# AnyWatt™ Programmable Power Supply Specification

RVE1.1

# Revision History

| Revision | Description | Issue Date |
|---|---|---|
| REV 1.0 | Initial release Revision 1.0 | 15 October, 2016 |
| REV 1.1 | Added 4.3 Linear feedback implementation | 4 December,2016 |
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# 1. Introduction

## 1.1 Overview

AnyWatt™ is a programmable power supply technology which bases on USB PD protocol. It allows the load program the power supply by standard USB PD communication to achieve constant voltage output of given voltage or constant current output of given current or constant power output of given power within the USB Type-C specifications.

## 1.2Applications

AnyWatt™ technology is designed for adapters and electrical equipments with USB Type-C interface, which power supply are below 20 volts and 100 watts. It can be applied in mobile terminals; home appliances; office equipments; industrial equipments and medical equipments. It is particularly suitable for electrical equipments (such as mobile phone) which built-in lithium-ion battery charging management, to reduce the heat of electrical charging control loop.

# 2. System Architecture

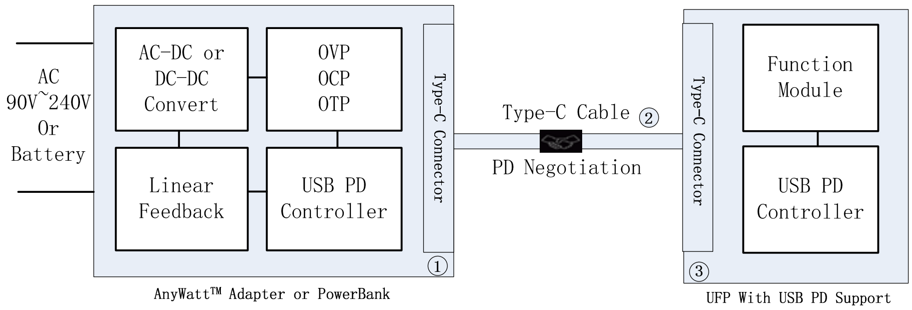


Figure 2-1 AnyWatt™ System Architecture

As shown in Figure 2-1, AnyWatt™ technology includes ①USB TYPE-C SRC (or DRP) ②USB TYPE-C Cable and ③USB TYPE-C SNK (or DRP). The SRC includes an USB PD Controller, a linear feedback module for constant voltage, constant current and constant power output control. USB TYPE-C Cable can be an Electronically Marked Cable (the maximum current to 5A) or a not Marked Cable (the maximum current to 3A). SNK device includes an USB PD controller, a function module and optional battery packets. If both the SRC and SNK are DRP Devices PR_Swap (Power Role Swap) packet can be used to exchange roles when necessary.

# 3. Implementation Flow

The implementation flow of AnyWatt™ is achieved by standard USB PD messages without any VDM messages.

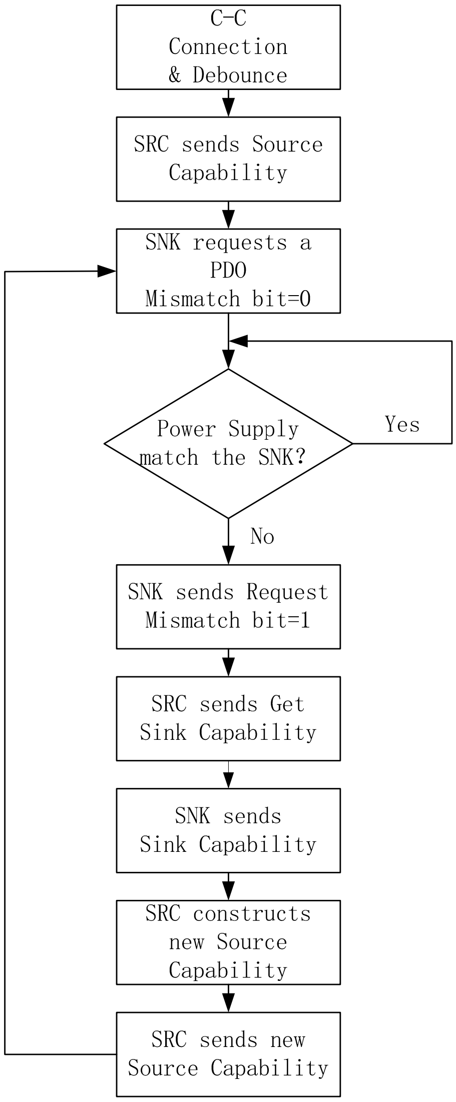


Figure 3-1 AnyWatt™ Workflow

In Figure 3-1, the Sink Capabilities packet sent by SNK can be a combination of one or more of Fixed Supply, Variable Supply, and Battery Supply, which correspond to constant voltage power supply, constant current power supply and constant power supply. The Source Capabilities of the SRC will be rebuild according to the SNK's Sink Capabilities, and SNK can reset the Source Capabilities to default value by sending SOFT_RESET packet.

