

TPS65982DMC and TPS65994BG Smart Power Management (SPM) Implementation Guide



Shang-Heng Hsieh

ABSTRACT

This application note describes a Smart Power Management (SPM) implementation using the TPS65982DMC Dock Management Controller together with TPS65994 family USB-C and PD controllers. The SPM architecture dynamically distributes power between an upstream host (UFP) and multiple downstream devices (DFPs) in a USB-C docking station, maximizing utilization of a fixed-capacity AC/DC adapter while preventing overloads. The report discusses the system architecture and sensing configuration, the firmware decision flows for power allocation, multilevel overload protection mechanisms (with mid and high threshold responses), and practical tips with test results. Implementing this SPM scheme yields an efficient and robust multiport power design: available adapter power is allocated in real-time to where the power is required (minimizing idle reserves), and protective measures safely handle power surges without user interruption.

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1 Introduction

1.1 System Architecture

TPS65982DMC is a dedicated USB-C Dock Management Controller that coordinates power distribution across all USB-C ports in a docking station. The device communicates through an I²C with one or more multiport USB-C Power Delivery controllers (such as the dual-port TPS65994 family) to manage the power strategy for the entire dock. The system uses a single AC/DC adapter with a fixed maximum output (for example, 180W) as the input source. TPS65982DMC monitors the total input current and dynamically modulates the PD output of each port to supply downstream devices, upstream host charging, and the circuitry of the dock— all within the power limit of the adapter. In essence, the internal smart power policy manager of the TPS65982DMC continuously adjusts the advertised and negotiated PD power on each port in response to real-time load changes, preventing the total draw from ever exceeding the capacity of the adapter.

At the adapter input, an INA series power monitor is used – the TPS65982DMC periodically reads the total output power of the adapter through an I²C. Through this architecture, the DMC obtains both the real-time power of each USB-C port (through ADC readings, referred to as *PR_DFPx* for device ports and *PR_UFP* for the host port) and the total system power consumption. This data supports the dynamic allocation algorithm. Unlike traditional designs that rely only on fixed PD contract values for budgeting, dynamic SPM reflects actual load conditions. For example, even if a port negotiated a 15W PD contract but is only drawing 3W, the controller sees that the *PR_DFP* of the port is approximately 3W and can reallocate the approximately unused 12W to other needs (such as boosting host charging), greatly improving overall power utilization.

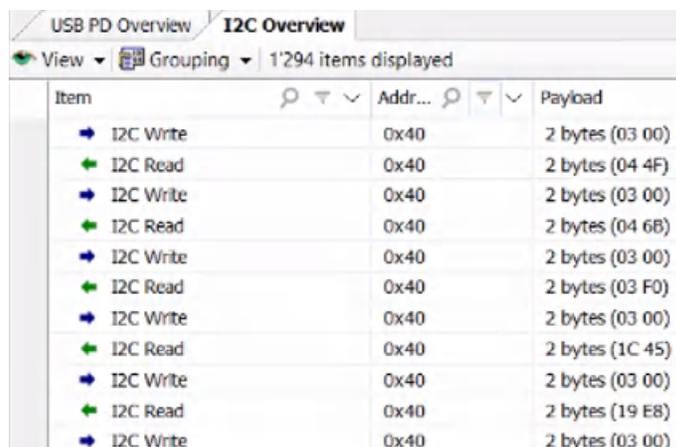
1.1.1 Implementation Steps

1.1.1.1 Hardware Power Sensing Integration

Each Type-C port of the TPS65994 reports the power status to the TPS65982DMC. The TPS65982DMC can then obtain the power budget of each Type-C port through the power contracts, allowing the device to estimate the total system power.

1.1.1.2 Periodic Total Power Polling

The TPS65982DMC firmware must periodically poll the total power consumption of the system from the INA power monitor. In this design, the DMC performs this system power read roughly every 100ms through an I²C. The frequent polling allows the controller to quickly detect changes in aggregate power consumption and provides real-time data for the SPM decisions of the algorithm. (this periodic measurement is referred to as the *Real-Time System Power (RSP) Check*), as shown in [Figure 1-1](#). This logic analyzer capture shows the I²C SDA (data) and SCL (clock) lines with periodic read transactions. Regular power polling enables the DMC to rapidly sense changes in total load, feeding timely information into the SPM decision loop. The logic analyzer capture shows the I²C SDA (data) and SCL (clock) signals with periodic read transactions. This frequent polling allows the controller to quickly detect changes in aggregate power consumption, providing real-time data for the SPM decisions of the algorithm (referred to as the Real-time System Power, RSP check).



Item	Addr...	Payload
I2C Write	0x40	2 bytes (03 00)
I2C Read	0x40	2 bytes (04 4F)
I2C Write	0x40	2 bytes (03 00)
I2C Read	0x40	2 bytes (04 6B)
I2C Write	0x40	2 bytes (03 00)
I2C Read	0x40	2 bytes (03 F0)
I2C Write	0x40	2 bytes (03 00)
I2C Read	0x40	2 bytes (1C 45)
I2C Write	0x40	2 bytes (03 00)
I2C Read	0x40	2 bytes (19 E8)
I2C Write	0x40	2 bytes (03 00)

Figure 1-1. SPM Firmware Polling an INA Power Sensor Approximately Every 100ms via I²C to Monitor Total System Power

1.1.1.3 SPM Firmware Configuration (Register 0x30)

TPS65982DMC firmware includes a System Power Management Configuration register (address 0x30) that defines various thresholds and parameters for the SPM algorithm. Figure 1-2 shows an example of this configuration register settings in the firmware. Key fields are highlighted and described in the following image, as the fields determine the SPM behavior. The GUI interface illustrates relevant parameters such as Guaranteed Host Power, Reserve Power, per-port power settings, and the mid- or high overpower thresholds.

