

## RRW30120

USB PD EPR Source Controller with Integrated Secondary-Side Regulation for AC/DC Power

### Description

The RRW30120 is a programmable USB PD controller with Extended Power Range (EPR) support for power source applications. The device integrates a secondary-side regulation controller, interface protocol controller, and USB VBUS NFET driver into a single IC. The RRW30120 supports EPR up to 48 V output voltage.

The RRW30120 has an internal MCU and hardware interface for the USB PD protocol. It allows rapid charge of any USB PD protocol-enabled sink devices such as mobile devices (MDs), notebook PCs (NB), monitors, and power tools. It resides on the secondary side of an AC/DC power supply and configures the adapter for multi-level voltage and current output.

RRW30120 measures the output voltage and load current in real time. The measurement results are sent to a digital compensator for closed-loop control of the power converter. The digital control signal generated by the compensator is converted to an analog signal and transferred to the primary-side controller via an optocoupler.

The RRW30120 is optimized to pair with Renesas's high-power-density QR and ZVS Flyback primary-side controller to achieve high efficiency, low no-load power consumption, accurate voltage/current control, and fast dynamic load response. The RRW30120 also includes the necessary hardware for multi-port power adapter design with minimum BOM cost.

### Features

- Internal MCU with programmable firmware
- Support USB PD3.2 PPS, SPR AVS, EPR AVS, and EPR 48V
- Reprogrammable application parameters
- Onboard programming through Type-C connector
- Built-in digital loop compensation with superior DLR performance to minimize the external component count.
- Adaptive primary switching detection that works with ZVS and QR flyback controllers.
- Optimized to pair with all Renesas primary-side controllers with secondary-side feedback.
- Optimized to pair with all Renesas SR controllers in both high-side and low-side configurations
- Intelligent standby mode enables zero standby power consumption, using Renesas "wattZERO" technology (<5 mW at adapter input) with the lowest system cost when pairing with Renesas primary-side controllers for a typical 65 W+ travel adapter
- Intelligent low-power mode
- Supports tight CV/CC regulation with optional CP mode operation
- NFET driver for VBUS switch
- Internal active fast discharge
- Support peak power mode
- Provide up to five GPIOs
- Built-in master/slave I<sup>2</sup>C controller
- Comprehensive firmware-configurable protection features, including OVP, OTP, OCP, OSP, DPDN/CC1/CC2 OVP, and LPS fault protection.
- Package: QFN16, 4 mm x 4 mm

### Applications

- AC/DC adapters for USB PD-enabled smartphones, tablets, notebook PCs, speakers
- Multi-port chargers
- Power supply for monitors, power tools, ebike and broad industrial applications
- Wall outlets