# 4. Power Requirements

## 4.1 Electrical Parameters

AnyWatt™ technology requires SRC to have constant voltage, constant current, constant power three kinds of power supply manners. The $U_{MAX}$, $I_{MAX}$, $P_{MAX}$ below, means the maximum ability of the power module of SRC.

Table 4-1 Maximum character with E-mark Cable support 5A

| | Max | Min |
|---|---|---|
| I | 5000mA | 100mA |
| U | 20V | 3V |
| P | 100W | 300mW |

Table 4-2 Maximum character without E-mark Cable support 3A

| | Max | Min |
|---|---|---|
| I | 3000mA | 100mA |
| U | 20V | 3V |
| P | 60W | 300mW |

Table 4-3 Values limited by the $P_{MAX}$, the $U_{MAX}$, the $I_{MAX}$ of power

| | Max | Min |
|---|---|---|
| I | $Max(I_{MAX},P_{MAX}/U_{OUT})$ | 100mA |
| U | $Max(U_{MAX},P_{MAX}/I_{OUT})$ | 3V |
| P | $Max(P_{MAX})$ | 300mW |

Note: These values should not exceed Table 4-1 and Table 4-2.

$P_{MAX}$ is the max power of the SRC, $U_{MAX}$ is the max voltage output of the SRC, $I_{MAX}$ is the max current output of the SRC, that usually limited by the AC-DC or DC-DC Module.

## 4.2 SRC USB PD Communication Function

AnyWatt™ technology requires SRC to have USB PD communication capability and be able to evaluate whether the Request packet contains mismatch flag. After a mismatch flag was detected, SRC should send a Get_Sink_Cap packet to survey the SNK. SNK then send a Sink Capabilities packet. SRC will rebuild the Source Capabilities packet according to the Sink Capabilities received, and then send the new Source Capabilities packet to the SNK. So that the SNK will be able to choose what it needs. SNK can change the power supply dynamically by repeating this procedure.

After receiving the Sink Capabilities packet, the SNK should rebuild the Source Capabilities follow the following rules. The $U_{MAX}$, $I_{MAX}$, $P_{MAX}$ below, means the maximum ability of the power module of SRC.

1. If the Sink Capabilities packet includes a fixed type PDO, SRC should try to include the same PDO in its new Source Capabilities packet. If this PDO exceeds the ability of the power module of the SRC, the voltage, current and power should be evaluated one by one. If $U > U_{MAX}$ then $U = U_{MAX}$. If $I > I_{MAX}$ then $I = I_{MAX}$. After the U and I were determined, the power should be examined. If $P>P_{MAX}$, then the current should be decreased to meet $P = P_{MAX}$.
2. If the Sink Capabilities packet includes a variable type PDO, SRC should divide the PDO into two. The first one is a fixed type PDO which voltage and current output is the maximum voltage and operation current of the received variable type PDO. The second PDO is a variable type PDO, best the same as received. The purpose of dividing variable type PDO into two is that some SNKs send variable type PDO to declare the power range that is acceptable but not the best match one. If the two PDOs exceed the ability of the power module of the SRC, they should follow the rule like No.1.
3. If the Sink Capabilities packet includes a battery type PDO, SRC should divide the PDO into two. The first one is a fixed type PDO which voltage output is the maximum voltage of the received battery type PDO. The output current of this fixed PDO should equal to the operation power divide the minimum voltage of the received battery type PDO. The second PDO is a battery type PDO, best the same as received. The purpose of dividing battery type PDO into two is that some SNKs send battery type PDO to declare the power range that is acceptable but not the best match one. If the two PDOs exceed the ability of the power module of the SRC, they should follow the rule like No.1.
4. In the case of the above three rules, the resulting PDOs should be arranged according to USB PD Specification that is fixed type PDOs first and then battery type PDOs and then variable type PDOs. If the resulting PDOs do not include a vsafe5v option, then a vsafe5v PDO should be added to be the first PDO.
5. In the case of the above four rules, if the number of PDO in the resulting Source Capabilities packet exceeds seven, the priority is fixed type then battery type then variable type, the redundant PDOs

should be discarded.

6. SOFT_RESET and HARD_RESET packets are used to reset the Source Capabilities of the SRC to the default value.

## 4.3 Linear Feedback Function Implementation

The traditional fixed resistance feedback function, can only output a few fixed voltage. But the linear feedback function, depending on the ADC detection and DAC output to form a closed-loop, such to achieve constant voltage or constant current or constant power output. The SRC of AnyWatt™ must be able to realize linear feedback function.

### 4.3.1 Constant Voltage Output with Linear Feedback

Fixed type PDO corresponds to the constant voltage output function. The linear feedback module can output the feedback signal to the AC-DC module or DC-DC module in digital or analog mode. For example, DAC module can be used to drive the feedback resistors, TL431 and optocoupler devices to tune the AC-DC module to achieve the output voltage that required by the load.