System Power Management Configuration (0x30)	
Field	Value
Enable PD Power Management	<input checked="" type="checkbox"/>
Enable Use Reserve Power	<input type="checkbox"/>
Enable PD Power Management BR	<input checked="" type="checkbox"/>
Guaranteed Host Power	60 W
Reserve Power	0 W
USB Max Power 1	0 W
USB Max Power 2	0 W
Max Adapter Power	180 W
Mid Over Power Threshold	185 W
High Over Power Threshold	190 W
Over Power Time	500 mS
DFP1 Extra Power	0 W
DFP2 Extra Power	0 W
DFP3 Extra Power	0 W
Enable Realtime System Power Protection	<input checked="" type="checkbox"/>
Realtime System Power	10 W
DFPx Guaranteed Power	27 W

Figure 1-2. System Power Management Configuration Register (0x30) Example Settings in TPS65982DMC

1.1.2 Key Fields Define SPM Behavior

- **Enable PD Power Management:** must enable for the SPM feature. This box must be checked to activate dynamic power management.
- **Enable Use Reserve Power:** Allows use of a reserved power budget for the system (own consumption of the dock), but only when *all* DFP ports are connected and drawing the allotted power. In this example, a DFP port is unchecked, meaning no extra reserve is set aside for the dock when ports are occupied.
- **Guaranteed Host Power:** The minimum power that is always verified for the host (UFP port). For example, setting 60W here means the system always leaves at least 60W for host charging. (This corresponds to the minimum host power (**Min_HP**) that the host is specified under any condition.)
- **Reserve Power:** An optional fixed power reserve for the system (internal needs of the dock). In this design the power reserve is 0W, meaning that there is no dedicated reserve – the full capacity of the adapter is available to USB-C ports unless spare room remains.
- **USB Max Power $\frac{1}{2}$:** Per-port default power allotments. These are set to 0W in a fully dynamic scheme, indicating no fixed reservation per port. Instead, the supply of each port is determined based on actual consumption. (These fields can be used if a particular port requires a guaranteed higher power by default, but that is not required in this design.)
- **Max Adapter Power:** The maximum output of the external adapter (180W in this example). This value establishes the total power budget that SPM enforces for the system.
- **Mid Overpower Threshold:** The threshold for a moderate overload condition, set slightly above the rating of the adapter (for example, 185W for a 180W adapter, roughly a 5W margin). Exceeding this threshold for longer than the configured duration triggers the mid-level overload protection routine.
- **High Overpower Threshold:** The threshold for a severe overload, set well above the rating of the adapter (for example, 190W for a 180W adapter). Crossing this value (for longer than the duration setting) triggers the high-level protection response (Safe State).
- **Overpower Time:** The duration that power must remain above a threshold to be considered an overload event. For instance, 0.5s in this example – total power must exceed a threshold continuously for 500ms before there is an actual overload. This helps filter out brief spikes and prevent false trips.

2 Dynamic SPM Decision Flow

After the hardware sensing is in place and parameters are configured, the TPS65982DMC firmware executes a series of dynamic decision flows based on real-time power data from each port. This section outlines the key SPM logic for how the host (upstream port) charging power is adjusted in response to load changes, and how the system responds to maintain the total power within limits.

2.1 Initial Host Power Allocation

Figure 2-1 shows the system power-up, or when the host is first connected, the SPM must decide how much charging power to give the host based on the current usage of the downstream ports.

