Application Report
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Integrating TPS6602x and TPS6612x With USB Type-C™ Power Delivery Controllers

Scott Tater

ABSTRACT

USB Power Delivery (PD) enhances the USB Type-C™ standard to provide increased voltage and current to power the needs of today's USB devices. A single PD connection enables a maximum of 100 W delivered as 5 A at 20 V. Many PD Controllers are unable to support this load on an internal power path or lack an internal path altogether. An external power switch in these systems will enable full USB PD support. Using TPS6602x can simply system design and reduce board layout costs while meeting USB PD performance requirements.

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Trademarks

1 Introduction

The TPS6602x is a full-featured power switch multiplexer that contains an integrated 5-V source power path and a 4-V to 22-V sink power path. The source power path can supply 5-V nominal power and supports two current limit settings (1.5 A or 3 A) and the sink power path can support up to 5 A at 20 V. Each power path supports overtemperature and reverse current protection. Both the Source and Sink power paths, current limit settings, and Fast Role Swap(FRS) are controlled by general-purpose I/O (GPIO). The TPS6612x integrates only the sink path described for the TPS6602x.

This document details how to integrate the TPS6602x and TPS6612x with a USB Type-C Power Delivery (PD) Controller by describing the device control interface and highlighting important features and characteristics. Depending on the system requirements, this document will detail different modes of operation to ease the burden of system integration. The Source power path features include current limit, over temperature, reverse-current, undervoltage, and overvoltage protection. The Sink power path features include soft-start to minimize in-rush currents, over temperature, reverse-current, under voltage, and over voltage protection. Both Source and Sink power paths, device current limit, and Fast Role Swap are controlled by a general-purpose I/O (GPIO) interface. The PD Controller requests the desired system operating state using the TPS6602x GPIO interface and the TPS6602x executes the transition automatically based on the current power path and device state.

Example code is included in Section 6 to demonstrate how the control interface may be used by PD Controller and to assist firmware authors to make necessary changes.

2 Device Overview

The TPS6602x device control interface is based on two digital control inputs signals, EN0 and EN1. They are used to set four possible modes of operation:

1. Disabled
2. Sink path enabled
3. Source path enabled at 1.5-A limit
4. Source path enabled at 3.0-A limit

The control signals EN0 and EN1 feature an input deglitch filter to prevent unintended device mode transition. In addition, the TPS6602x supports a fault pin, FLT, that indicates over current and over temperature events.

Figure 1 shows TPS6602x in a typical two-port configuration. The PD Controller supplies general-purpose I/O (GPIO) connections to each of the TPS6602x EN0 and EN1 inputs.