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# 1. Overview

## 1.1 Block Diagram

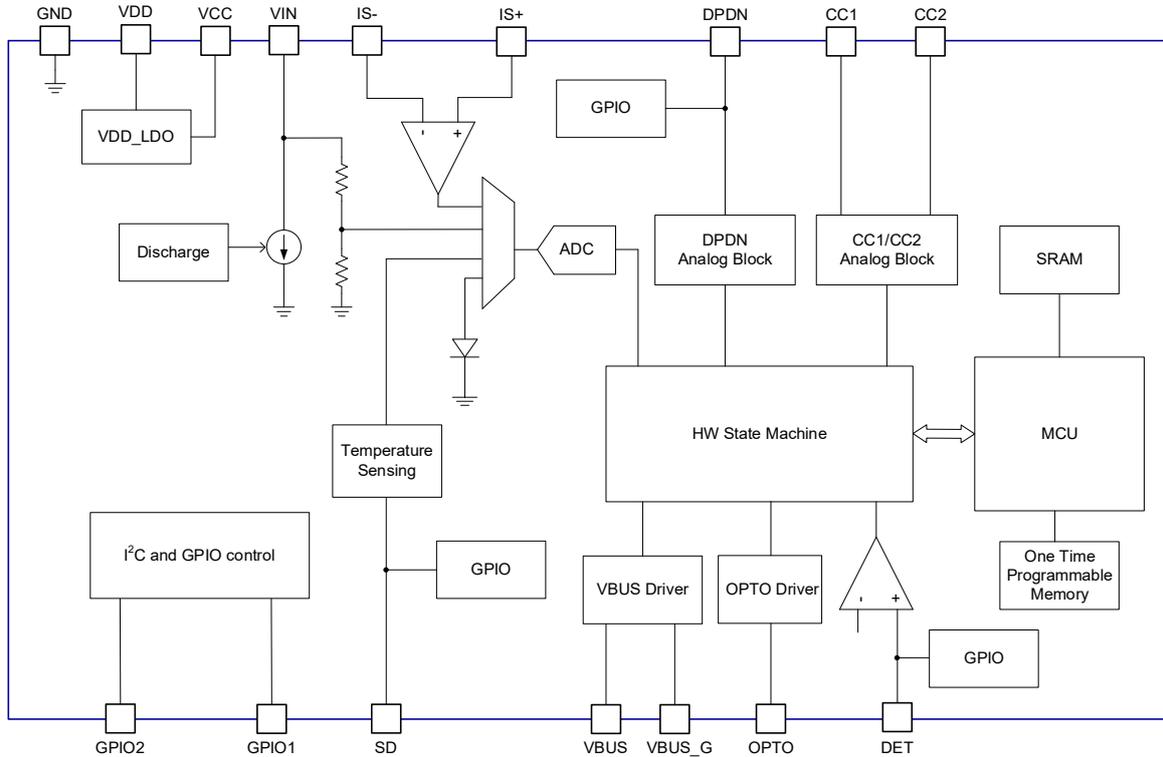


Figure 1. RRW30120 Functional Block Diagram

## 1.2 Typical Application

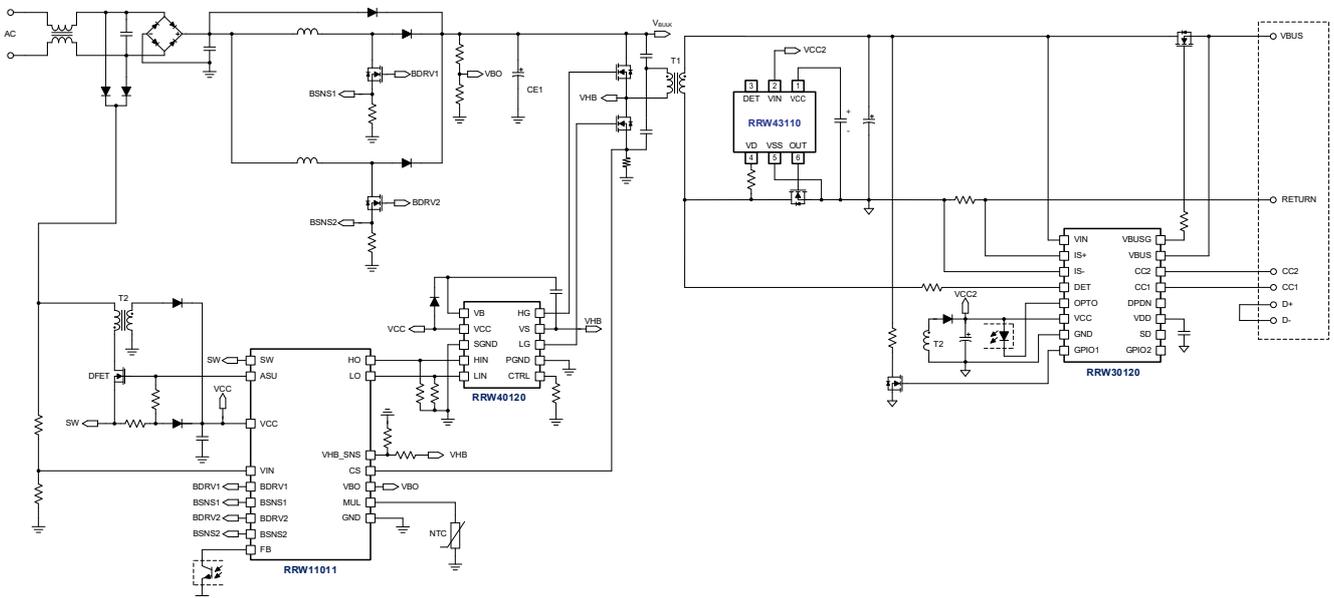


Figure 2. RRW30120 Typical Application Circuit with RRW11011/RRW40120/RRW43110 for USB PD EPR Charger

## 2. Pin Information

### 2.1 Pin Assignments

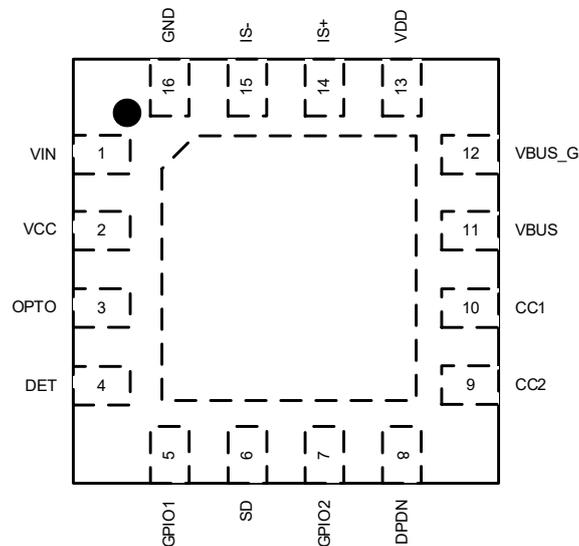


Figure 3. 16-Pin QFN (4 mm x 4 mm) Pinout Diagram (Top View)

### 2.2 Pin Descriptions

Table 1. Pin Descriptions

Pin Number	Pin Name	Type	Description
1	VIN	Analog Input/Output	Output voltage sensing input and discharge
2	VCC	Power	Voltage supply for the IC
3	OPTO	Analog Output	Optocoupler driver
4	DET	Analog Input/Output	Primary-side switching detection. It can also be configured as a GPIO input.
5	GPIO1	Analog Input/Output	GPIO pin. It can also be configured as I2C_SDA.
6	SD	Analog Input/Output	Connect to an NTC for temperature sensing. It can also be configured as a GPIO pin.
7	GPIO2	Analog Input/Output	GPIO pin. It can also be configured as I2C_SCL.
8	DPDN	Analog Input/Output	USB D+/D- signal. It can also be configured as a GPIO pin.
9	CC2	Analog Input/Output	Communication channel 2
10	CC1	Analog Input/Output	Communication channel 1
11	VBUS	Analog Input	Connect to VBUS switch source pin
12	VBUS_G	Analog Output	Gate driver for the external VBUS switch
13	VDD	Power	Digital circuit power supply. Connect to an external 4.7 $\mu$ F capacitor.
14	IS+	Analog Input	Connect to current sensing resistor "+" end
15	IS-	Analog Input	Connect to current sensing resistor "-" end
16	GND	GND	IC ground

### 3. Specifications

#### 3.1 Absolute Maximum Ratings

**Caution:** Do not operate at or near the maximum ratings listed for extended periods of time. Exposure to such conditions can adversely impact product reliability and result in failures not covered by warranty.

Table 2. Absolute Maximum Ratings

Parameter	Symbol	Minimum	Maximum	Unit
VIN DC Supply Voltage Range	$V_{VIN}$	-0.3	60	V
VCC Voltage	$V_{VCC}$	-0.3	32	V
Continuous DC Supply Current at VCC pin ( $V_{VIN} = 21$ V)	$I_{VCC}$	-	10	mA
VDD Voltage	$V_{VDD}$	-0.3	2.5	V
Continuous DC Supply Current at VDD pin ( $V_{VIN} = 4.5$ V)	$I_{VDD}$	-	10	mA
OPTO Voltage	$V_{OPTO}$	-0.3	32	V
DPDN Voltage	$V_{DPDN}$	-0.3	32	V
CC1 Voltage	$V_{CC1}$	-0.3	54	V
CC2 Voltage	$V_{CC2}$	-0.3	54	V
IS+ Voltage	$V_{IS+}$	-0.3	6	V
IS- Voltage	$V_{IS-}$	-0.3	6	V
GPIO1 Voltage	$V_{GPIO1}$	-0.3	6	V
GPIO1 Voltage	$V_{GPIO2}$	-0.3	6	V
SD Voltage	$V_{SD}$	-0.3	6	V
VBUS Voltage	$V_{VBUS}$	-0.7	60	V
VBUS_G Voltage	$V_{VBUS\_G}$	-0.7	65	V
DET Voltage	$V_{DET}$	-0.3	6	V
Junction Temperature	$T_J$	-40	150	°C
Storage Temperature	$T_{STG}$	-65	150	°C

