Application Report

TPS6598x USB PD Power Negotiation and Multiport Source/Sink Behavior Application Note

ABSTRACT

USB Power Delivery Specification allows a Source or Sink to advertise up to 7 PDOs that include Fixed, Variable and Battery PDOs. Depending on the Source / Sink role of the PD controller port, it is essential for the system to deterministically achieve a state of optimum power. The TPS6598x devices have a feature where a higher power / voltage PDO can be selected by configuration automatically. In addition to this, a 2-port system such as the TPS65988 has Multiport management features to optimize on the power drawn on the Type-C ports should both the ports enter a Source role or both the ports enter a Sink role.

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1 Automatic RDO for Explicit Contracts in SINK Role

This feature is applicable to both TPS65987 and TPS65988 devices. The feature allows the TPS6598x device in a Sink role to select one PDO from a list of PDOs advertised by the Source connected to its port as part of its *Source Capabilities* during the process of negotiating / renegotiating an explicit power contract. The parameters advertized by this PDO are then used to construct an RDO to be sent out as part of the *Request* message by the TPS6598x device on the applicable port.

The singling out of a PDO from a list of Source PDOs is largely based on the following criteria:

1. *Power requirement as per TPS6598x configuration*
2. *Priority of Offer over Voltage / Current / Power*

This is configurable in the Autonegotiate Sink Register (0x37).

1.1 Autonegotiate Sink Register (0x37)

This register allows the configuration of the TPS6598x device's automatic RDO selection behavior. The details of this register can be found in the ***Host Interface Technical Reference Manual*** of TPS6598x devices [SLVUBH2B]. Below is the register definition as available in the Technical Reference Manual (TRM).

Note

Writing this register while a sink contract is in place will not cause an automatic renegotiation. Changes will take effect the next time a contract is negotiated. The *ANeg* command forces a re-evaluation of this register and a new *Request* message will be issued if appropriate.

Note

The PD controller negotiates the PD contracts per the settings in this register regardless of the SNK Policy mode. However, power switches configured as input waiting for SRDY will only be enabled in SNKAutomaticMode. The PD controller in SNKIntrusiveMode can still disable specific switches during contract changes as described in the TRM.

Table 1-1. 0x37 Auto Negotiate Sink Register

Address	Name	Access	Length	Power-Up Default
0x37	Auto Negotiate Sink	Read/Write	24	0 (Initialized by Application Customization)

Table 1-2. 0x37 Auto Negotiate Sink Register Bit Field Definitions

Bits	Name	Description
Bytes 17-20: Non-Battery PDO Parameters		
31:22	Reserved	Reserved.
21:20	PeakCurrent	Peak Current (See PD Spec)
19:10	Reserved	Reserved.
9:0	MaximumCurrent	Maximum Current (10-mA steps)
Bytes 13-16: Battery PDO Parameters		
31:22	MinimumVoltage	Minimum Voltage (50-mV steps)
21:20	Reserved	Reserved (Write 0)
19:10	MaximumVoltage	Maximum Voltage (50-mV steps)
9:0	MaximumPower	Maximum Power (250-mW steps)
Bytes 9-12: RDO Current Parameters		
31:20	Reserved	Reserved (Write 0)
19:10	MinOperatingCurrent	Min Operating Current (10-mA steps)
9:0	OperatingCurrent	Operating Current (10-mA steps)
Bytes 5-8: RDO Power Parameters		
31:20	Reserved	Reserved (Write 0).
19:10	MinOperatingPower	Min Operating Power (250-mW steps)

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Table 1-2. 0x37 Auto Negotiate Sink Register Bit Field Definitions (continued)