**Table 6-10 Fixed Supply PDO - Sink**

| Bit(s) | Description |
|---|---|
| B31..30 | Fixed supply |
| B29 | Dual-Role Power |
| B28 | Higher Capability |
| B27 | Externally Powered |
| B26 | USB Communications Capable |
| B25 | Dual-Role Data |
| B24..20 | ***Reserved*** – shall be set to zero. |
| B19..10 | Voltage in 50mV units |
| B9..0 | Operational Current in 10mA units |

Figure 4-1 Fixed type PDO of Sink Capabilities

**Table 6-6 Fixed Supply PDO - Source**

| Bit(s) | Description |
|---|---|
| B31..30 | Fixed supply |
| B29 | Dual-Role Power |
| B28 | USB Suspend Supported |
| B27 | Externally Powered |
| B26 | USB Communications Capable |
| B25 | Dual-Role Data |
| B24..22 | ***Reserved*** – shall be set to zero. |
| B21..20 | Peak Current |
| B19..10 | Voltage in 50mV units |
| B9..0 | Maximum Current in 10mA units |

Figure 4-2 Fixed type PDO of Source Capabilities

As shown in Figure 4-1 and Figure 4-2, if the power supply module of the source is able to support, the PDO in Source Capabilities will contain the same voltage and current as the Sink Capabilities (see 4.2). On the other hand, if the Sink Capabilities PDO exceeds the ability of the source, the correspond PDO of the Source Capabilities should obey first rule of 4.2.

### 4.3.2 Constant Current Output with Linear Feedback

**Table 6-11 Variable Supply (non-Battery) PDO - Sink**

| Bit(s) | Description |
|---|---|
| B31..30 | Variable Supply (non-Battery) |
| B29..20 | Maximum Voltage in 50mV units |
| B19..10 | Minimum Voltage in 50mV units |
| B9..0 | Operational Current in 10mA units |

Figure 4-3 Data structure of Variable type PDO of Sink Capabilities

Table 6-8 Variable Supply (non-Battery) PDO - Source

| Bit(s) | Description |
|---|---|
| B31..30 | Variable Supply (non-Battery) |
| B29..20 | Maximum Voltage in 50mV units |
| B19..10 | Minimum Voltage in 50mV units |
| B9..0 | Maximum Current in 10mA units |

Figure 4-4 Data structure of Variable type PDO of Source Capabilities

As shown in Figure 4-3, in the Sink Capabilities packet, the variable type PDO contains the maximum acceptable voltage $V_{MAX}$, the minimum acceptable voltage $V_{MIN}$, and the current $I_{OP}$ required for operation of the sink. There are two ways for the source to resolve this data packet.

The first way is that the sink can accept a fixed voltage input power supply, the maximum voltage $V_{MAX}$ is defined by B29 ~ B20, the minimum voltage $V_{MIN}$ is defined by B19 ~ B10, and the operation current is defined by B9 ~ B0. In this way you can construct a fixed type of PDO with $V_{MAX}$ and $I_{OP}$. If the power of the PDO exceeds the capacity of the power module of source, then it follows the first rule described in Section 4.2.

The second way is that the sink needs constant current power supply, operation current $I_{OP}$ is defined as B9 ~ B0, the maximum voltage acceptable $V_{MAX}$ is defined as B29 ~ B20, the minimum Voltage acceptable $V_{MIN}$ is defined as B19 ~ B10. If the supply voltage has been rose to $V_{MAX}$, but the current is still less than $I_{OP}$, the $V_{MAX}$ voltage output is maintained. On the other hand, if the output voltage has been reduced to $V_{MIN}$, but the output current is still greater than the $I_{OP}$, then the over-current protection should be performed. In this way, you can construct a PDO packet of variable type which the highest voltage is defined by B29 ~ B20, the lowest output voltage is defined by B19 ~ B10 and the maximum current is defined by B9 ~ B0 of PDO of the Sink Capabilities. If this power exceeds the capability of the power module of the source, then it follows the first rule described in Section 4.2.

### 4.3.3 Constant Power Output with Linear Feedback

Table 6-12 Battery Supply PDO - Sink

| Bit(s) | Description |
|---|---|
| B31..30 | Battery |
| B29..20 | Maximum Voltage in 50mV units |
| B19..10 | Minimum Voltage in 50mV units |
| B9..0 | Operational Power in 250mW units |

Figure 4-5 Data structure of Battery type PDO of Sink Capabilities

Table 6-9 Battery Supply PDO - Source

| Bit(s) | Description |
|---|---|
| B31..30 | Battery |
| B29..20 | Maximum Voltage in 50mV units |
| B19..10 | Minimum Voltage in 50mV units |
| B9..0 | Maximum Allowable Power in 250mW units |

Figure 4-6 Data structure of Battery type PDO of Source Capabilities

As shown in Figure 4-5, in the Sink Capabilities packet, the battery type PDO contains the maximum acceptable voltage $V_{MAX}$, the minimum acceptable voltage $V_{MIN}$, and the power $P_{OP}$ required for operation of the sink. There are two ways for the source to resolve this data packet.

The first way is that the sink can accept a fixed voltage input power supply, the maximum voltage $V_{MAX}$ is defined by B29 ~ B20, the minimum voltage $V_{MIN}$ is defined by B19 ~ B10, and the operation power is defined by B9 ~ B0. In this way you can construct a fixed type of PDO with $V_{MAX}$ as the output voltage and $I_{OP}$ equal to $P_{OP}$ divided by $V_{MIN}$ as output current. If the power of the PDO exceeds the capacity of the power module of source, then it follows the first rule described in Section 4.2.