#### 3.2 ESD Ratings

Table 3. ESD Ratings

ESD Model/Test	Rating	Unit
JEDEC JS-001-2017 (CC1/CC2/D+/D- pins)	±4,000	V
JEDEC JS-001-2017 (all other pins)	±2,000	V

#### 3.3 Thermal Specifications

Table 4. Thermal Specifications

Thermal Resistance (Typical)	$\theta_{JA}$ (°C/W)
16-Pin QFN Package	66.9

### 3.4 Recommended Operating Conditions

Table 5. Recommended Operating Conditions

Parameter	Symbol	Minimum	Maximum	Unit
Maximum junction temperature	$T_{J\_MAX}$	-40	+150	°C
Maximum ambient temperature	$T_A$	-40	+85	°C
Voltage on VIN pin	$V_{VIN}$	-	51	V

### 3.5 Electrical Specifications

$V_{VIN} = 5\text{ V}$ ,  $-40\text{ °C} \leq T_A \leq 85\text{ °C}$ , unless otherwise specified.

Table 6. Electrical Specifications

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
<b>VDD Section</b>						
Digital power source	$V_{VDD}$	$I_{LOAD} = 10\text{ mA}$	1.5	1.8	2.15	V
<b>VCC Section</b>						
VCC maximum operation voltage	$V_{VCC\_DC\_MAX}$	-	-		30	V
VCC POR threshold	$V_{VCC\_POR}$	-	2.6	3.14	3.65	V
VCC UVLO threshold	$V_{VCC\_UVLO}$	-	2.4	2.8	3	V
VCC OVP threshold from the comparator	$V_{VCC\_OVP}$	-	29.7	32	32.9	V
IC's operation current when communication is busy <sup>[1]</sup>	$I_{VCC\_BUSY}$	$V_{VIN} = 21\text{ V}$ , $I_{LOAD} = 0$	-	8	-	mA
IC's operation current when communication is idle <sup>[1]</sup>	$I_{VCC\_IDLE}$	$V_{VIN} = 21\text{ V}$ , $I_{LOAD} = 0$	-	2	-	mA
IC's standby current when the sink device is unplugged	$I_{VCC\_STBY}$	With standard Type-C cable	-	100	-	μA
		With Type-C EMC cable	-	170	-	μA
<b>DPDN Section</b>						
Data detection voltage	$V_{DAT\_REF1}$	-	0.38	0.425	0.48	V
DPDN leakage resistance	$R_{DM\_LKG}$	-	-	1	-	MΩ
DNDN OVP threshold <sup>[2]</sup>	$V_{DPDN\_OVP}$	-	-	4.5	-	V
<b>CC1/CC2 Section</b>						
CC TX logic high signal voltage	$V_{CC\_TX\_HIGH}$	-		1.125		V
CC TX logic low signal level	$V_{CC\_TX\_LOW}$	-	-75		75	mV
BMC transmitter output impedance	$Z_{DRIVER}$	-		50		Ω
BMC signal bit rate	$f_{BMC}$	-		300		kbps
CC1 sourcing current <sup>[2]</sup>	$I_{CC1}$	1.5 A @ 5 V	163	180	197	μA
		3.0 A @ 5 V	298	330	362	
CC2 sourcing current <sup>[2]</sup>	$I_{CC2}$	1.5 A @ 5 V	163	180	197	μA
		3.0 A @ 5 V	298	330	362	

$V_{VIN} = 5\text{ V}$ ,  $-40\text{ °C} \leq T_A \leq 85\text{ °C}$ , unless otherwise specified.

**Table 7. Electrical Specifications (Cont.)**

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
R <sub>D</sub> attach detection threshold	V <sub>TH_RD_ATTACH</sub>	CC1/CC2	2.36	2.6	2.83	V
R <sub>A</sub> attach detection threshold	V <sub>TH_RA_ATTACH</sub>	CC1/CC2	0.53	0.56	0.63	V
CC1 OVP threshold	V <sub>CC1_OVP</sub>	-	5.30	5.65	5.95	V
CC2 OVP threshold	V <sub>CC2_OVP</sub>	-	5.30	5.65	5.95	V
<b>VCONN Section</b>						
V <sub>VCONN</sub> voltage <sup>[1]</sup>	V <sub>VCONN</sub>	I <sub>LOAD</sub> = 10 mA, T <sub>A</sub> = 25 °C	3	-	5.5	V
V <sub>VCONN</sub> discharge resistor <sup>[1]</sup>	R <sub>VCONN_DIS</sub>	-	-	1	-	kΩ
<b>VBUS Section</b>						
VBUS discharge current	I <sub>VBUS_DIS</sub>	-	1.5	-	-	mA
VBUS leakage impedance <sup>[1]</sup>	R <sub>VBUS_LKG</sub>	VBUS switch off,	72.4	-	-	kΩ
V <sub>SAFE_OV</sub> threshold	V <sub>SAFE_OV</sub>	Falling edge	0.5	0.6	0.7	V
<b>VBUS_G Section</b>						
VBUS_G to VBUS regulation range	V <sub>GS</sub>	I <sub>GATE</sub> = 110 μA	-	6.9	-	V
VBUS_G to VBUS resistor	R <sub>GS</sub>		-	2000	-	kΩ
<b>VIN Section</b>						
VIN maximum operation voltage	V <sub>VIN_DC_MAX</sub>	-	-	-	51	V
VIN OVP threshold from the comparator	V <sub>VIN_OVP</sub>	-	-	55	-	V
VIN under voltage threshold to turn off the VBUS switch	V <sub>VIN_LOW</sub>	-	3.15	3.5	3.75	V
Internal maximum discharge current	I <sub>DIS_MAX</sub>	-	-	150	-	mA
<b>SD Section</b>						
SD pin maximum sourcing current	I <sub>SD_HIGH</sub>		94.5	100	103.5	μA
<b>ADC Section</b>						
VIN sensing range <sup>[1]</sup>	V <sub>VIN_RANGE</sub>	-	2.8	-	52	V
VIN sensing tolerance	V <sub>VIN_TOL</sub>	T <sub>A</sub> = 25 °C	-	2	-	%
I <sub>SENSE</sub> sensing current range <sup>[1]</sup>	I <sub>SENSE_RANGE</sub>	R <sub>SENSE</sub> = 5 mΩ, ADC buffer gain = 40	0	-	9	A
		R <sub>SENSE</sub> = 5 mΩ, ADC buffer gain = 20	0	-	18	A
I <sub>SENSE</sub> sensing tolerance	I <sub>SENSE_TOL</sub>	R <sub>S</sub> = 5 mΩ, I <sub>LOAD</sub> = 3 A, T <sub>A</sub> = 25 °C	-	3	-	%
NTC temperature sensing range	T <sub>SD_RANGE</sub>	-	0	-	150	°C
NTC temperature sensing tolerance	T <sub>SD_TOL</sub>	T <sub>A</sub> = 120 °C	-	3	-	°C

