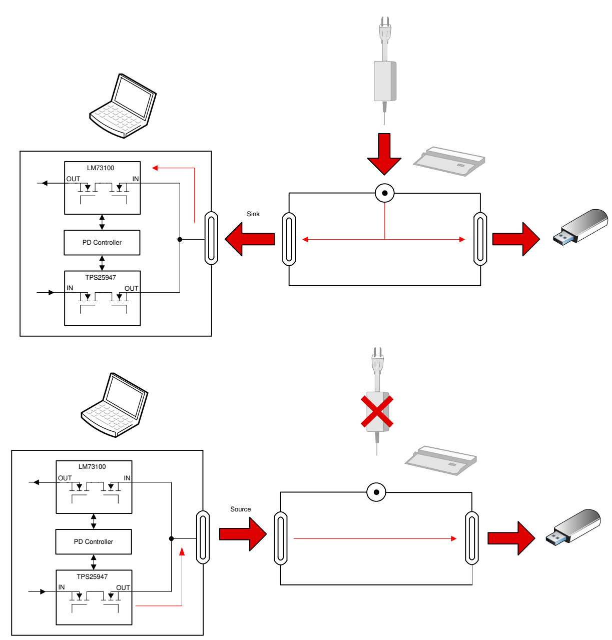

Figure 2. FRS for a Laptop Docking Station

In addition to voltage protections, TPS25947 uses fast charging to control inrush current to meet the FRS time requirement. Conventionally, inrush current control is implemented with adjustable slew rate control. By controlling the slew rate, efuse devices can prevent the initial voltage spike caused by inrush current at startup. However, conventional adjustable slew rate control is too slow for the FRS time requirements. By integrating a variable frequency charge pump and internal control logic, TPS25947 is able to detect switching and quickly boost the frequency to rapidly charge the gate of the FET.

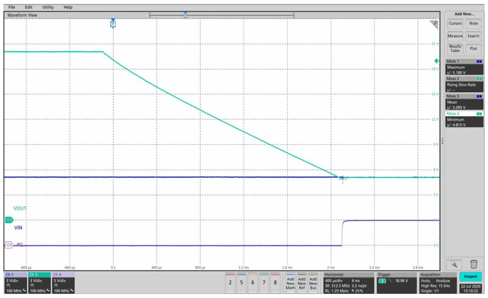

Figure 3. FRS Test

For this test in Figure 3-1, Vout was initially supplied at 20 V by an external source, indicating that the end device is initially a power sink. Once the external supply is disconnected, Vout quickly drops and the end device switches to a power source to match a constant 5-V output. As shown by Figure 3-1, TPS25947 is able to FRS in ~30 µs.

Linear ORing is True Reverse Current Blocking (RCB)

When multiple USB Type-C ports could supply or receive power, robust RCB is required to prevent current leakage between adjacent ports as shown in Figure 4-1. Without RCB, any buildup of reverse current leakge could cause permanent damage to the entire system. A typical slow ramp-up test can identify current leakage. If present, increasing the power on one port would charge up the adjacent port.

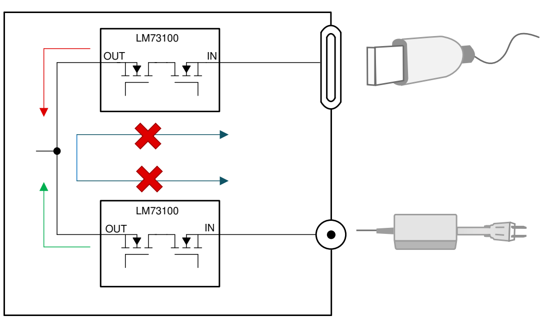

Figure 4. Adjacent USB Type-C Ports

RCB is implemented using back-to-back FETs. Shown in Figure 4-2, switching off the blocking FET allows the device to block reverse current from output to input.

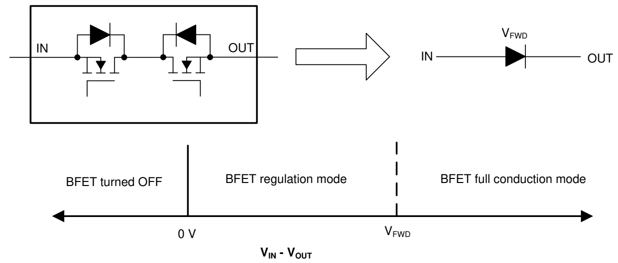

Figure 5. Reverse Current Blocking Response

Conventionally, a comparator controls the switching of the FET for RCB. Reverse current is allowed to build up as long as the current does not exceed the comparator threshold. Linear ORing provides true RCB by adjusting the resistance of the blocking FET to maintain a constant voltage across it. If forward current is increasing, the resistance of the blocking FET is reduced. If forward current is decreasing, the resistance of the blocking FET is increased, eventually shutting off the blocking FET before reverse conduction occurs. Linear ORing forces the device to go from forward conduction to a 0 point without allowing reverse conduction to ever occur.

With fast charging and linear ORing, TPS25947 and LM73100 not only allow fast switching during FRS but also provide true reverse current blocking and other power protection functions. As USB-C devices become increasingly popular, power protection for these devices must offer reliable features without sacrificing performance in high-power delivery and high-speed data transfer.

Table 5-1. Device Recommendations

Device	Description	Package
TPS25947	2.7 - 23 V, 5.5 A, 28 mΩ Reverse Current Blocking eFuse with Input Reverse Polarity Protection	QFN(10) 2 x 2 mm
LM73100	2.7 - 23 V, 5.5 A, 28 mΩ Integrated Ideal Diode with Input Reverse Polarity and Overvoltage Protection	QFN(10) 2 x 2 mm

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