The second way is that the sink needs constant power supply, operation power $P_{OP}$ is defined as B9 ~ B0, the maximum voltage acceptable $V_{MAX}$ is defined as B29 ~ B20, the minimum Voltage acceptable $V_{MIN}$ is defined as B19 ~ B10. If the supply voltage has been rose to $V_{MAX}$, but the power is still less than $P_{OP}$, the $V_{MAX}$ voltage output is maintained. On the other hand, if the output voltage has been reduced to $V_{MIN}$, but the output power is still greater than the $P_{OP}$, then the over-current protection should be performed. In this way, you can construct a PDO packet of battery type which the highest voltage is defined by B29 ~ B20, the lowest output voltage is define by B19 ~ B10 and the maximum power is defined by B9 ~ B0 of PDO of the Sink Capabilities. If this power exceeds the capability of the power module of the source, then it follows the first rule described in Section 4.2.

### 4.4 SRC Over-voltage Protection

The SRC needs to monitor the output voltage from the AC-DC or DC-DC. If the output voltage remains above 20% of the PD negotiated voltage after the feedback setting is complete, VBUS_EN must be disabled. SRC should monitor continuously, when the VBUS voltage does not exceed 10% of the PD negotiation, VBUS out can be enabled again. If the CC connection is interrupted, or the PD communication is Hard Reset during protection, the power supply process should be reinitialized.

### 4.5 SRC Over-current Protection

The SRC needs to detect the output current value continuously, and when the output current value exceeds 10% of the PD negotiated value, the voltage should be reduced linearly. When the output current exceeds the negotiated value of 20%, SRC should start the over-current protection mechanism, close the VBUS output, and reinitialize the power supply process 3 seconds later.

### 4.6 SRC Over-temperature Protection

The SRC needs to monitor its own temperature continuously, when PCBA temperature is higher than 120 degrees, SRC should start over-temperature protection mechanism. The VBUS output is turned off and the power supply process is reinitialized when the temperature drops below 80 degrees.

## 5. Load Requirements

### 5.1 Electrical Parameters

AnyWatt™ technology requires SNK able to perform the normal work of the PD module when in the 5V power supply condition and support dead battery function.

### 5.2 SNK USB PD Communication Function

The SNK must support USB PD 2.0 or higher version for communication. It should monitor the working status of the system at all times. If the power requirements of the system is going to exceed the current power supply, SNK should send a Request packet with mismatch = 1 to SRC, to re-negotiate power supply. When SRC receives a Request packet with Mismatch = 1, it should send a Get_Sink_Cap packet after the current negotiation finished. The SNK then send a Sink Capabilities packet to notice the SRC what it needs. SRC will analyze the Sink Capabilities packet and generate a new Source Capabilities packet based on the Sink Capabilities and the capabilities of its own power module. SNK will be able to choose the most suitable PDO, to complete a dynamic power supply negotiation.

### 5.3 SNK Over-voltage Protection

The SNK needs to monitor the supply voltage from SRC continuously. If the output voltage remains above 20% of the PD negotiated voltage after SRC sends PS_RDY, VBUS_EN must be disabled. SNK should monitor continuously, when the VBUS voltage does not exceed 5% of the PD negotiated, it can be re-opened VBUS input. If the CC connection is interrupted, or the PD communication is Hard Reset during protection, the power supply process should be reinitialized.

### 5.4 SNK Over-current Protection

The SNK needs to check the input current value continuously. When the input current value exceeds 10% of PD negotiated value, VBUS_EN should be turned off and Hard Reset should be sent.

### 5.5 SNK Over-temperature Protection

The over-temperature protection of SNK, is depended on the device's own function and performance , it is not the scope of this article.

# Appendix A Example of **AnyWatt™** for Quick Charging(Constant Voltage Mode)

AnyWatt™ technology allows SRC to output a voltage between 3V and 20V with a minimum resolution of 50mV. This technique adjusts the output voltage of SRC in time as the charge voltage changes with the battery.

Figure A-1 and Figure A-2 show the communication process using the AnyWatt™ feature to achieve a fast charge of mobile phone.