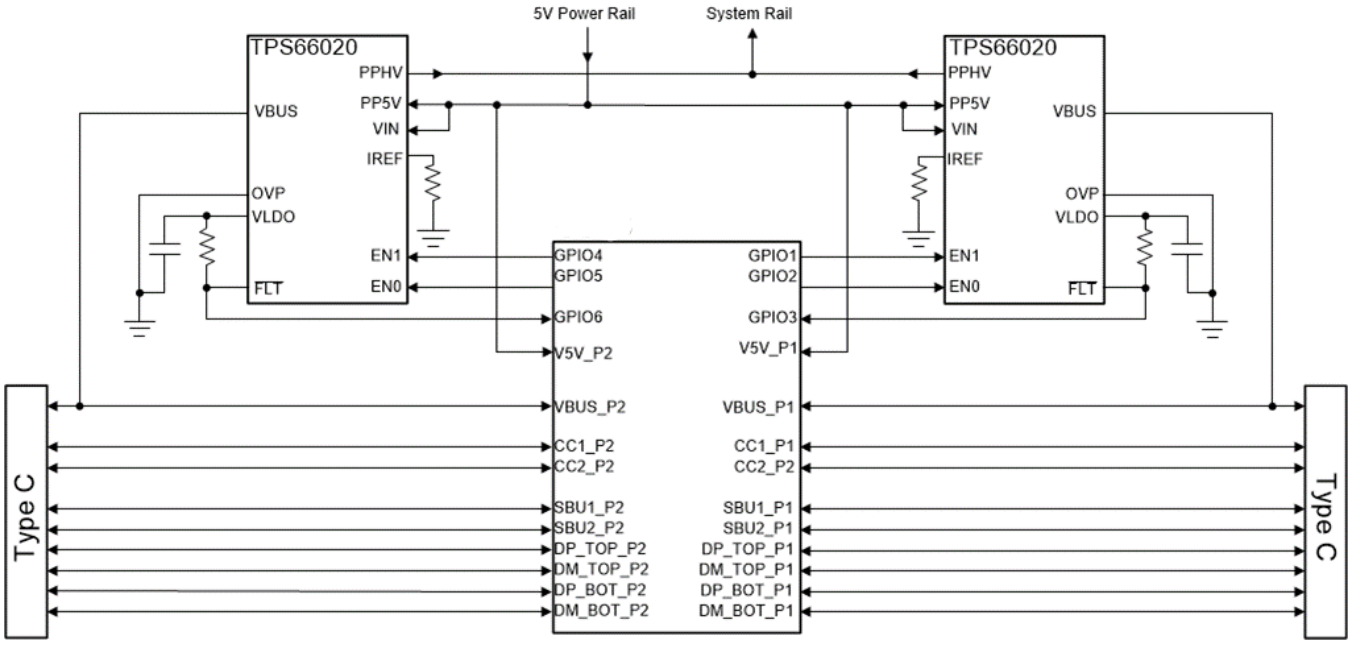

Figure 1. Typical Two Port System With TPS66020

The EN0 and EN1 inputs control the TPS6602x operating mode. Transitions on these inputs request a change to the specified operating mode. A Fast Role Swap (FRS) may be requested with a specific Source to Sink transition. The FRS operation is described in the *Fast Role Swap Transitions* section. Table 1 shows the device input function table

Table 1. Input Function Table

EN[1]	EN[0]	Device State
0	0	Source and sink paths disabled
0	1	Sink path enabled.
1	0	Source path enabled, 1.5 A
1	1	Source path enabled, 3.0 A

3 Operating Mode Transitions

EN0 and EN1 are used by the application to control the state of the device.

3.1 Input Deglitch Filter

The inputs of EN0 and EN1 contain a deglitch filter. Complete specifications for this filter is found in the *TPS6602x Integrated Source and Sink Power Multiplexer with VBUS LDO Regulator Data Sheet* table *Input-output (I/O) Characteristics* parameter tDG_EN. For PD controller integration, note that pulses on EN0 and EN1 less than tDG_EN (MIN) are not sent to the control logic. EN0 and EN1 may each transition to a new operating mode independently given any intermediate state is held less than tDG_EN (MIN). The exception to this rule is the filter is not applied to EN1 on transition to Fast Role Swap (FRS) State.

3.2 Power On Transitions

3.2.1 Normal Power Up

During normal power up, V_{IN} supplies power to the TPS6602x. Neither the Sink or Source Paths are enabled and PD Controller firmware should set the initial device state as Disabled (EN0 and EN1set to 0). The PD Controller firmware should assert EN0 and EN1 as required for system operation and hold the signals for tDN_EN to enable the desired TPS6602x operating mode.

3.2.2 Dead Battery Power On

As in the Normal Power Up sequence, the initial device state is Disabled and EN0 and EN1 should be set to 0. Upon Dead Battery state detection, the PD controller will assert Rd to advertise as a Sink. When a Source connection occurs, VBus will be powered and the TPS6602x VBUS LDO is enabled to provide limited power to the device and the system. Next the PD Controller will negotiate a Sink contract and then the PD Controller firmware should assert EN0 to enable the Sink path to power the system.