Bits	Name	Description	
9:0	OperatingPower	Operating Power (250-mW steps)	
Bytes 3-4: Auto Negotiate Minimum Sink Required Operating Power			
15:10	Reserved	Reserved (Write 0)	
9:0	ANSinkMinRequiredPower	Minimum operating power required by the Sink in 250mW per LSB. Typically, this field is set to the maximum power across the PDOs defined in the TX Sink Capabilities Register (0x33). NOTE: If the TX Sink Capabilities Register includes Battery supply type PDO(s), then the maximum power of Battery PDOs should be considered even when Fixed supply and Variable supply PDOs of higher power are available.	
Byte 2: Auto-negotiate control			
7:1	Reserved	Reserved (Write 0)	
0	AutoComputeSinkMinPower	Decides if FW should compute minimum Sink operating power based on Sink Capability PDOs programmed in the TX Sink Capability register	
		0b	PD Controller uses the value stored in the ANSinkMinRequiredPower field as the minimum operating power required by the SInk.
		1b	PD Controller will automatically compute the minimum operating power required by the SInk based on the Sink PDOs stored in the TX Sink Capabilities Register (0x33) and store it in the ANSinkMinRequiredPower field. The ANSinkMInRequiredPower is updated during the negotiation of a new contract.
Byte 1: Auto-negotiate control and RDO flags			
7	RDOGiveBackFlag	RDO GiveBack Flag	
6	RDONoUsbSuspFlag	RDO NoUSBSusp Flag	
5:4	OfferPriority	Offer Priority when evaluating PDOs offered by source	
		00b	Higher current priority
		01b	Higher voltage priority
		10b	Higher power priority
		11b	Reserved.
3	RDOUsbCommCapable Flag	RDO USB Communications Capable Flag	
2	AutoNgtSnkVariable	Auto Negotiate using Variable PDO	
1	AutoNgtSnkBattery	Auto Negotiate using Battery PDO	
0	AutoNgt	Auto Negotiate Fixed PDO This bit must be set for AutoNgtSnkVariable/Battery.	

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1.2 Automatic PDO Selection as a Sink

The Automatic PDO selection depends on the below fields from the AutoNegotiate Sink register:

Bytes 3-4: Auto Negotiate Minimum Sink Required Operating Power	
9:0	ANSinkMinRequiredPower
Byte 2: Auto-negotiate control	
0	AutoComputeSinkMinPower
Byte 1: Auto-negotiate control and RDO flags	
5:4	OfferPriority
0	AutoNgt

Bit Field Descriptions and PDO Selection Behavior:

- **AutoNgt:** Setting this bit enables the Autonegotiate Sink behavior. This bit is the master control that enables / disables this feature.
- **OfferPriority:** These bits allow the user a choice of precedence between Highest Voltage, Highest Current and Highest power. This is irrespective of a capability mismatch being set.
- **AutoComputeSinkMinPower:** Setting this bit enables the PD controller to determine the power requirement of the system based on the Sink PDOs. The *minimum* power required by the Sink is computed as the *maximum* of power computed per Sink PDO.
- **ANSinkMinRequiredPower:** If the bit **AutoComputeSinkMinPower** is not set, the parameter entered in this field is used as the *minimum* power requirement of the sink.

1.3 Autonegotiate PDO Selection Flow

The PDO selection logic is triggered once the PD controller port is in an Attach. SNK state and the port partner (far end) has advertized its source capabilities. The PDOs received are captured in **0x30 RX Source Capabilities Register**. The PDO selection algorithm iteratively processes these PDOs to identify the best fit PDO based on the criteria below:

- The Autonegotiate behavior is not applicable even if **AutoNgt**=1 if **SNKIntrusiveMode** = 1 (Bit 9, *Port Control Register [0x29]*).
- The autocomputed / user selected *Minimum Power* for the Sink port is compared with every single Source PDO to find a best fit.
- The Sink PDO voltage range must match or fall within the selected Source PDO advertized voltage.
- The Source PDO supply type (eg: Fixed / Variable / Battery) matches the supply type of the Sink PDO that closely matches the *Minimum Power* requirement (applicable to a perfect PDO match).
- In the process of Autonegotiation, if a perfectly matching Source PDO is found, the iteration ends here. A matching PDO would have the below characteristics:
  - *Minimum Power* requirement is satisfied by the selected Source PDO.
  - If there are multiple Source PDOs that can satisfy the *Minimum Power* requirement, the latest one from the list of PDOs that satisfies the criteria is chosen.
  - Capability mismatch bit is not set.
- If a perfectly matching PDO is *not* found, then the iteration resets until a Source PDO matches the setting chosen for **OfferPriority**. The setting of Highest Voltage / Current / Power in **OfferPriority** allows a Source PDO selection that meets the Highest Voltage / Current / Power parameters of the Sink PDO fully / closely matching the *Minimum Power* value.

The flowchart below shows the Autonegotiate Sink behavior for selecting a PDO.