V<sub>VIN</sub> = 5 V, -40 °C ≤ T<sub>A</sub> ≤ 85 °C, unless otherwise specified. (Cont.)

Table 8. Electrical Specifications (Cont.)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
IC junction temperature sensing range	T <sub>J_RANGE</sub>	-	0	-	150	°C
IC junction temperature sensing tolerance	T <sub>J_TOL</sub>	-	-10	-	10	°C
T <sub>J</sub> OTP threshold [2]	T <sub>J_OTP</sub>	-	-	140	-	°C
<b>DET Section</b>						
DET pull-down resistor	R <sub>DET_PD</sub>	-	18	20.5	23	kΩ
<b>OPTO Section</b>						
Maximum OPTO drive current [1]	I <sub>OPTO_MAX</sub>	-	-	4	-	mA
<b>GPIO Section</b>						
GPIO V <sub>CC</sub>	V <sub>CC_GPIO</sub>	I <sub>LOAD</sub> = 5 mA	-	3.3	-	V
GPIO1 logic high output	V <sub>OH_GPIO1</sub>	I <sub>LOAD</sub> = 3 mA, T <sub>A</sub> = 25 °C	-	3.3	-	V
GPIO1 logic low output	V <sub>OL_GPIO1</sub>	I <sub>LOAD</sub> = 3 mA, T <sub>A</sub> = 25 °C	-	-	0.3	V
GPIO2 logic high output	V <sub>OH_GPIO2</sub>	I <sub>LOAD</sub> = 3 mA, T <sub>A</sub> = 25 °C	-	3.3	-	V
GPIO2 logic low output	V <sub>OL_GPIO2</sub>	I <sub>LOAD</sub> = 3 mA, T <sub>A</sub> = 25 °C	-	-	0.3	V
GPIO1 RX threshold (low to high)	V <sub>RX_GPIO1_L2H</sub>	T <sub>A</sub> = 25 °C	1.75	1.9	2.15	V
GPIO1 RX threshold (high to low)	V <sub>RX_GPIO1_H2L</sub>	T <sub>A</sub> = 25 °C	1.6	1.85	2.1	V
GPIO2 RX threshold (low to high)	V <sub>RX_GPIO2_L2H</sub>	T <sub>A</sub> = 25 °C	1.75	1.9	2.15	V
GPIO2 RX threshold (high to low)	V <sub>RX_GPIO2_H2L</sub>	T <sub>A</sub> = 25 °C	1.6	1.85	2.1	V
GPIO1 RX input impedance	R <sub>RX_IN_GPIO1</sub>	T <sub>A</sub> = 25 °C	1	-	-	MΩ
GPIO2 RX input impedance	R <sub>RX_IN_GPIO2</sub>	T <sub>A</sub> = 25 °C	1	-	-	MΩ
GPIO1 weak pull-up resistor	R <sub>PU_GPIO1</sub>	T <sub>A</sub> = 25 °C	-	10	-	kΩ
GPIO2 weak pull-up resistor	R <sub>PU_GPIO1</sub>	T <sub>A</sub> = 25 °C	-	10	-	kΩ
SD logic high output	V <sub>OH_SD</sub>	I <sub>LOAD</sub> = 3 mA, T <sub>A</sub> = 25 °C	-	3.3	-	V
SD logic low output	V <sub>OL_SD</sub>	I <sub>LOAD</sub> = 3 mA, T <sub>A</sub> = 25 °C	-	-	0.3	V

$V_{VIN} = 5\text{ V}$ ,  $-40\text{ °C} \leq T_A \leq 85\text{ °C}$ , unless otherwise specified. (Cont.)

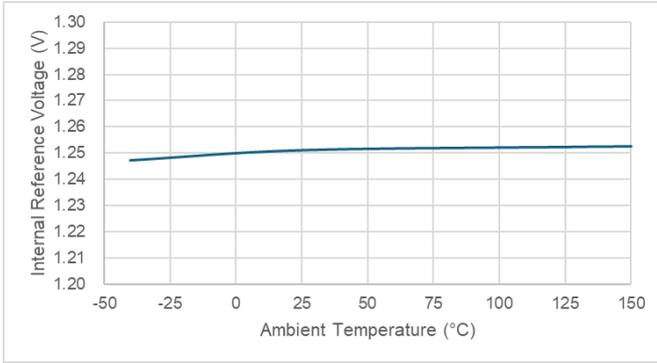
**Table 9. Electrical Specifications (Cont.)**

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
SD weak pull-up resistor	$R_{UP\_SD}$	$T_A = 25\text{ °C}$	-	10	-	k $\Omega$
SD RX input impedance	$R_{RX\_IN\_SD}$	$T_A = 25\text{ °C}$	1	-	-	M $\Omega$
SD RX threshold (low to high)	$V_{RX\_SD\_L2H}$	$T_A = 25\text{ °C}$	1.75	1.9	2.15	V
SD RX threshold (high to low)	$V_{RX\_SD\_H2L}$	$T_A = 25\text{ °C}$	1.6	1.85	2.1	V
DPDN RX input impedance	$R_{RX\_IN\_SD}$	$T_A = 25\text{ °C}$	1	-	-	M $\Omega$
DPDN RX logic high threshold (low to high)	$V_{RX\_DN\_L2H}$	$T_A = 25\text{ °C}$	-	1.9	-	V
DPDN RX logic low threshold (high to low)	$V_{RX\_DN\_H2L}$	$T_A = 25\text{ °C}$	-	1.85	-	V
DPDN pull-down resistor	$R_{DN\_DPDN}$	$T_A = 25\text{ °C}$	-	1	-	k $\Omega$
DET RX threshold (low to high) <sup>[1]</sup>	$V_{RX\_DET\_L2H}$	$T_A = 25\text{ °C}$	-	1.2	-	V
DET RX threshold (high to low) <sup>[1]</sup>	$V_{RX\_DET\_L2H}$	$T_A = 25\text{ °C}$	-	1.15	-	V