3.3 Regular State Transitions

Regular Transitions are changes in operating mode without Fast Role Swap. These transitions between Source Path enabled and Sink path enabled should pass through the Disabled state where EN0 = EN1 = 0. PD Controller firmware should ensure EN0 and EN1 are held for at least tDG_EN (MAX).

3.4 Source to Sink Transition

To transition from Source Path enabled to Sink Path enabled, the PD Controller first requests Disabled state by setting EN0 = EN1 = 0 and holding EN stable for tDG_EN. Next the PD Controller requests Sink State by setting EN0 = 1. The TPS6602x will transition to the requested state after tDG_EN.

3.5 Fast Role Swap State Transitions

The FRS state is a transitional state that transitions automatically from the Sink state to the Source 3.0-A state upon successful completion of the fast role swap sequence. On detecting the FRS signal, the PD Controller initiates the FRS sequence by asserting EN1 = 1 immediately. The TPS6602x device does not transition to Disabled during the FRS state transition. Because the FRS transition is initiated by the PD Controller, it is critical that the delay from detection of the FRS signal to the assertion of EN1 be minimized. After setting EN1 = 1, the TPS6602x PPHV path is disabled automatically by the fast role swap hardware. Once fast role swap is completed, it reverts back to the 3.0-A setting. The PD Controller may then choose to stay at the 3.0-A setting or transition directly to 1.5-A setting.

3.6 Fault Mode Operation

The TPS6602x includes an active low fault pin, FLT. Internally the TPS6602x distinguishes between two fault states: Source Fault and Sink Fault. The Source Fault state is entered when any PP5V fault event is detected. The Sink Fault state is entered when any PPHV fault event is detected. If any fault event occurs and the FLT pin is asserted, it will remain asserted for a minimum of tHOLD_FLT regardless if the fault condition is cleared. After tHOLD_FLT, if all fault conditions have cleared, the FLT pin is deasserted. No action on the TPS6602x control interface is required during a fault event. The FLT pin does not latch the fault event. The PD Controller may continue to assert the desired TPS6602x operating mode during a fault event and TPS6602x will resume the requested operating mode after the fault condition is cleared.

4 TPS6612x System Use Cases and Implementations

4.1 Sink Only

The state machine in Figure 2 shows the EN0 state transitions for a sink only application. When a sink PD contract is negotiated the PD controller will toggle EN0 to a value of 1, which will enable the internal sink path to the TPS6612x which can support up to 5 A at 20 V. Once the PD controller detects a port disconnect, it will toggle EN0 to a value of 0 which will disable the internal power path, isolating the system power from VBUS.

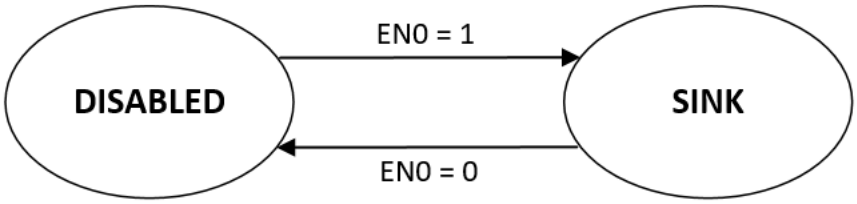

Figure 2. Sink Only State Machine

5 TPS6602x System Use Cases and Implementations

5.1 Sink With 1.5-A Source

The following state machine shows the EN0 and EN1 state transitions for an application that supports sinking as well 1.5-A sourcing. In this type of application, the PD controller GPIO connected to EN0 can be responsible for enabling or disabling the sink path, while the GPIO connected to EN1 can be responsible for enabling or disabling the source path.

