

## Wide Input Range CV/CC/CP Step-Down Converter for Quick Charge 3.0™

### General Description

The NT3885 is a synchronous-rectified step-down converter capable of delivering 3A output current and 3.6V~12V output voltage, dedicatedly designed for CLA applications. Integrated 30mW MOSFETs enables high efficiency and minimizes thermal loading. The NT3885 is designed to work with a wide supply voltage range from 9V to 30V.

The NT3885 integrates smart DP/DM interface that complies with Qualcomm® Quick Charge™ 3.0 specification. The output voltage is adjustable through Quick Charge™ 3.0 protocol. It also features constant current operation ( $V_{OUT} < 7V$  typ.) and constant power operation ( $V_{OUT} > 7V$  typ.), fulfilling power profile requirement of Qualcomm® Quick Charge™ 3.0. The external compensation makes feedback control have good line and load regulation with flexible external design.

The NT3885 features input over voltage, output over voltage, output under voltage and over temperature protections. It is available in WDFN5x6-14L package.

### Applications

- Car Chargers
- Portable Charging Devices
- High-Brightness Lightings
- General-Purposed DC/DC Converters with Current Limit

### Ordering Information

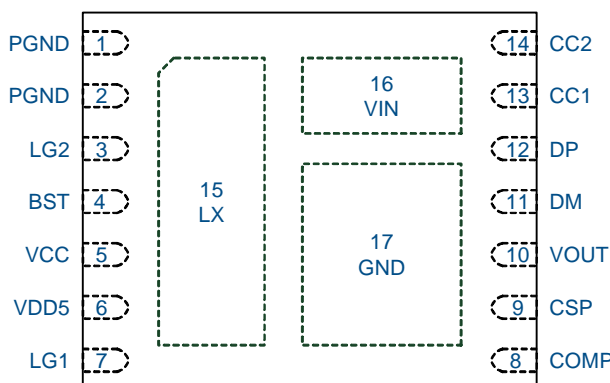
Order Number	Package	Top Marking
NT3885ADEC	WDFN5x6-14L	NT3885A

Note: EOSMEM products are compatible with the current IPC/JEDEC J-STD-020 requirement. They are halogen-free, RoHS compliant and 100% matte tin (Sn) plating that are suitable for use in SnPb or Pb-free soldering processes.

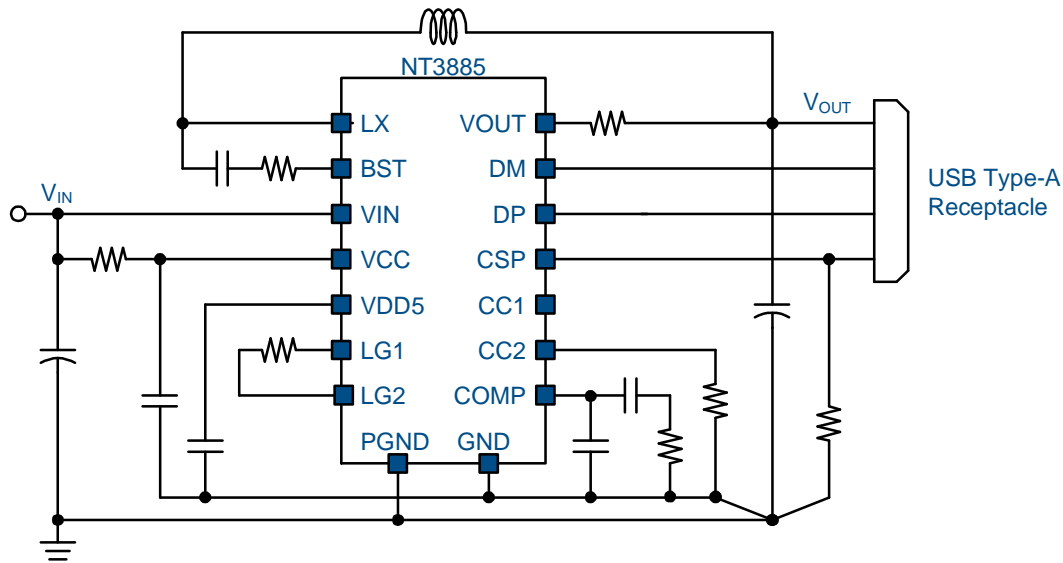
### Features

- High Efficiency Power Conversion
  - n Integrate 30mW Switches
  - n Capable of Delivering 3A Output Current
  - n 125kHz Fixed Frequency Operation
  - n 0%~95% Duty Cycle
  - n 1% Output Voltage Accuracy Over Line
  - n 5% Constant Current Accuracy
  - n 3.6V~12.0V Adjustable Output Voltage
  - n Cable Compensation
- Smart USB Charger Identification Circuit
  - n Compliant with Quick Charge 2.0/3.0 Class A
  - n Support Apple 2.4A Applications
  - n Support BC1.2 & YD/T 1591 Battery Charging Specifications
- CC/CP Power Profile
- Comprehensive Protections
  - n Input Over Voltage Protection
  - n Output Over Voltage Protection
  - n Output Under Voltage Protection
  - n Over Temperature Protection
  - n Output Voltage Discharge Function
- DFN5x6-14L Package
- RoHS Compliant and Halogen-Free