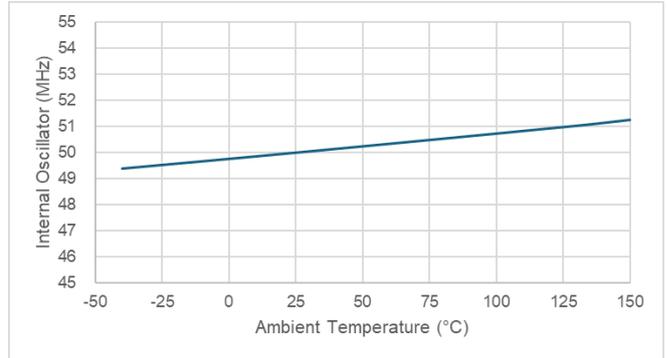
1. These parameters are not 100% tested. They are guaranteed by design.
2. Value used depends upon specific product option.

## 4. Typical Performance Graphs

V<sub>CC</sub> = 5 V



**Figure 4. Internal Reference Voltage vs. Ambient Temperature**



**Figure 5. Internal Clock Frequency vs. Ambient Temperature**

## 5. Functional Description

The RRW30120 is a programmable USB PD source controller for AC/DC adapters. The RRW30120 can interface with sink devices that support USB-PD protocol. It is also backward compatible with USB BC1.2 compliant devices to provide a 5 V output by default setting. After the initial detection stage, based on the CC1/CC2 signal voltage from the sink device, the RRW30120 interprets it to be a USB PD device and reads its associated output voltage/current requests. When RRW30120 receives a valid voltage/current request, it adjusts the voltage/current target of the control loop accordingly to regulate the output voltage/current to the requested level. The RRW30120 features a built-in digital compensator for output voltage/current regulation. It eliminates the need for external compensation resistors and capacitors. The output voltage and current are sampled by a 10-bit ADC and fed into the digital compensator. The digital compensator generates the error signal by comparing the requested voltage/current from the sink device to the actual output voltage/current. The digital compensator generates an output regulation control signal based on the error signal and feeds it to the optocoupler driver. The optocoupler driver converts the output regulation control signal to a driving current at the cathode of the optocoupler input side to send the signal to the primary controller.

The RRW30120 also monitors the real-time output voltage and current and internal IC temperature or external temperature to provide protection when over-voltage, over-current, and over-temperature conditions occur. The RRW30120 also features a programmable active discharging function to discharge the output capacitor quickly after a request for a lower voltage or an unplugging of the sink device.

The RRW30120 can be paired with Renesas' high-performance primary-side controllers and supports ZVS and QR solutions to achieve high efficiency, low no-load power consumption, accurate voltage/current control, and fast dynamic load response. When pairing with specific Renesas primary-side controllers, the AC/DC adapter designed with the RRW30120 can achieve less than 5 mW standby power consumption when a sink device is detached.

The RRW30120 also includes multiple GPIOs that can be configured to support multi-port power adapters and other applications, such as monitors and power tools.

The RRW30120 can also be used in notebook adapters with peak current support and low IC operation current.

### 5.1 Pin Detail

#### 5.1.1 Pin 1 – VIN

Sense and discharge the output voltage.

#### 5.1.2 Pin 2 – VCC

Voltage supply for the IC power.

#### 5.1.3 Pin 3 – OPTO

Optocoupler driver output. It is a current sink controlled by the digital compensator.

#### 5.1.4 Pin 4 – DET

Primary-side switching detection from the transformer's secondary-side winding active node. It can also be configured as a GPIO pin.

#### 5.1.5 Pin 5 – GPIO1

General purpose input/output pin 1. It can be configured as an I2C\_SCA.

#### 5.1.6 Pin 6 – SD

Connect to an external NTC to measure temperature. It can also be configured as a GPIO pin.

#### 5.1.7 Pin 7 – GPIO2

General purpose input/output pin 2. It can be configured as an I2C\_SCL.

### 5.1.8 Pin 8 – DPDN

USB D+/D- signal for BC1.2 detection. It can also be configured as a GPIO pin.

### 5.1.9 Pin 9 – CC2

USB Type-C configuration channel pin 2. Used for sink device attach/detach detection and PD communication.

### 5.1.10 Pin 10 – CC1

USB Type-C configuration channel pin 1. Used for sink device attach/detach detection and PD communication.

### 5.1.11 Pin 11 – VBUS

Connect to VBUS switch source pin to monitor VBUS voltage. It is used for VBUS switch control.

### 5.1.12 Pin 12 – VBUS\_G

Connect to the external N-FET gate pin for the VBUS switch gate-source voltage control.

### 5.1.13 Pin 13 – VDD

IC digital power supply. Connect a 4.7  $\mu$ F capacitor from this pin to the ground.

### 5.1.14 Pin 14 – IS+

Output current sensing resistor + terminal.

### 5.1.15 Pin 15 – IS-

Output current sensing resistor - terminal.

### 5.1.16 Pin 16 – GND

IC ground.

## 5.2 Initialization and Handshaking with the Primary-Side Controller

An AC/DC power adapter, designed with a Renesas primary-side PWM controller and the RRW30120, starts up initially at a default 5 V state. During startup, before the VCC voltage of the RRW30120 reaches  $V_{VCC\_POR}$ , the optocoupler driver of the RRW30120 is turned off. The Renesas primary-side PWM controller controls the power adapter output voltage ramping independently.