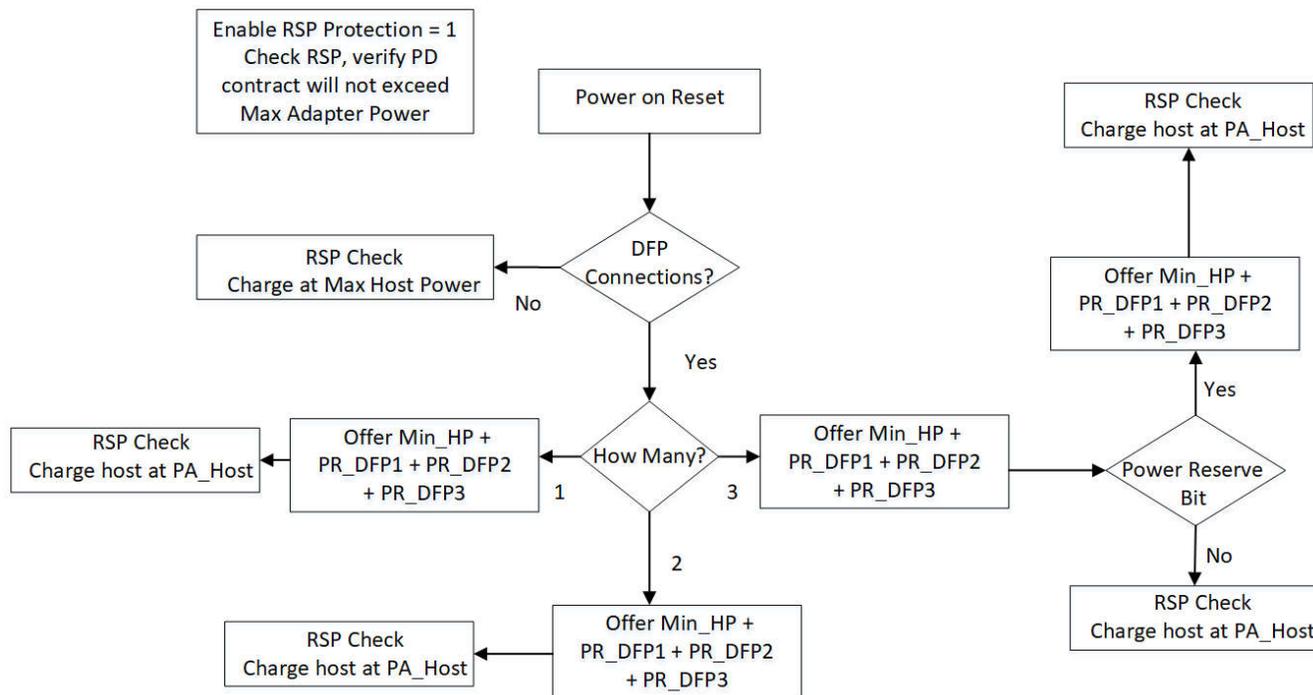


Figure 2-1. Host Charging Flow (Initial Power Allocation)

First, the controller checks how many DFP ports are connected. If zero device ports are active (0 DFPs), the host can charge at the maximum allowed power (up to the capacity of the adapter or the PD contract limit of the host). If one or more DFP ports are in use, the SPM calculates actual power draw of each port (PR_DFP1, PR_DFP2, and so on.). The TPS65982DMC available power of the host is then computed as *Guaranteed Host Power (Min_HP)* plus the sum of all connected DFP port power readings. For example, if Min_HP is 60W and currently one device port draws approximately 5W (PR_DFP1 is approximately 5W), the host is allocated about 60W + 5W = 65W. If multiple DFPs are connected, the measured powers are summed accordingly. If all downstream ports are occupied and the *Enable Use Reserve Power* option is enabled, the reserved system power budget is also added to the allocation of the host at this stage. The resulting calculation gives the host charging power budget (referred to as P_{A_Host}), and the PD controller advertises an appropriate PDO to supply that power to the host. Finally, an RSP check is performed to verify that the total of all active PD contracts (after this host allocation) does not exceed the adapter's maximum, which is an extra safety confirmation to make sure the overall system stays within limits.

Once the initial host power is set, SPM continues to monitor for changes. The charging power of the host can be dynamically reduced when new loads appear, or increased when loads disappear, as described in the following sections.

2.2 Dynamic Reduction of Host Power (New Load Connects)

When a new downstream device connects or the consumption of an existing DFP suddenly increases, SPM can lower the charging power of the host to avoid overloading the adapter.

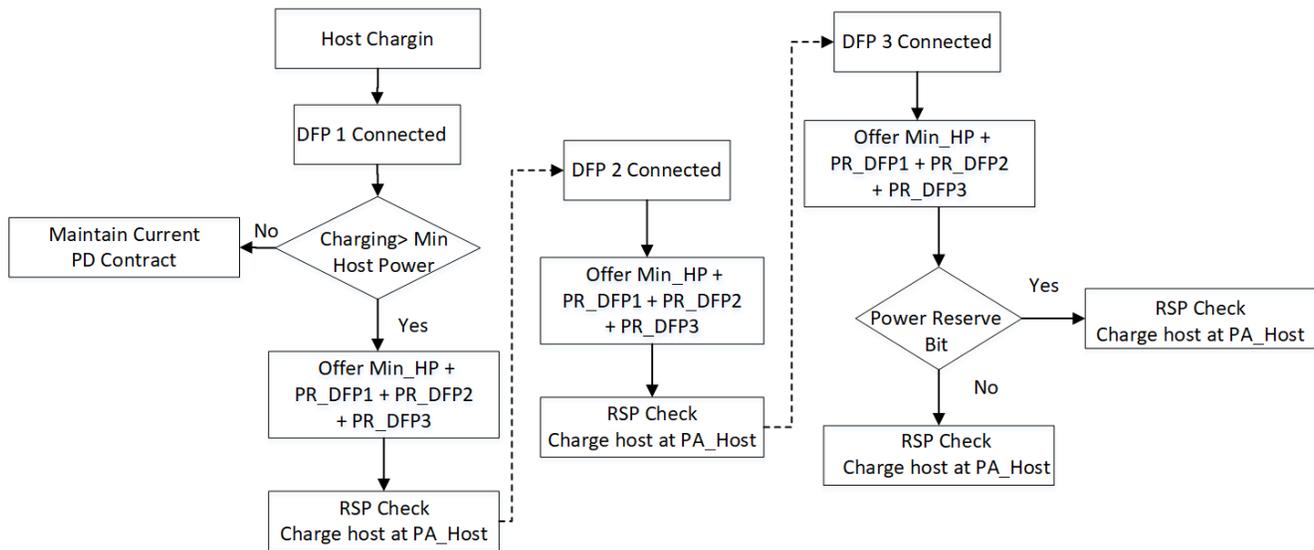


Figure 2-2. Reducing Host Charging Flow (Dynamic Reduction when New Loads Connect)