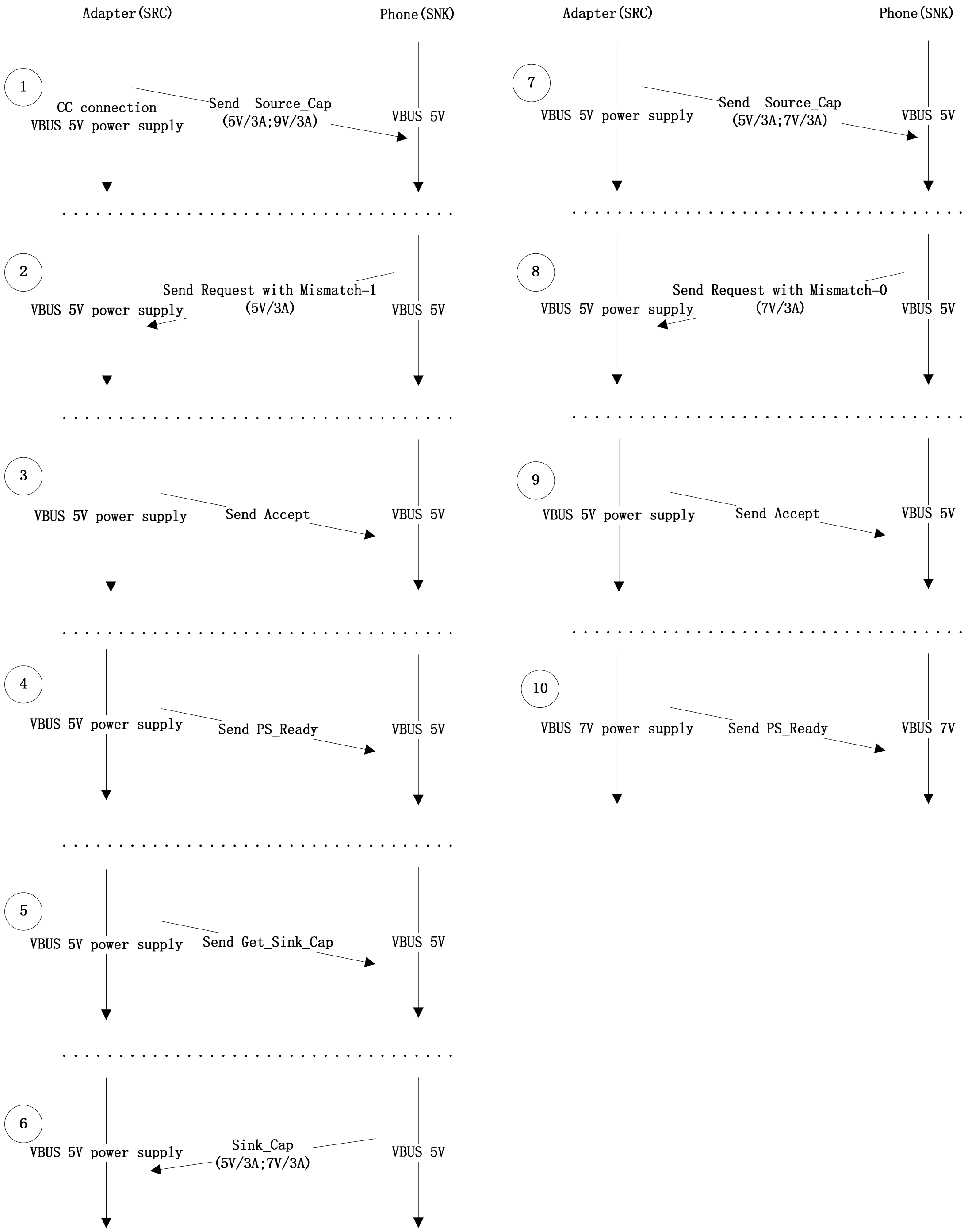


Figure A-1 AnyWatt™ Fixed Supply Power Negotiation

Table A-1 Power Negotiation steps

| Steps | Adapter | Phone |
|---|---|---|
| 1 | The adapter detects a phone attached, turns on VBUS, provides 5V voltage, and sends its default Source_Cap | |
| 2 | | The phone receives the Source_Cap of |

| | | |
|---|---|---|
| | | the adapter and evaluates to find that the Source_Cap is not fully satisfied. So it sends a Request containing Mismatch = 1 to request one of the power |
| 3 | The adapter sends Accept | |
| 4 | The adapter sends PS_Ready | |
| 5 | The adapter detects the Mismatch = 1 in the previous Request of the phone, so it sends Get_Sink_Cap to make out what the phone needs. | |
| 6 | | The phone receives Get_Sink_Cap from the adapter, and replies Sink_Cap to inform the adapter what it need. |
| 7 | The adapter receives the Sink_Cap of the phone and constructes new Source_Cap within its capabilities and sends to the phone | |
| 8 | | The phone receives a new Source_Cap and sends a Request containing Mismatch = 0 |
| 9 | The adapter sends Accept | |
| 10 | The adapter sends PS_Ready | |

During the charging process, the phone will evaluate the voltage of the battery, and initiate new power negotiation when needed. The procedure is shown in Figure A-2 (increasing the voltage).