When the RRW30120's VCC pin reaches  $V_{VCC\_POR}$ , it starts the initialization and monitors the output voltage at the VIN pin. The optocoupler driver's sink current is adjusted to ramp up the output voltage to the default voltage smoothly.

## 5.3 CC1/CC2 Attach/Detach Detection and VBUS Control

The VBUS switch is off initially upon powering up the AC/DC adapter. After the VCC pin voltage reaches  $V_{VCC\_POR}$ , both CC1 and CC2 are connected to an internal voltage source through two 56 k $\Omega$  resistors. The CC1 and CC2 voltages are compared with  $V_{TH\_RD\_ATTACH}$  to detect if the sink device or cable is attached. The sink device and/or cable attach will cause the CC1 and/or CC2 voltage to be lower than  $V_{TH\_RD}$ . Once the sink device and/or cable attachment is detected, the RRW30120 will apply  $I_{CC1}$  and  $I_{CC2}$  on CC1 and CC2 simultaneously to determine if CC1 and CC2 are connected to  $R_D$  (5.1 k $\Omega$  to GND inside the sink device) or  $R_A$  (1 k $\Omega$  to GND inside cable) by comparing CC1/CC2 voltage with  $V_{TH\_RD\_ATTACH}$  and  $V_{TH\_RA\_ATTACH}$ . The VBUS switch will turn on after 150 ms if the following three conditions are met:

1.  $V_{VBUS}$  is less than  $V_{SAFE\_OV}$
2.  $V_{VIN}$  is 5 V
3. Only one of CC1 and CC2 connects to  $R_D$ , and the other one connects to  $R_A$  or open

After the VBUS switch turns on, the RRW30120 determines which of the two currents,  $I_{CC1}$  or  $I_{CC2}$ , that was previously applied to CC1 and CC2, respectively, was connected to  $R_A$  (or open) and will turn off that current source. The remaining  $I_{CC1}$ / $I_{CC2}$  is only applied to the CC pin connecting with  $R_D$  to detect the detachment of the sink device. If the sink device is detached, the CC1 or CC2 voltage initially connected with  $R_D$  will be higher than  $V_{TH\_RD}$  to indicate the sink device is detached. The VBUS switch will thus turn off, and  $V_{VBUS}$  will be discharged through  $I_{DIS}$  if  $V_{VBUS} > V_{SAFE\_OV}$ . At this point, the Renesas primary-side PWM controller and the RRW30120 will change the output voltage (and  $V_{VIN}$  of the RRW30120) to the default 5 V level if it is not already 5 V. The current limit will be set to the default level per product option. To start a new attach detection cycle, two 56 k $\Omega$  resistors will be reconnected to CC1/CC2 from the internal voltage source.

### 5.4 Protocol Initialization and Handshaking

When the power adapter is connected to the sink device and the VBUS switch is on, the RRW30120 begins the protocol detection procedure. The RRW30120 sends out USB PD Source\_Capabilities messages via the CC pin (either CC1 or CC2, whichever pin is connected to  $R_D$ ) and waits for the sink device's response to make a PD explicit contract. If PD protocol is not detected after about 7.5 s, the RRW30120 will stop sending Source\_Capabilities. After that, if a PD hard reset message is received, the RRW30120 will disable the VBUS switch for 0.85 s and enable the VBUS switch again at the default output voltage of 5 V and default current and start the PD detection procedure again as described previously. [Figure 6](#) shows the flowchart for a power adapter's handshake sequence using the RRW30120.

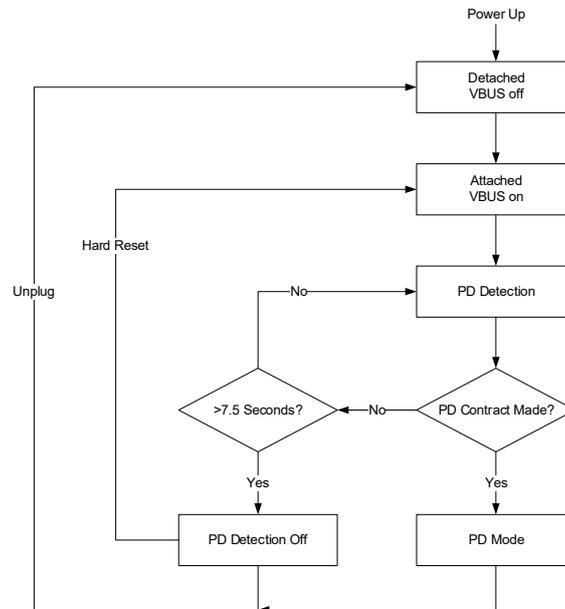


Figure 6. Hand-Shake Flowchart

### 5.5 ADC

The RRW30120 integrates a 10-bit ADC for accurate output voltage, current, and internal/external temperature measurement. The ADC input is from  $V_{IN}$ ,  $IS+/IS-$ ,  $SD$ , and internal junction diode.

$V_{OUT}$  sensing is done through the  $V_{IN}$  pin, with a  $V_{OUT}$  range of 2.8 V to 51 V at 20 mV resolution. An external  $R_{IN}/C_{IN}$  filter may be added to  $V_{IN}$  to improve noise immunity.  $R_{IN}$  can be configured by the IC option as 0  $\Omega$ /1  $\Omega$ /2  $\Omega$ . The typical value for  $C_{IN}$  is 1  $\mu F$ , see [Figure 7](#).