In [Figure 2-2](#), the SPM checks if the host is currently using more than the verified minimum power (for example, is host charging > Min_HP?). If the host is already at the minimum allotment (meaning the host has no headroom to give), then no reduction is possible. SPM maintains the current PD contract for the host (the new device only receives whatever small remaining power is available). However, if the host is using more than Min_HP (so some reducible headroom exists), SPM recalculates the allowed power of the host as $Min_HP + PR_DFP1 + PR_DFP2 + PR_DFP3$, which is the sum of all DFP port power readings (now including the power of the newly connected device). Because an additional port is drawing power, the total DFP sum increases, so the budget of the host decreases accordingly. The PD controller then scales down the power contract of the host to this new value by offering a lower-power PDO to the host. This adjustment repeats for each new DFP connection: for example, after the first device connects, the host power is reduced to $Min_HP + PR_1$; if a second DFP connects, the host is further reduced to $Min_HP + PR_1 + PR_2$ (as depicted by the dashed boxes for DFP2 in [Figure 2-2](#)), and so on for additional ports. If the system is configured with a Reserve Power budget and now all DFP ports are occupied, SPM also checks the *Reserve Power* setting – if reserve is enabled, the final budget of the host at full load includes that reserve ($Min_HP + PR_1 + PR_2 + PR_3 + Reserve$, for instance). At each step of lowering the host power, an RSP check is executed to verify the new configuration does not overload the adapter. Through this mechanism, SPM prioritizes powering newly attached devices by taking any necessary power headroom from the host (down to the minimum), which prevents the total draw from exceeding the adapter limit.

2.3 Dynamic Increase of Host Power (Load Disconnects)

Conversely, when a downstream device is unplugged or the demand drops significantly, SPM can raise the charging power of the host if additional headroom becomes available.

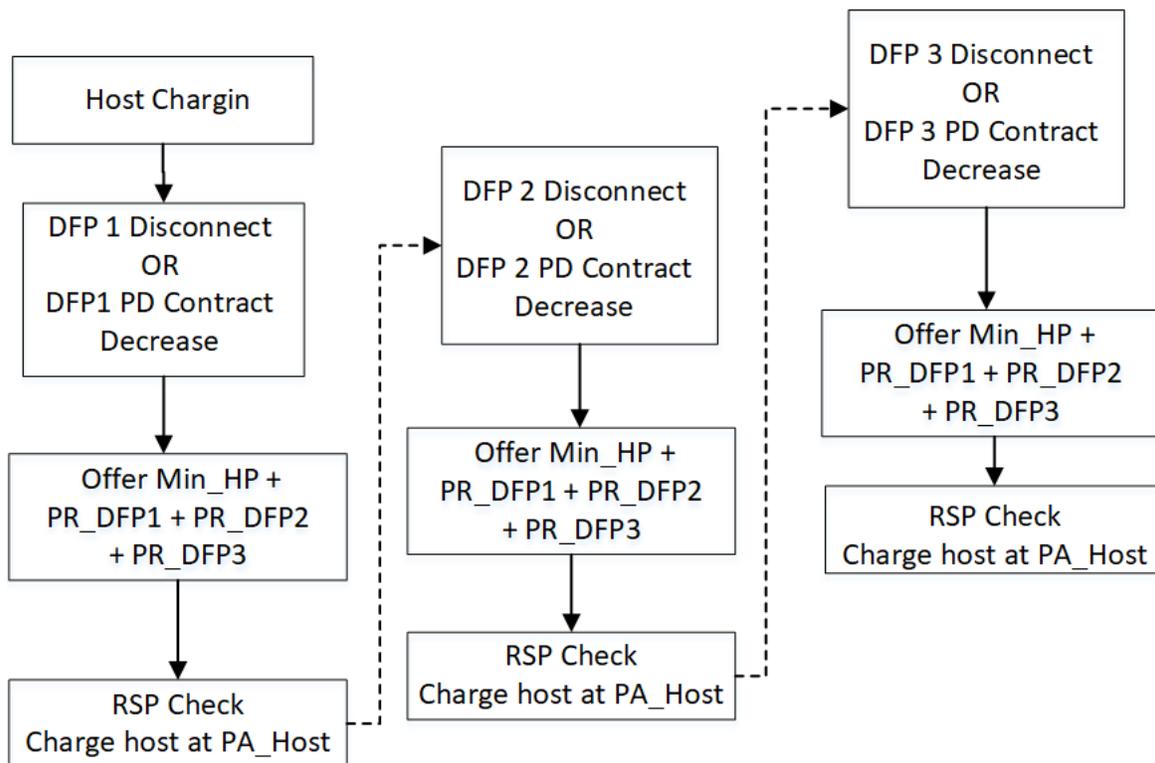


Figure 2-3. Increasing Host Charging Flow (Dynamic Increase When Loads Disconnect)