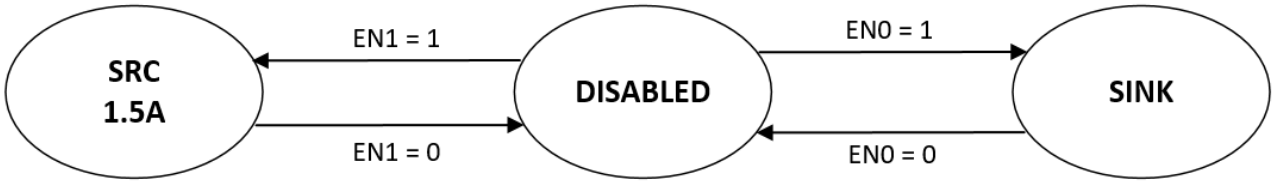

Figure 3. Sink With 1.5-A Source State Machine

To transition from sink path enabled to Source Path Enabled with 1.5-A current limit, the PD Controller first requests Disabled state by setting EN0 = 0 and holding EN stable for tDG_EN. TPS6602x will transition after tDG_EN. Next, the PD Controller requests 1.5-A Source by setting EN1 to 1. TPS6602x will transition to the requested state after tDG_EN.

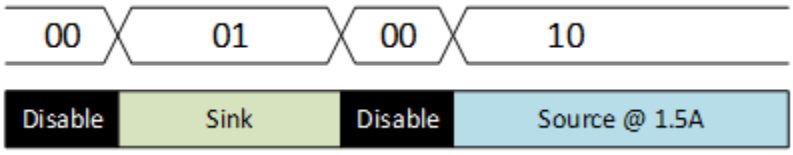

Figure 4. Sink to 1.5-A Source Transition

5.2 Sink With 3.0-A Source

The state machine in Figure 5 shows the EN0 and EN1 state transitions for an application that supports sinking as well 3-A sourcing. Unlike the 1.5-A source option, to support 3.0-A sourcing, the PD controller will need to toggle both EN0 and EN1 to a value of 1.

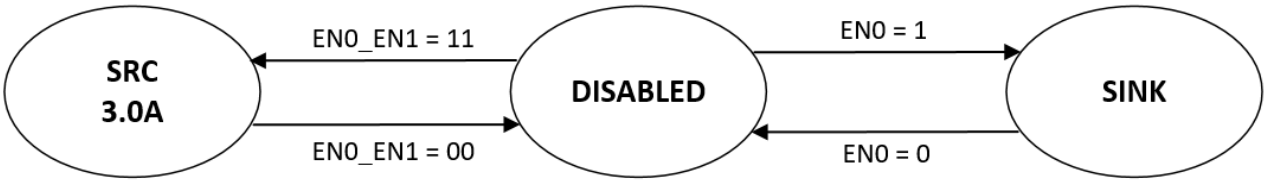

Figure 5. Sink With 3.0-A Source State Machine

To transition from Sink path enabled to Source Path Enabled with 3.0-A current limit, the PD Controller first requests Disabled state by setting EN0 = 0 and holding EN stable for tDG_EN. Next the PD Controller requests 3.0-A Source by setting EN1 = EN0 = 1 and holding EN stable for tDG_EN. The TPS6602x will transition to the requested state after tDG_EN. The device may temporarily limit at 1.5 A during the transition to 3.0 A.

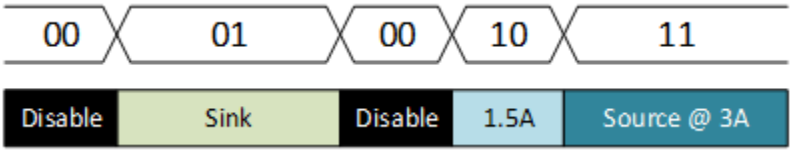

Figure 6. Sink to 3.0-A Source Transition

5.3 Sink With 1.5-A and 3.0-A Source Enabling FRS

The state machine in Figure 7 shows the EN0 and EN1 state transitions for an application that supports sinking, 1.5-A and 3-A sourcing, as well as fast role swap.