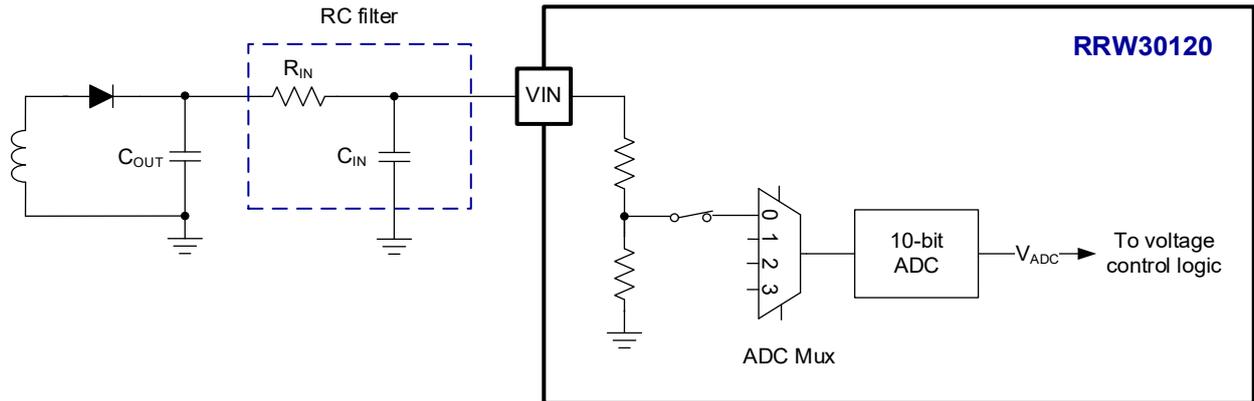


Figure 7. Sensing with an External RC Filter

Output current is measured by the voltage across the sensing resistor connected to IS+/IS-. The RRW30120 can support a wide current range by a programmable current amplifier and supports a wide range of sensing resistors from 0.5 mΩ to 15.5 mΩ with 0.5 mΩ step.

An NTC thermistor connected to the SD pin measures temperature. The NTC's R<sub>25</sub> and B values are programmable, and the temperature measurement range is from 0 °C to 150 °C.

The ADC also measures the IC's junction temperature for over-temperature protection.

## 5.6 Output Voltage and Current Regulation

The RRW30120 monitors the output voltage by reading the VIN pin voltage through a 10-bit ADC. The same ADC is also used to monitor the voltage across the current sensing resistor for output current sensing. The output voltage/current information from the ADC is fed to the digital compensator for control loop regulation control. The digital compensator compares the output voltage/current with the regulation target. The voltage regulation target at startup slowly ramps up and stays at the default voltage at the end of the startup. The current limit at startup is set at the default current. After startup, RRW30120 may adjust the voltage target and current limit according to a valid request from the sink device.

The RRW30120 decides the output regulation mode based on the voltage/current information. If the load is in the normal range, the RRW30120 maintains a constant output voltage (CV) based on the regulation target. If the load current increases beyond the acceptable range specified by the sink device, the RRW30120 transitions to constant current (CC) mode, in which it maintains a constant output current determined by the sink device and allows the output voltage to drop depending on the loading.

In either regulation mode, the RRW30120 compares the output voltage/current to the regulation target, and the difference is sent to the digital compensator to generate the proper control signal. The built-in optocoupler driver of the RRW30120 converts the control signal to a proper level of current going through the diode side of the optocoupler. Renesas' primary-side PWM controller receives this control signal through the BJT side of the optocoupler and controls the primary switch(es) accordingly to complete the closed-loop regulation.

## 5.7 Voltage Transition and Discharge

When a higher voltage request is confirmed, the RRW30120 slowly ramps the internal reference to the target to avoid a significant overshoot. Similarly, when a lower voltage request is confirmed, the RRW30120 slowly ramps down the internal reference to prevent a big undershoot.

Discharge of the output capacitor is necessary for a quick voltage transition from a higher level to a lower level when the load is light. An internal current source between the VIN pin and GND pin is turned on to provide a current path to discharge. The discharge current is programmable up to 150 mA. Discharge stops when the target voltage is reached to avoid excess load current and high-power dissipation inside the IC.

## 5.8 GPIO

The RRW30120 has five GPIO pins, GPIO1, GPIO2, SD, DPDN, and DET, that can be used as input and output in various configurations with a logic level of 3.3 V.

- GPIO1/GPIO2/SD are full-functional GPIO pins
- GPIO TX can be configured as push-pull, open-drain, and weak pull-up
- GPIO logic level: 3.3 V
- One built-in hardware I<sup>2</sup>C master, SCL/SDA = GPIO2/GPIO1

Below is the pin assignment of the GPIO functions.

**Table 10. GPIO Pin Assignment**

Pin Name	Pin Type	Pin Function
GPIO1	I/O	Full-function GPIO, I2C_SDA
GPIO2	I/O	Full-function GPIO, I2C_SCL
SD	I/O	Full-function GPIO
DPDN	I/O	GPIO RX and TX with open-drain output
DET	I/O	GPIO RX only

## 5.9 Low-Power Mode and Standby Mode

After startup, the RRW30120 works with an operating current of  $I_{VCC\_BUSY}$ . If the communication with the sink device is idle for a specific time, it will enter the low-power mode with an operating current of  $I_{VCC\_IDLE}$ . When a new message arrives, RRW30120 wakes up and enters Normal mode again.

If the sink is detached for a certain time, the RRW30120 enters Standby mode. In Standby mode, the  $I_{VCC}$  is about 100  $\mu$ A with a standard Type-C cable and about 170  $\mu$ A with a Type-C EMC cable attached.

## 5.10 Protection

### 5.10.1 Over-Voltage/Over-Current Protection

The RRW30120 uses the sampled voltage/current information for over-voltage and over-current detection. If the output voltage exceeds the programmable over-voltage threshold, default at 2 V above the target, the RRW30120 enters the fault state. Besides the ADC-based over-voltage protection (OVP), RRW30120 has an additional comparator-based OVP. In the RRW30120 application, as shown in [Figure 2](#), VIN\_OVP comparator will flip if  $V_{OUT}$  is higher than  $V_{VIN\_OVP}$ . VCC\_OVP fault will trigger if the voltage exceeds  $V_{VCC\_OVP}$ . In the fault state, the RRW30120 disables the VBUS switch and resets the power adapter to the default voltage.

In the over-current condition (OCP), the output voltage drops since the control loop clamps the output current. If the output voltage drops below a certain level, known as the CC shutdown voltage, the RRW30120 turns off the VBUS switch and resets the power adapter to the default 5 V.

### 5.10.2 Output Short Protection (OSP)

After the sink device is attached to a Type-C connector, the RRW30120 enables the VBUS NFET switch after 150 ms. If the VBUS switch turns on into output short, the output capacitor discharges. The output short is detected when VBUS discharges below a threshold ( $V_{VIN\_LOW}$ ). The RRW30120 disables the VBUS switch immediately to limit the current output and resets the power adapter to default 5 V.