This flow is essentially the inverse of the above reduction flow. When a DFP device disconnects or the PD contract is reduced (for example, a peripheral goes into standby and draws much less power), a portion of the adapter budget is freed. Upon detecting a DFP port disconnection or drop in load, SPM recalculates the available power limit of the host port using the same formula: $\text{Min_HP} + \text{sum of remaining connected DFP port powers}$. With one less active port (or a lower overall DFP load), the total PR_DFP sum decreases, so the calculation yields a higher power available for the host. The PD controller can then renegotiate and offer a higher-power PDO to the host, effectively increasing the charge of the host. If multiple DFP ports disconnect sequentially, this step repeats each time (the flowchart segments these events for DFP2, DFP3, and so on, with dashed outlines). Eventually, after external device loads have been removed or reduced, charging power of the host gradually restores toward the maximum allowed by the adapter (and the capability of the host) once external loads are removed. This assumes the power of the host had been previously curtailed. Each increment of host power is also protected by an RSP check to verify that the overall system remains within safe limits. Through this mechanism, SPM makes full use of any power headroom freed by device disconnections – accelerating host charging when possible and improving the experience of the user.

2.4 Including System Power Usage in Host Adjustment

The host power flows above focus on changes in external device loads. In the latest SPM generation, the power consumption of the dock is also taken into account during host power management. The TPS65982DMC, at each RSP check interval, calculates the internal power usage of the dock (non-USB power) defined as: *total adapter output power (INA reading) minus the power being used by all PD ports (sum of PR_DFPx + PR_UFP)*. The device measures how much power the circuitry of the dock is drawing.

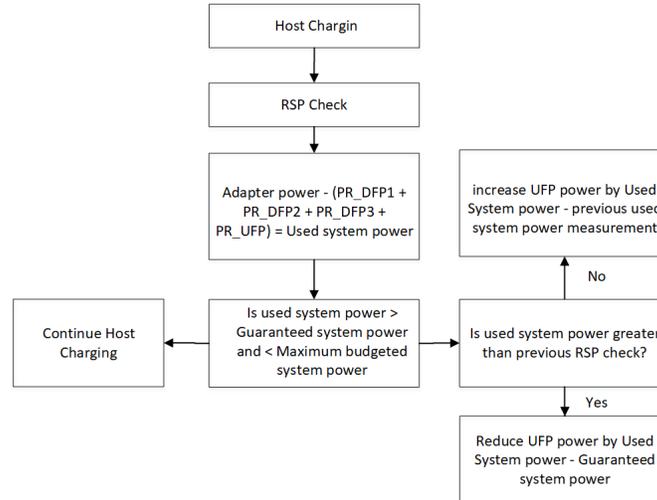


Figure 2-4. Host Charging Adjustment with System Power Consideration.

In each cycle, SPM compares the current system (dock) power use to the previous measurement. If the system power has increased beyond the previously allocated *System Power* allowance (for example, the system is using some of the headroom that was free for the system) but is still below the *Maximum Budgeted System Power*, then the internal circuits of the dock have started to consume power that was previously available for host and ports. In response, SPM reduces the charging power of the host by roughly the amount the system power exceeded the verified allowance. For instance, if the own power consumption of the dock increases by an extra 5W beyond what the power consumption was. (using up 5W of the *free* budget), the limit of the host is temporarily lowered by approximately 5W to compensate and keep the total draw in check. Conversely, if the power usage of the system drops (say some internal circuits go into low-power mode) and the power of the host is previously cut back because of a higher system load, SPM gives that power back to the host, which increases the charging allotment of the host again. Each adjustment still respects the minimum host power and the maximum system power constraints, making sure that the host is never dropped below Min_HP and the dock never exceeds the reserved budget. In short, when the internal circuits of the dock require more power, the charge of the host is momentarily sacrificed by that same amount; when the system load decreases, that power is returned to the host. This additional refinement helps verify the capacity of the adapter is always used fully and flexibly.

3 Protection Mechanisms and Overload Handling

To safeguard both the system and the adapter, the SPM design incorporates multilevel overload protection mechanisms. There are distinct responses as the total power approaches or exceeds certain thresholds: handling near-maximum adapter power, a moderate overpower event, and a severe overpower event. These verify that when total demand nears or breaches the limits, the system reacts in time to avoid disruptive overload conditions.

3.1 Pre-Overload Behavior (Maximum Adapter Power)

As the total system load approaches the maximum rated output of the adapter (before actually exceeding the maximum rated output), SPM takes preventive measures. In this stage, through the periodic RSP checks, the DMC restricts any new high-power PD requests and monitors the available margins. If required, the DMC can proactively throttle down non-critical loads (for example, slowing the charging of the host to create headroom. This is essentially the *Maximum Adapter Power* protection behavior – before an overload happens, the system adjusts to keep total power in the safe range. For example, if the adapter is 180W and the total demand is climbing close to 180W, SPM can pause further increases in host charging or temporarily limit certain internal loads (this maneuver is internally termed *Maximum Adapter Handle*) to prevent crossing the limit.