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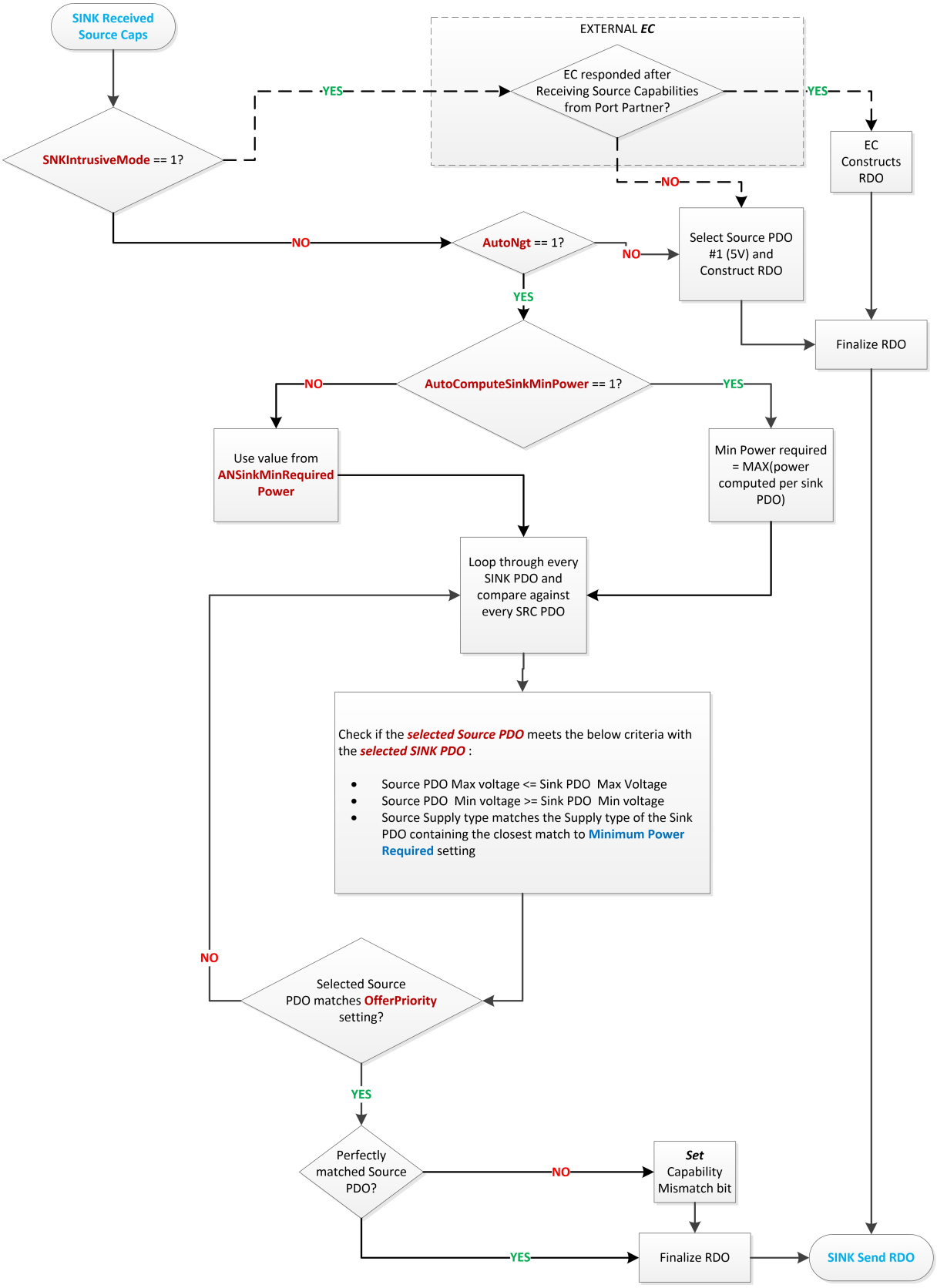

Figure 1-1. Autonegotiate PDO Selection Flowchart

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Note

1. For Variable Sink PDOs, the power computed is a product of *Operating Current* and *Maximum Voltage* of the PDO.
2. For Variable Source PDOs, the PDO power computed is a product of the *Operating Current* and *Minimum Voltage* advertized.
3. For Battery Sink PDOs, the *Operating Power* is used.
4. RDO requested current is limited by the Cable's Maximum current rating.
5. External EC's intervention is asynchronous.