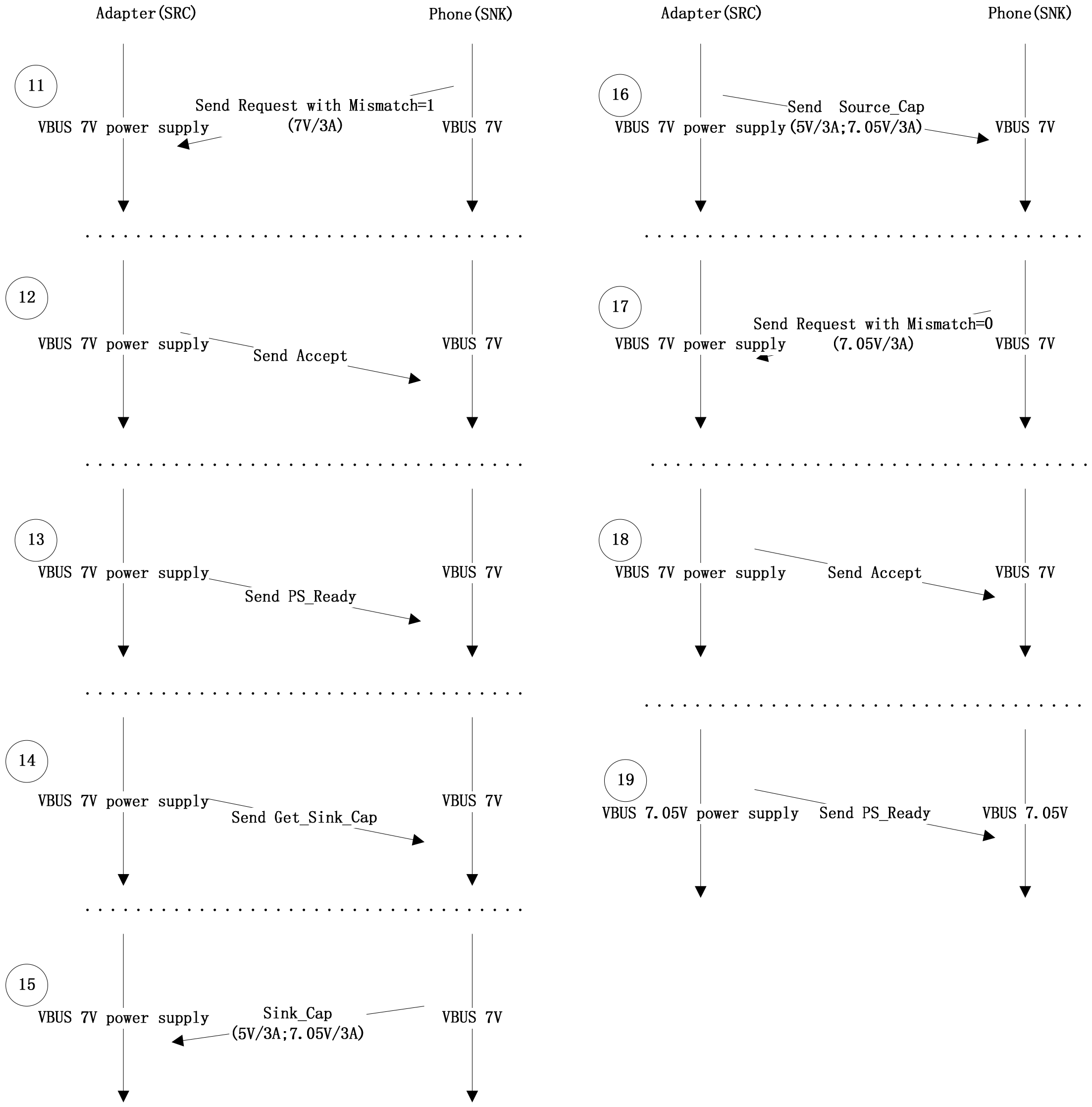


Figure A-2　Phone initiates Power Negotiation

Table A-2　SNK initiates Power Negotiation

| Steps | Adapter | Phone |
|---|---|---|
| 11 | | The phone needs higher voltage to charge its battery, so it sent a Request containing Mismatch = 1. It requests the same power as the last request, but Mismatch bit is different |
| 12 | After the adapter receiving the phone request, it sends Accept immediately because it is the same as the previous request | |
| 13 | The adapter sends PS_Ready immediately | |
| 14 | The adapter detects there is Mismatch = 1 in the previous Request of the phone, and sends Get_Sink_Cap to make out the power that the phone need | |
| 15 | | The phone receives Get_Sink_Cap from the adapter, and replies Sink_Cap to inform the adapter the power it needs. The voltage value increased by 0.05V compared with the last time |
| 16 | After the adapter receiving the Sink_Cap of the phone, it constructs the most suitable Source_Cap in its power supply range and sends to the phone | |
| 17 | | The phone receives a new Source_Cap and sends a Request containing Mismatch = 0 |
| 18 | The adapter sends Accept | |
| 19 | The adapter sends PS_Ready | This dynamic power negotiation is completed |

## Appendix B Example of AnyWatt$^{TM}$ for Direct Charging(Constant Current Mode)

AnyWatt$^{TM}$ technology supports constant current power supply mode and allows the mobile phone charge the battery directly from the adapter during the constant current charging stage of the battery(the pre-charge and constant voltage charging stage is still using the traditional charge management mode).

Figure B-1 and Figure B-2 show the communication process using the AnyWatt$^{TM}$ feature to implement the phone's direct charging.