3.2 Mid Overpower Protection

A mid overpower condition means the total consumption has exceeded the ratings of the adapter by a small to moderate margin, but not high enough to trigger the most severe alarm. The mid overpower condition is between the normal maximum and the high overpower threshold.

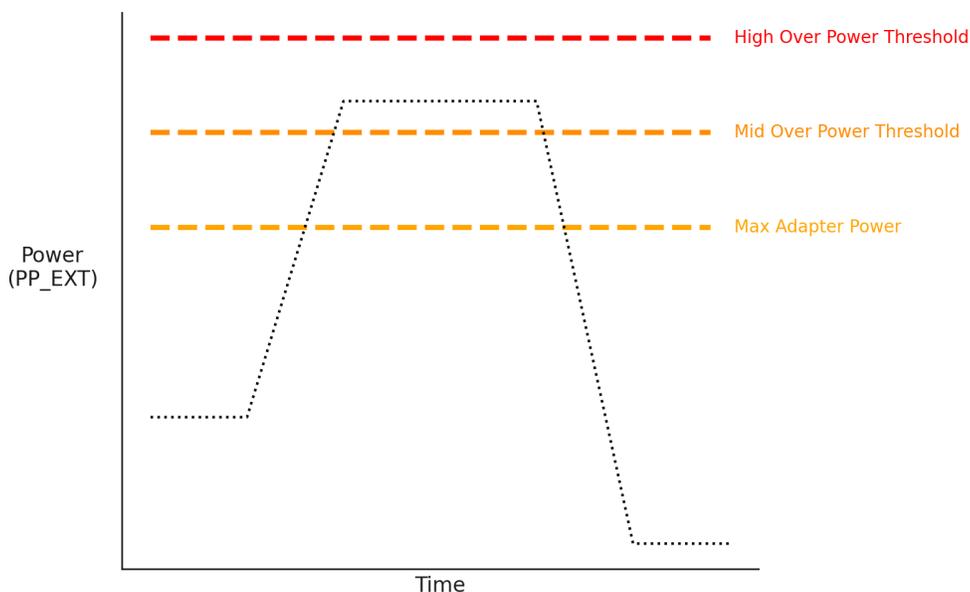


Figure 3-1. Power Protection Threshold

In this example graph of total power (PP_EXT) vs. time, (shown in [Figure 3-1](#) the yellow dashed line represents the maximum power of the adapter (180W), the orange dashed line is the mid over-power threshold (for example, approximately 185W), and the red dashed line is the high overpower threshold (for example, approximately 190W). If the system power surpasses the mid threshold (orange line) – say running at approximately 185W, which is approximately 5W above a 180W capacity of the adapter – and power stays above this level for longer than the configured duration (Overpower time, 0.5s in this case), then the mid over-power protection routine is triggered.

Once a mid-level overload is detected, SPM executes a specific response flow.