1.4 Autonegotiate Behavior Examples

SL No.	Source PDO Set	Sink PDO Set	Offer Priority	Autocompute Sink Min Power	Computed / Set Min Power	RDO Position	RDO Power / Current / Voltage	Cap Mismatch	Remarks
1	Fixed: 5 V @ 3 A	Fixed: 5 V @ 3 A	Power	Yes	40 W	4	45 W	FALSE	Perfect match
	Fixed: 9V @ 1 A	Variable: 5–20 V @ 2 A							
	Fixed: 15 V @ 1 A								
	Fixed:15 V @ 3 A								
2	Fixed: 5 V @ 3 A	Fixed: 5 V @ 3 A	Power	Yes	40 W	3	15 W	TRUE	PDO #3 provides highest power
	Fixed: 9 V @ 1 A	Variable: 5–20 V @ 2 A							
	Fixed: 15 V @ 1 A								
	Fixed: 20 V @ 0.5 A								
3	Fixed: 5 V @ 3 A	Fixed: 5 V @3 A	Current	Yes	40 W	4	4 A	FALSE	Ignore Offer Priority since Minimum Power Requirement has been met
	Fixed: 9 V @ 4 A	Variable: 5–20 V @ 2 A							
	Fixed: 15 V @ 1 A								
	Fixed: 20 V @ 2 A								
4	Fixed: 5 V @ 3 A	Fixed: 5 V @ 3 A	Voltage	Yes	40 W	4	20 V	TRUE	PDO #4 provides highest voltage
	Fixed: 9 V @ 4 A	Variable: 5-20 V @ 2 A							
	Fixed: 15 V @ 2.5 A								
	Fixed: 20 V @ 1 A								

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SL No.	Source PDO Set	Sink PDO Set	Offer Priority	Autocompute Sink Min Power	Computed / Set Min Power	RDO Position	RDO Power / Current / Voltage	Cap Mismatch	Remarks
5	Fixed: 5 V @ 3 A	Fixed: 5 V @ 3 A	Power	Yes	40 W	4	45 W	FALSE	Ignore Offer Priority since Minimum Power Requirement has been met. SRC PDO #4 power computed :: 15 V@ 3 A = 45 W
	Fixed: 9 V @ 4 A	Variable: 5–20 V @ 2 A							
	Fixed: 15 V @ 2.5 A								
	Variable: 15–20 V @ 3 A								
6	Fixed: 5V @ 3 A	Fixed: 5 V @ 3 A	Power	No	30 W	3	37.5 W	FALSE	PDO #3 provides highest power SRC PDO #4 power computed :: 5 V@ 3 A = 15 W
	Fixed: 9V @ 4 A	Variable: 5–20 V @ 2 A							
	Fixed: 15 V @ 2.5 A								
	Variable: 5–20 V @ 3 A								
7	Fixed: 5V @ 3 A	Fixed: 5 V @ 3 A	Power	Yes	40 W	4	1.8 W	TRUE	PDO #4 provides highest power Source Current cannot exceed cable limit of 3 A
	Fixed: 9 V @ 1 A	Variable: 5–20 V @ 2 A							
	Fixed: 15 V @ 1 A								
	Battery: 15–20 V @ 75 W								

Example Scenarios:

Some of the examples have been discussed below:

- **Example #1:** *Minimum Power* value, i.e. the maximum power the Sink requires is determined by **AutoComputeSinkMinPower**. Hence, of the two Sink PDOs, PDO #2 (5–20 V @ 2 A) results in a *Minimum Power* value of 40 W. The PD controller hence chooses PDO #4 (15 V @ 3 A) which can deliver 45 W. Capability mismatch is not set.
- **Example #2: AutoComputeSinkMinPower** = 1. Therefore, Sink PDO #2 (5–20 V @ 2 A) results in a *Minimum Power* value of 40 W. However, the Source PDO list has the highest offerable power of 15 W. This would be a capability mismatch and the PDO selection would now be dependent on the **OfferPriority** setting. In this example, the offer priority is set to *Highest Power*, so PDO #3 (15 V @ 1 A) would be selected.
- **Example #4: AutoComputeSinkMinPower** = 1. Therefore, Sink PDO #2 (5–20 V @ 2 A) results in a *Minimum Power* value of 40 W. However, the Source PDO list has the highest offerable power of 37.5 W (Source PDO #3–15 V @ 2.5 A). PDO #4 (20 V @ 1 A) would be chosen since the **OfferPriority** setting is set to Highest Voltage. Capability mismatch is set since there isn't a perfect match to the *Minimum Power* requirement.
- **Example #6: AutoComputeSinkMinPower** = 0, which means the *Minimum Power* value is *not* autocomputed by the PD controller, but is directly taken as the value entered in the field **ANSinkMinRequiredPower** (30 W). Source PDO #2 (9 V @ 4 A) and Source PDO #3 (15 V @ 2.5 A)