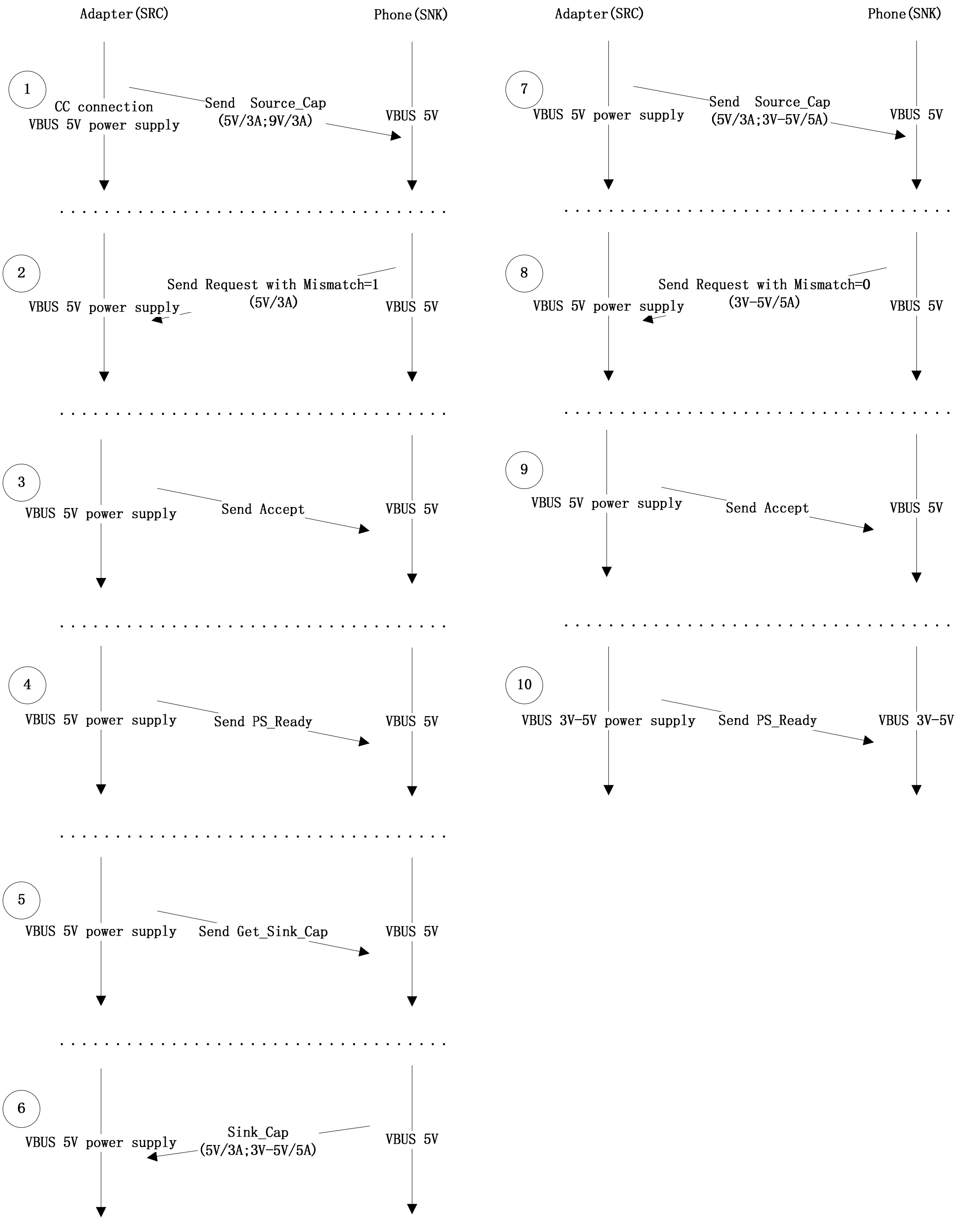


Figure B-1 Variable Supply type Power Negotiation

Figure B-1 corresponds to the steps shown in Table B-1:

Table B-1 Power Negotiation steps

| Steps | Adapter | Phone |
|---|---|---|
| 1 | The adapter detects a phone attached, turns on VBUS and provides 5V voltage and sends default Source_Cap | |
| 2 | | The phone receives the Source_Cap of the adapter, and tries to find whether this source supports constant current mode. So it sends a Request with mismatch=1. |
| 3 | The adapter sends accept | |
| 4 | The adapter sends PS_Ready | |
| 5 | The adapter detects there is Mismatch = 1 in the previous request, so it sends Get_Sink_Cap to make out the power that the phone needs | |
| 6 | | The phone receives Get_Sink_Cap from the adapter, and replied Sink_Cap to inform the adapter what power it needs |
| 7 | The adapter receives the Sink_Cap of the phone and constructs the most appropriate Source_Cap within its capabilities and sends to the phone | |
| 8 | | The phone receives a new Source_Cap which meets its need and sends a Request containing Mismatch = 0 |
| 9 | The adapter sends Accept. | |
| 10 | The adapter sends PS_Ready | |

It can be seen that the communication flow in Figure B-1 shows that the power supply type of the adapter switches from the fixed supply type to the variable supply type according to the requirements of the phone. In fact, the three power supply types can be switched arbitrarily with SNK’s requirements.

Figure B-2 shows the communication process of the phone requests to reduce the current.