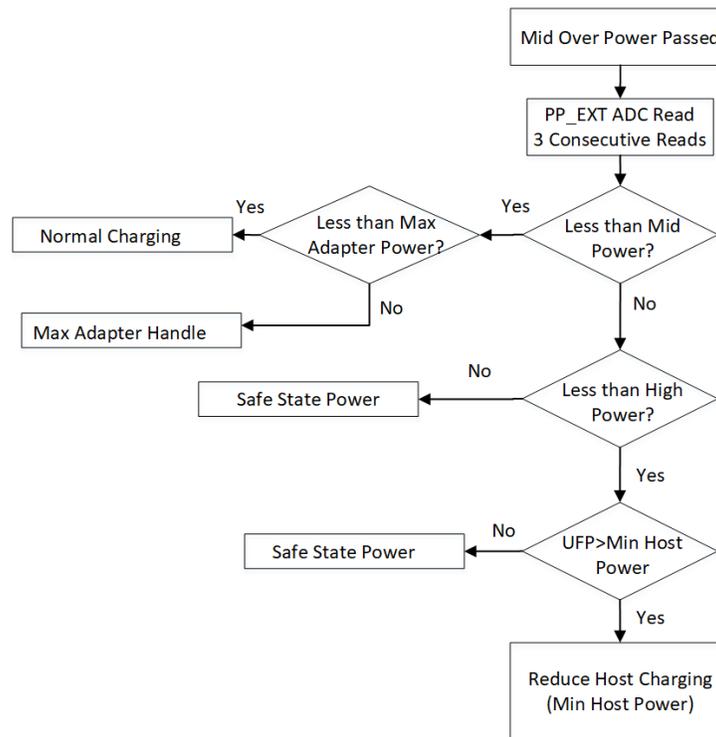


Figure 3-2. Mid Over-Power Protection Flow

The DMC first takes a few rapid ADC readings of the total power (for example, three consecutive samples in quick succession) to confirm that the overload is not a brief transient spike. If during this short window the power falls back below the limit of the adapter (for example, *Less than Max Adapter Power?* = Yes), then the surge was momentary – the system returns to normal charging with no intervention (the adapter can handle a quick spike). However, if the power remains above the maximum of the adapter (No), SPM then checks the level against the mid threshold. If the consumption is exceeding the mid threshold (*Less than Mid Power?* = No – meaning the situation is closer to a high overload), then for safety SPM immediately escalates to Safe State Power mode (described later) without further delay. If the load is above the adapter’s max but *below* the mid threshold (*Less than Mid Power?* = Yes – a mild overload), SPM attempts to mitigate the threshold by shedding some load. SPM checks whether the host has any spare power that SPM can relinquish (*UFP > Min_Host Power?*). If the host is charging above the minimum requirement (Yes), SPM performs a *Reduce Host Charging* action, cutting the power of the host down to the Min_HP (as a result, freeing up some watts and bringing the total back under the limit). If the host has no headroom to give (No – meaning the host was already at Min_HP and this overload cannot be resolved by reducing host power), then the system enters Safe State protection. Following this flow, most moderate overload situations can be resolved by temporarily reducing the charging power of the host (or other adjustable loads) without severely impacting system operation, pulling the total power back into the sustainable range of the adapter.

3.3 High Overpower Protection

When total power substantially exceeds the ratings of the adapter – beyond the high threshold (for example, greater than 190W on a 180W adapter) – this constitutes a severe overload condition. The response of the SPM at this level is more drastic to protect the hardware and adapter.

If an overpower condition above the high threshold (red line) is detected, the reaction is swift. Typically with virtually no delay (or only a very brief confirmation window), the DMC again takes multiple rapid ADC samples. If during those samples the power is confirmed to still be above the high threshold (meaning the overload is severe and persistent), SPM immediately forces the system into *Safe State Power* mode.

In *Safe State*, the PD controllers sharply reduce all port outputs to a minimal safe level. For instance, the charging of the host can be dropped to a very low level (fallback to 5V basic USB power or disabling fast-charge), and each high-voltage supply of each downstream port is either lowered to 5V or turned off entirely (leaving only a minimal 5V and limited current supply to keep devices alive). This drastic load shedding causes the total power draw to quickly fall back below the safe limit, avoiding an adapter overcurrent shutdown or a system power failure. At the same time, the system can log or signal an alert (for example, setting a GPIO or status register bit to indicate that *Safe State* was entered).

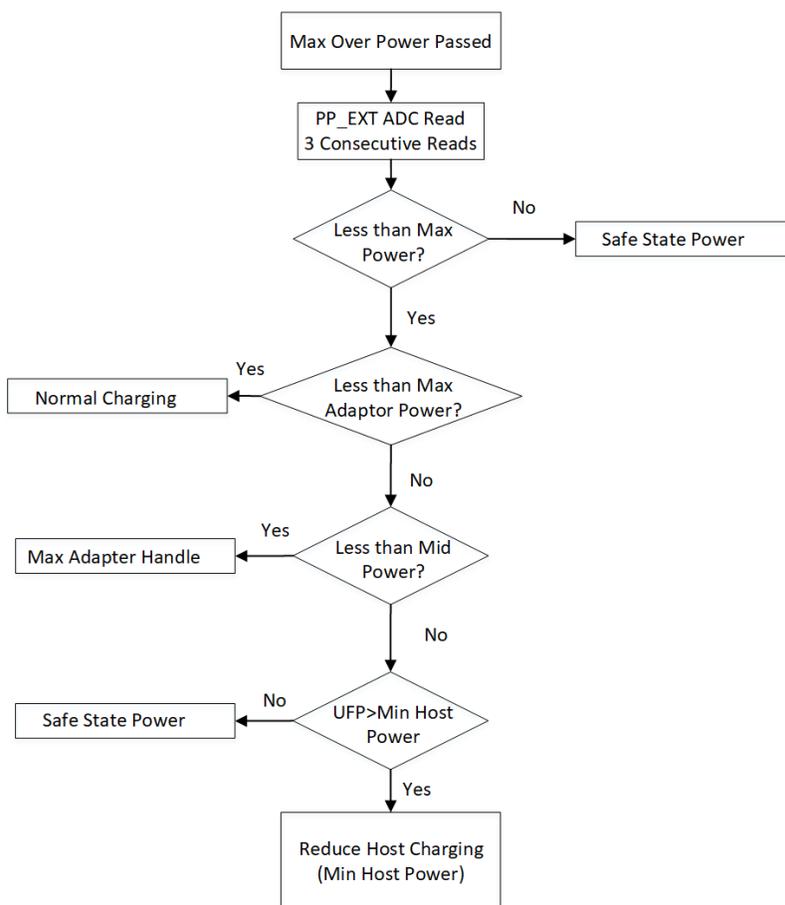


Figure 3-3. High Over-Power Protection Flow

If the high overload condition subsides during the sampling interval (such as a transient spike and power fell back below the threshold), SPM evaluates accordingly – The SPM can treat the event as a more moderate overload instead, following the mid overpower routine (for example, if after the spike the level is only slightly above normal, SPM can simply reduce host power rather than stay in *Safe State*). In general, however, triggering the high overpower protection means an immediate entry into *Safe State* mode, which persists until the cause of the overload is removed or the user reduces the load. The *overpower time parameter* (500ms in this design) makes sure that SPM does not overreact to extremely brief power spikes, but for any sustained serious overload, the parameter verifies the firmware intervenes decisively.