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meet the criteria. The PDO selected would be the latest iterated matching source PDO, i.e. PDO #3 (15 V # 2.5 A). Capability mismatch bit is ***not*** set.

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2 Multi Port Source Policy Management

The Source Policy Manager is a feature of the TPS65988 (dual port) PD controller that allows the system to restrict power sourced when both the port controllers inside the TPS65988 device are in the Source role. This feature is enabled by setting **MultiPortSourcePolicy** to 1 (Bit #7 of byte 13 of the *Global System Configuration Register (0x27)*). This feature is also dependent on two other bits:

- **TBTControllerType** [Bits 5:4 of *Global System Configuration Register (0x27)*]
- ***Prevent High Current Contract Event*** (GPIO Input configuration (*port specific*))

2.1 Multi Port Source Policy Management Flow

The Source Policy Management (SPM) on the TPS65988 PD controller operates on the below criteria:

- The SPM is enabled by setting **MultiPortSourcePolicy** = 1.
- The SPM works only when there is an explicit PD contract or a disconnect on one port while the adjacent port is already in an explicit contract.
- The SPM may affect either port, regardless of the port which triggered a negotiation of PDOs or a disconnect.
- The SPM allows *any one* port to have a high current contract. It may be triggered by the current port or the adjacent port. The adjacent port would be in a default USB current contract (900 mA).
- The SPM feature is available only for Ice Lake processors, meaning, the **TBTControllerType** setting should be **0x03**. It is not available for other platforms.

SPM Behavior:

As mentioned previously, the SPM feature works only on Ice Lake settings and with the adjacent port already in an explicit PD contract. The behavior is as described below:

- If SPM is triggered by a PDO negotiation on a port:
  - If the present port receives a Request Data Object (RDO) with an operating current above the default USB current (900 mA), the adjacent port's active contract current is lowered to the default USB current and a renegotiation of an explict contract occurs on the Adjacent port.
  - If the RDO current of the present port is already at the default USB current or lesser (based on the Sink's request) or if a GPIO mapped to ***Prevent High Current Contract Event*** (#80) is **HIGH**, the adjacent port's advertised current is restored as per the *TX Source Capabilities Register (0x32)* settings and a renegotiation of an explict contract occurs on the Adjacent port if SPM had previously restricted its advertisement.
- If a port gets disconnected then SPM will restore the advertised current in adjacent port's TX SourceCapability register and force adjacent port to renegotiate if needed.