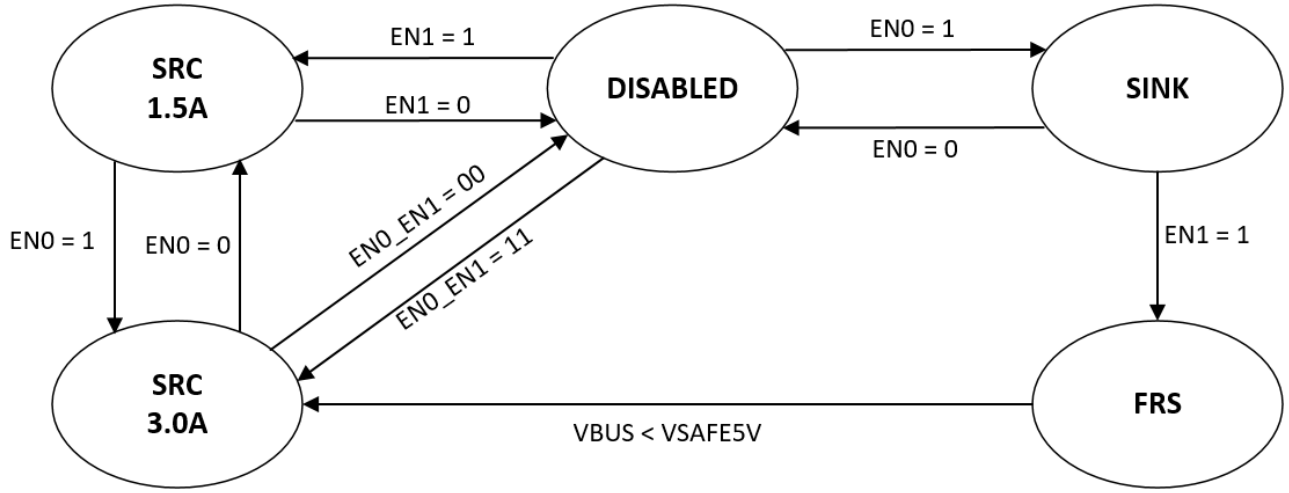

Figure 7. Sink and Source With FRS State Machine

5.3.1 Sink to 1.5-A Source FRS Transition

PD Controller sets EN1 = 1 immediately on FRS detect. Because the device is not set to Disabled state during the transition, FRS is triggered. Current-limit setting during FRS is independent of sourcing mode. FRS automatically terminates after a predetermined period of time. PD Controller may write EN0 = 0 and hold for tDG_EN to set device in 1.5-A mode before the end of FRS.

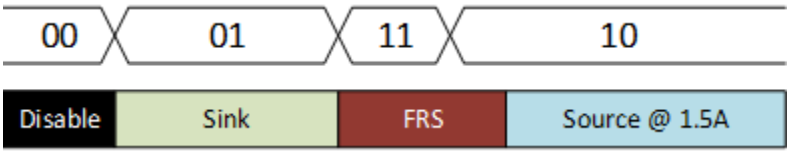

Figure 8. Sink to 1.5-A Source FRS Transition

5.3.2 Sink to 3.0-A Source FRS Transition

PD Controller sets EN1 = 1 immediately on FRS detect. Because the device is not set to Disabled during the transition, FRS is triggered. Current-limit during FRS is independent of sourcing mode. FRS automatically terminates after predetermined period of time. PD Controller does not set EN0 to leave device in 3.0-A mode at the end of FRS.

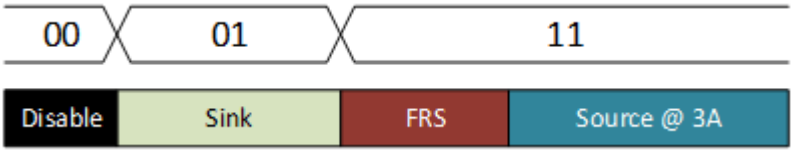

Figure 9. Sink to 3.0-A Source FRS Transition

5.4 Full Functionality (Sink, Source at 1.5 A and 3 A, FRS, Fault)

The state machine in Figure 10 shows the EN0 and EN1 state transitions for an application that supports sinking, 1.5-A and 3-A sourcing, fast role swap, as well as the fault pin from the TPS6602x.