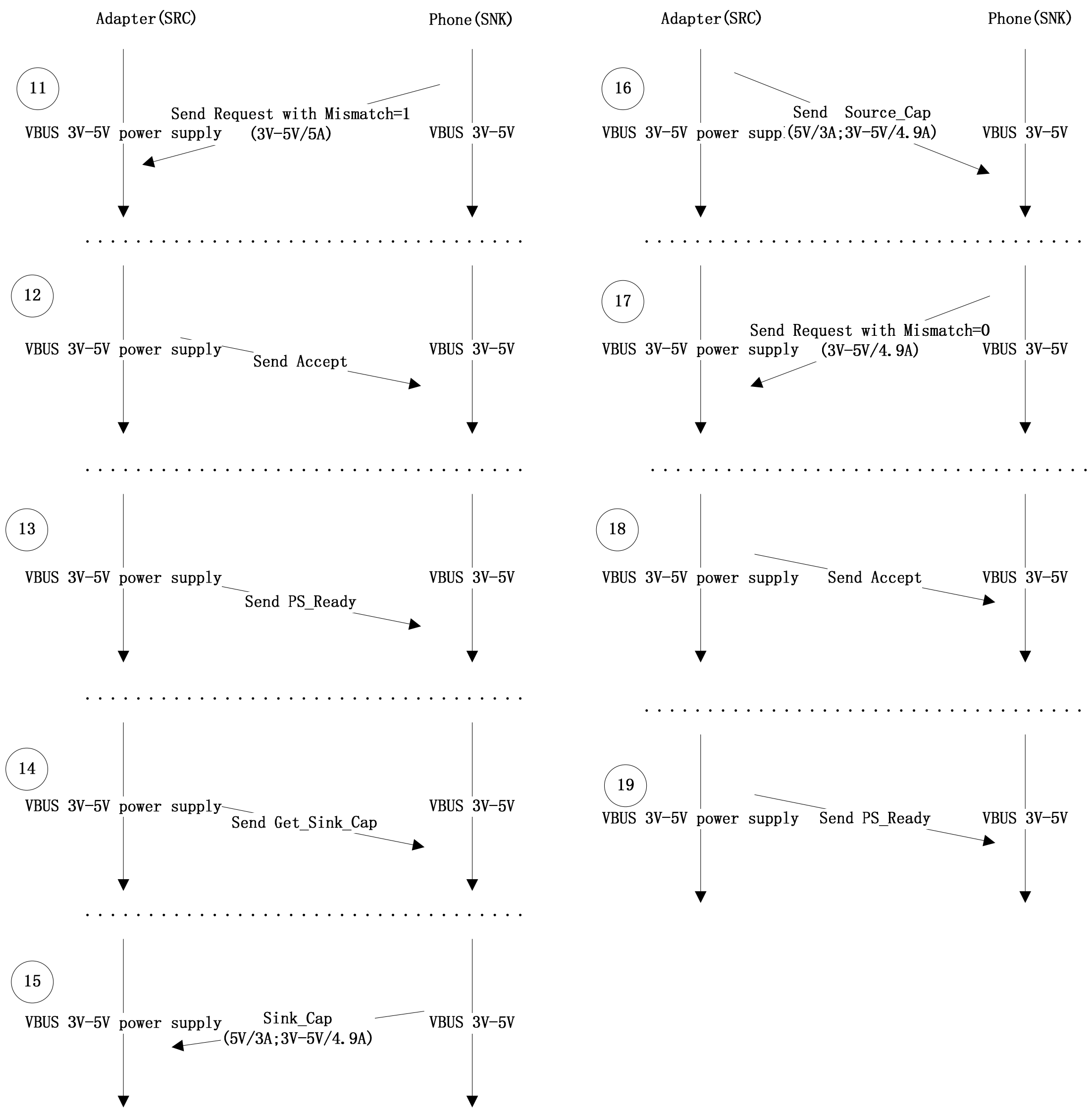


Figure B-2 Phone initiates Power Negotiation

Figure B-2 corresponds to the steps shown in Table B-2:

Table B-2 Phone initiates Power Negotiation

| Steps | Adapter | Phone |
|---|---|---|
| 11 | | Along with the constant current charging process, the voltage of the embedded battery reached its limit, for example 4.35V. At this time, the power management module should try to decrease the charging current. So it initiates a power negotiation process by sending a Request packet the same as previous except mismatch=1 |
| 12 | After the adapter receiving the phone request, it sends Accept immediately because it is the same as the previous request | |
| 13 | The adapter sends PS_Ready | |
| 14 | The adapter detects there is Mismatch = 1 in the Request of the phone, and sends Get_Sink_Cap to | |

| | | |
|---|---|---|
| | make out what the phone needs. | |
| 15 | | The phone receives Get_Sink_Cap from the adapter, and replies Sink_Cap to inform the adapter to decrease the charge current by 100mA. |
| 16 | After the adapter receiving the Sink_Cap of the phone, it constructs a new Source_Cap and sends it to the phone | |
| 17 | | The phone receives a new Source_Cap and sends a Request containing Mismatch = 0 |
| 18 | The adapter sends Accept | |
| 19 | The adapter sends PS_Ready | |