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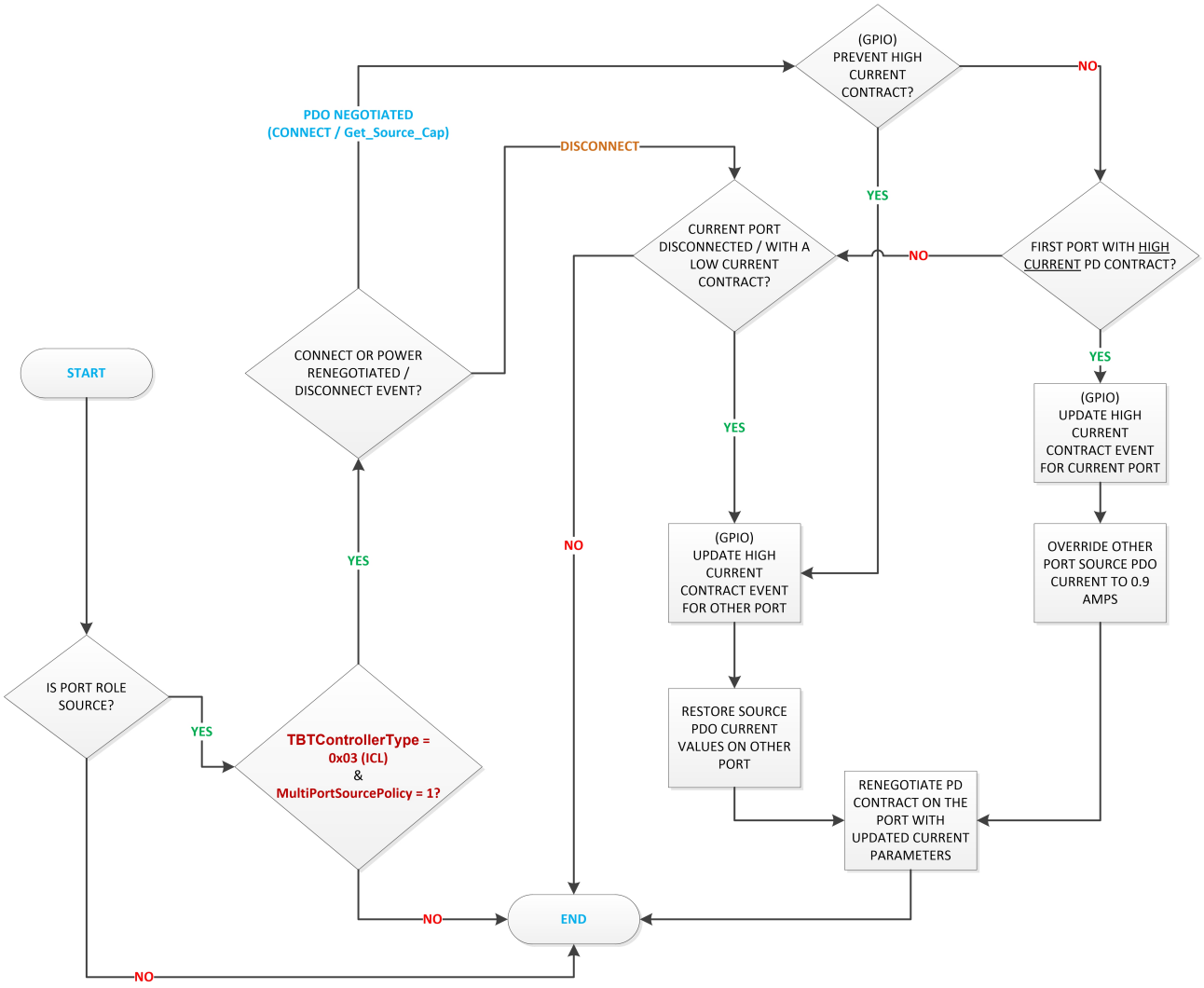

Figure 2-1. Multi Port Source Policy Manager Flowchart

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3 Multiport Sink Policy Management

The Multiport Sink Policy Management feature of the TPS65988 (dual port) PD controller enables the system to optimize the power drawn when both ports are acting in the Sink power role. The main objective of this feature is to sink power from a port that has higher power contract and disable the sink power path on adjacent port. The power contract on any of the ports is not disturbed. This feature results in only one port actually sinking power. This feature is dependent on the setting of the below bits:

- **MultiPortSinkPolicy** [Bits 1:0 of *Global System Configuration Register (0x27)*]
- **MultiPortSinkNonOverlapTime** [Bits 10:9 of *Global System Configuration Register (0x27)*]

In addition to these bits, setting the bit **AutoNgt** = 1 [Bit 0 of *Auto Negotiate Sink Register (0x37)*] will allow for drawing higher power which otherwise would default to 5-V contracts only (First PDO from the list of Source PDOs).

Multiport Sink Policy Management Behavior:

The Multiport Sink Management feature functions with the below criteria:

- When the port is entering a Sink role in an Implicit / Eplicit or Legacy mode.
- When in dead battery, the Sink switch would always be enabled.
- If the adjacent port does not have its Sink switch closed on account of being in a disconnected / Source / Sink (open switch) state, the current port's Sink switch would be enabled.
- If the adjacent port is already in a Sink contract with its Sink switch closed, the PD contract power of both ports would be compared and the port with the Higher PD contract power would close its switch while the other would be opened (if already closed) or suppressed from closing.
- In a case where the adjacent port is in a Sink contract and its Sink switch requires to be opened and the current port's Sink switch needs to be closed, the operation would be a *break-before-make* operation where the below sequence is followed:
  - Open adjacent Sink switch.
  - Wait for a time determined by the setting **MultiPortSinkNonOverlapTime** (Bits #10:9 of byte 14 of the *Global System Configuration Register (0x27)).*
  - Close the current port Sink switch.