### 5.10.3 DPDN/CC1/CC2 Over-Voltage Protection

The RRW30120 features DPDN over-voltage protection, which addresses soft short issues in the output cables and connectors and protects against damage. If the DPDN pin voltage is above  $V_{DPDN\_OVP}$ , the DPDN OVP fault is triggered. The CC1 and CC2 voltages are also monitored after the IC power-up. If the voltage on the CC1 or

CC2 pin is above  $V_{CC1\_OVP}$  or  $V_{CC2\_OVP}$ , the CC1/CC2 OVP fault is triggered. When the RRW30120 detects a DPDN/CC1/CC2 OVP, the VBUS switch turns off, and the power adapter will reset to the default voltage.

#### **5.10.4 Over-Temperature Protection (OTP)**

The RRW30120 has two sources for over-temperature protection. One is from the IC's internal junction temperature. The SD pin can provide another OTP function when an NTC resistor is connected between SD and GND. An internal  $I_{SD}$  current flows through the NTC, and the internal ADC measures the NTC resistor voltage  $V_{SD}$  on the SD pin. The RRW30120 determines the NTC resistor  $R_{SD}$  value by calculating  $V_{SD}/I_{SD}$ . The NTC temperature  $T_{SD}$  is calculated by:

$$T = \frac{1}{\left[ \frac{1}{298.15} + \frac{1}{B} \times \ln\left(\frac{R_{SD}}{R_{25}}\right) \right]}$$

B is the material factor, and R25 is the resistance of the NTC device at 25 °C. The RRW30120 constantly monitors the NTC temperature. If the NTC temperature exceeds the programmable OTP threshold, the RRW30120 enters the fault state by turning off VBUS and resetting the power adapter to the default voltage. The B value, R25, and OTP threshold are all programmable.

The RRW30120 also monitors the IC's junction temperature. If the IC's junction temperature is higher than  $T_{J\_OTP}$ , the RRW30120 disables the VBUS switch, resets the power adapter to the default voltage, and informs the primary side to shut down the power adapter.

## 6. Package Outline Drawings

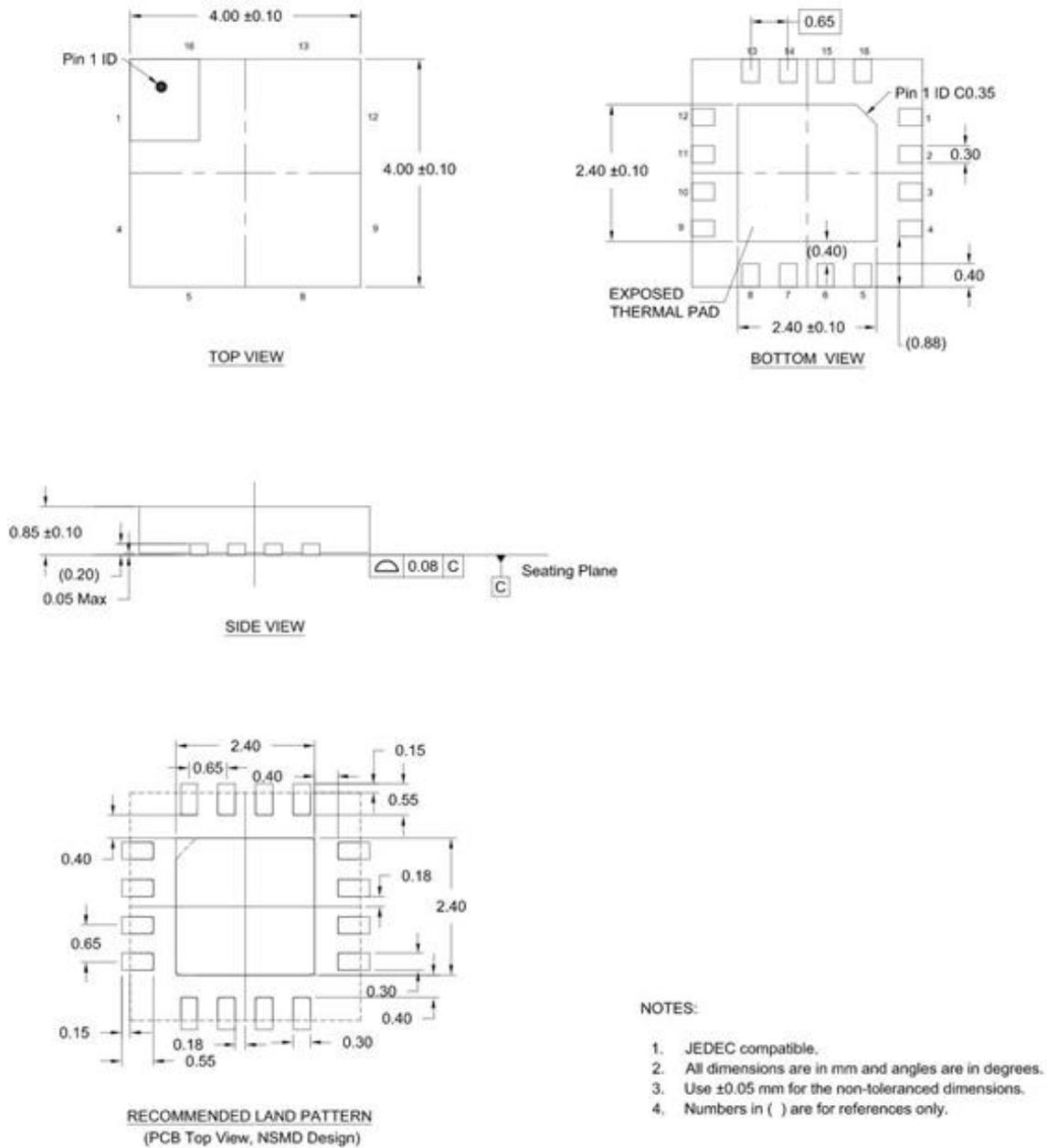


Figure 8. 16-Pin QFN (4 mm x 4 mm) Package

## 7. Ordering Information

Part no.	Date Description		Package	Description
	PDO/APDO	Output power		
RRW30120-XXX	TBD	TBD	QFN-16	Tape & Reel <sup>1</sup>

Note 1: Tape & Reel packing quantity is 3,000/reel. Minimum packing quantity is 3,000.

## 8. Revision History

Revision	Date	Description
1.0	Oct 07, 2025	Initial release.

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