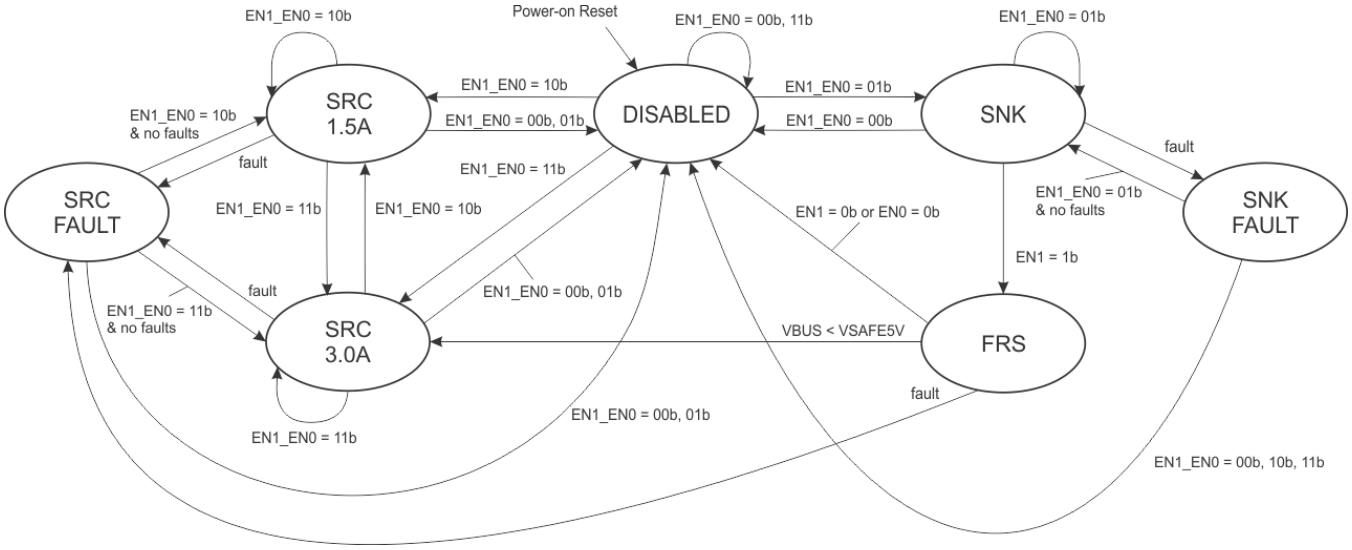

Figure 10. Sink and Source With FRS and Fault State Machine

6 Source Example

```
int tps66020EnableSink(int port){
    check Sink not already enabled
    lookup GPIO by Port number
    set GPIO(EN0,EN1) = 0,0 and hold for Disable
    set GPIO(EN0,EN1) = 1,0 and hold for Sink Enable
}
int tps66020EnableSource(int port, int enableFRS, int currentLimit){
    check Source not already enabled
    lookup GPIO by Port number
    if enableFRS = true {
        set GPIO(EN1) = 1
        if currentLimit = 1.5A {
            set GPIO(EN0) = 0
        }
        else {
            set GPIO(EN0) = 1
        }
    }
    if enableFRS = false {
        set GPIO(EN0,EN1) = 0,0 and hold for Disable
        if currentLimit = 1.5A {
            set GPIO(EN0,EN1) = 1,0
            }
        else {
            set GPIO(EN0,EN1) = 1,1
        }
    }
}
int tps66020Disable(int port){
    lookup GPIO by Port number
    set GPIO(EN0,EN1) = 0,0 and hold for Disable
}
```

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