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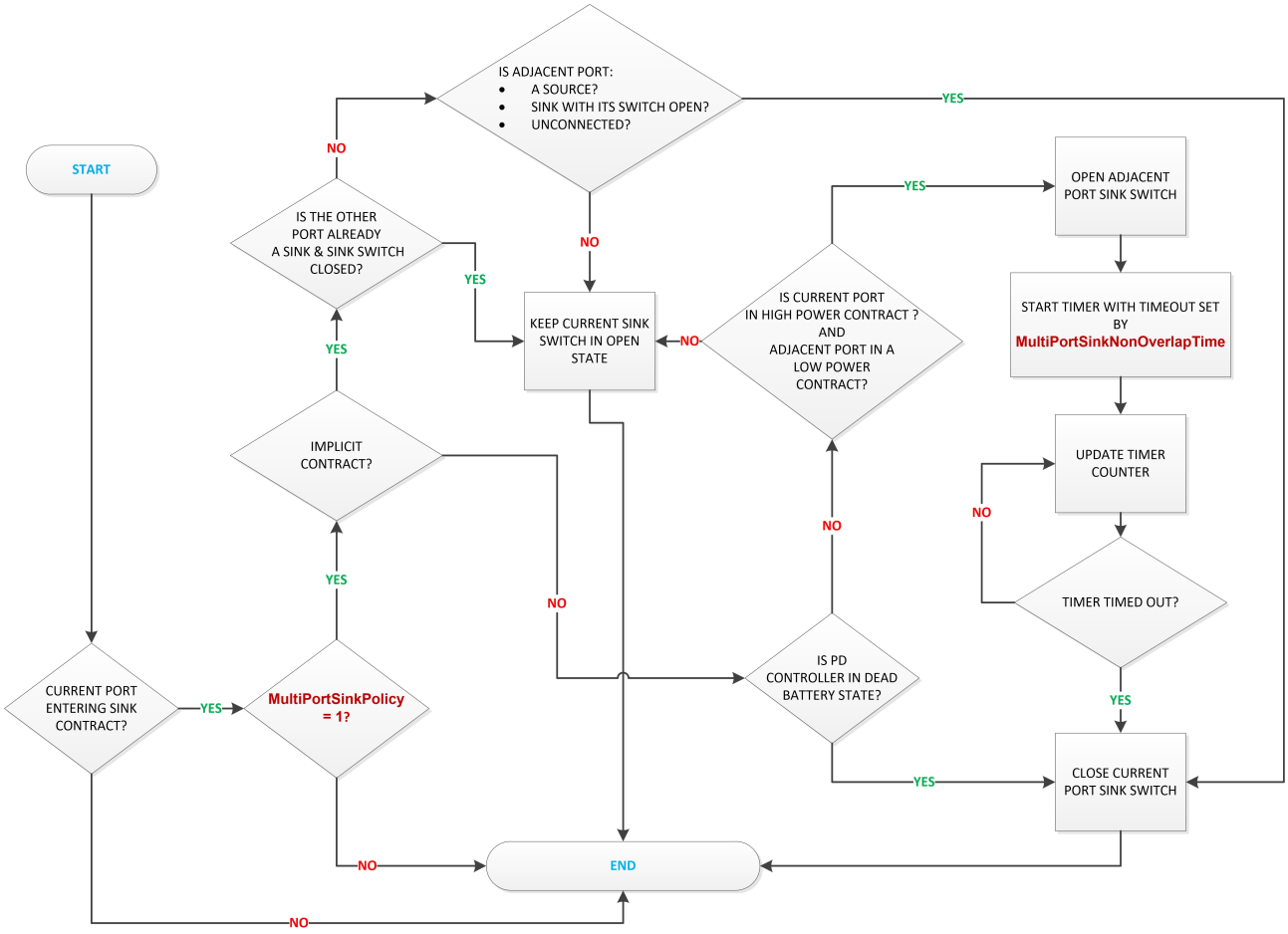

Figure 3-1. Multiport Sink Policy Management Flowchart

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4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

DATE	REVISION	NOTES
April 2021	*	Initial Release

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