In summary, the multitier protection strategy of the SPI first attempts to handle mild to moderate overloads through power reallocation (for example, limiting host charging as needed) – through the *Max Adapter Power* preventive adjustments and the *Mid Overpower* mitigation routine – and only resort to the extreme *Safe State* measure when an overload is too severe to remedy by those means.

4 Application Tips and Test Results

Through the above smart power management implementation, a TPS65982DMC + TPS65994-based system demonstrates several clear benefits in real-world use:

- Improved Power Utilization and Efficiency:** Testing confirms that dynamic SPM significantly boosts overall power utilization. In a traditional static allocation, each port often reserves the maximum PDO power upfront, leading to some ports' budget sitting idle while the host's charging is throttled. With dynamic SPM, if a device's actual consumption is below the negotiated limit, the system automatically reallocates that port's unused power to other needs (such as the host or another device). For example, a port that negotiated 15W but only draws 5W frees up approximately 10W that can be shifted to the charging of the host, shortening the charge time of the host. At the same time, the total output of the adapter more closely tracks the actual demand, avoiding the energy waste of permanently reserved headroom. In some low-load cases, the output power of the adapter was automatically reduced, which lowers heat dissipation and provides a minor energy-saving benefit.
- Overload Prevention and System Stability:** The real-time adjustments of the SPM greatly enhance system stability under large load transients. In stress tests simulating the nearly simultaneous connection of multiple high-power devices, a traditional design can experience sudden overloads that trigger adapter protection or cause the system to throttle the voltage. With SPM, as the total draw approaches the limit, the system already preempts issues by refusing or scaling back new power requests via the RSP checks. If an overload is imminent, the charging of the host is temporarily reduced the host's charging power to keep the total in check. Test results showed that SPM successfully prevented overload-induced shutoffs. For example, in a system with a 180W adapter, the dock was intentionally loaded to approximately 200W total. SPM reacted immediately by cutting the charge of the host from 60W down to around 30W, pulling the total back under 180W. The system continued running stably with no reset or shutdown. This dynamic protection is far more proactive and smooth than relying on conservative fixed limits or simple fuses, making sure that the user does not experience an interruption due to overload events.
- Design and Tuning Recommendations:** To fully leverage SPM, consider the following during design and testing:
 - Accurate Power Sensing:** Make sure that the ADC measurements for IMON and CDC voltages are properly calibrated to actual power. Implement averaging or filtering in firmware for the PR_DFP readings to avoid reacting to momentary fluctuations that can cause excessive oscillation in power allocation.
 - Proper Parameter Configuration:** Set the **Min_Host_Power** (Guaranteed Host Power) according to the minimum charging requirement of the host device (for example, the power level at which a laptop can still sustain or slowly charge the battery). Decide on a *Reserve Power* budget only if the system (dock) truly requires a dedicated reserve. In many designs, the dedicated reserve can be left at 0W to prioritize the host and peripherals. Align the *Max Adapter Power* setting exactly with the rated output of the adapter. For mid and high overpower thresholds, TI recommends a margin of about 5–10% above the adapter rating, and adjust the overpower time based on the ability of the adapter to handle transients (500ms is a common starting point, but this can be shortened or extended depending on the overcurrent protection characteristics of the adapter).
 - Comprehensive Scenario Testing:** Test a variety of load conditions. For example, one port at full load versus all ports at moderate load, sudden disconnection of a large load, sudden addition of a new high-power load, and so on. Observe how the host and the PDO of each port (negotiated power contract) change in response. Verify that each branch of the SPM flowcharts is exercised and behaves as expected. Using instruments such as an oscilloscope and logic analyzer to capture the I2C power readings and PD negotiations over time can be extremely helpful. These measurements allow fine-tuning of parameters (such as polling frequency or power calculation methods) to achieve a good balance of response speed versus stability.
 - Documentation and Debugging:** Clearly document all SPM-related parameters, decision flows, and assumptions in your design documents. If issues arise (for example, host charge oscillating or an unexpected *Safe State* trigger), having a well-documented reference of the intended SPM behavior pinpointing the error simpler. This allows for quicker adjustments to configuration or firmware to resolve the issue.

5 Summary

Implementing smart power management with TPS65982DMC and TPS65994BG provides an efficient and robust power design for multiport USB-C docks. By dynamically managing power distribution among multiple ports, the system verifies every watt of the capacity of the adapter is used effectively – supplying power where power is required while not letting unused capacity go to waste. At the same time, the multilevel overload protection strategy safeguards the hardware by reacting smoothly to prevent power interruptions or shutdowns. Test results show that a dock with SPM can handle heavy load scenarios and protect the dock far better than a traditional static design. The architecture overview, configuration guidelines, and flowchart walk-through provided in this note help design engineers implement and fine-tune the TPS65982DMC and TPS65994BG SPM functionality, yielding high-performance and reliably-powered multiport USB-C systems.

6 References

- Texas Instruments, [TPS65982DMC Dock Management Controller](#), data sheet.
- Texas Instruments, [TPS65995AD Dual Port USB Type-C® and USB PD Controller with Integrated Source Power Switches Supporting USB4 and Alternate Mode](#), data sheet.

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