### Pin Configuration



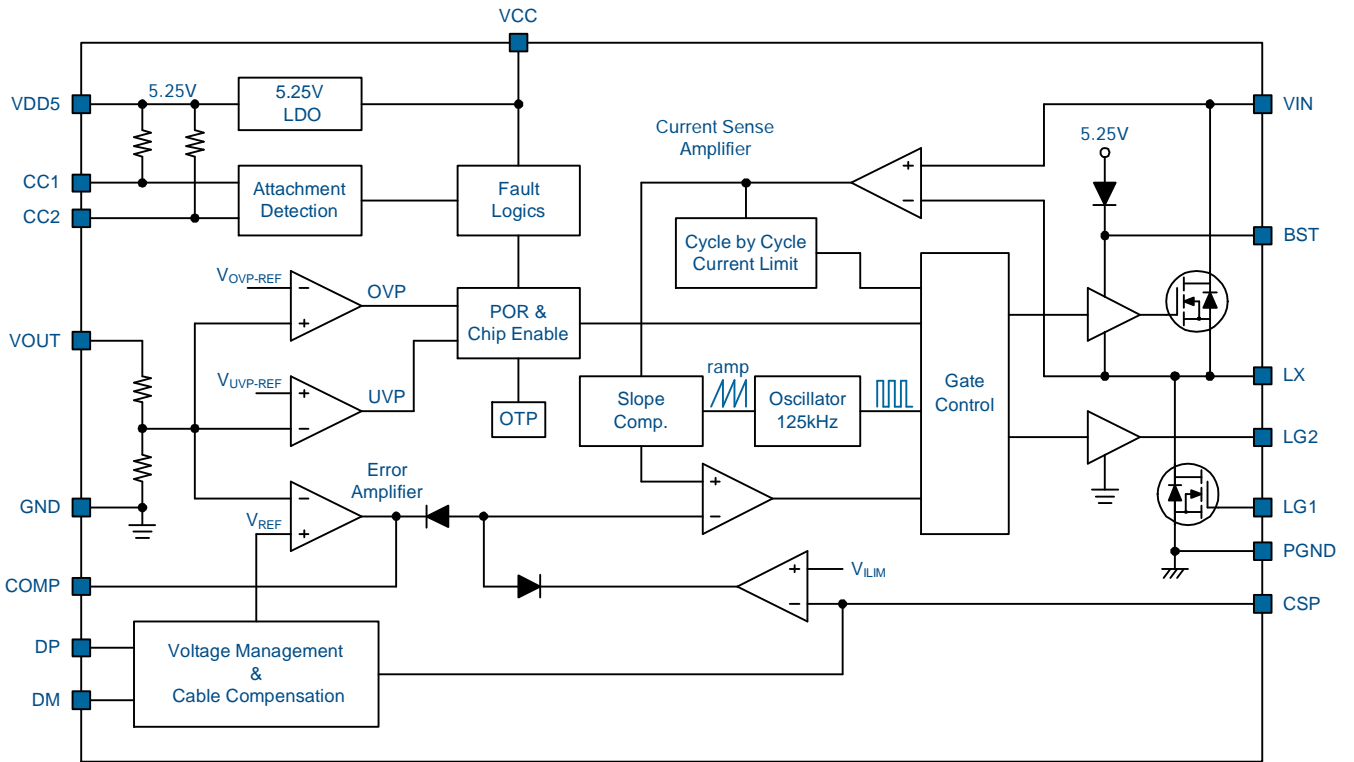
Typical Application Circuit



Functional Pin Description

Pin No.	Pin Name	Pin Function
1, 2	PGND	<b>Power Ground</b>
3	LG2	<b>Gate of Lower MOSFET</b>
4	BST	<b>Bootstrap Pin.</b> This pin provides power to the internal higher MOSFET gate driver. Connect a 470nF capacitor from BST pin to LX pin.
5	VCC	<b>Power Supply Input.</b> Bypass this pin with a 1uF ceramic capacitor to GND, placed as close to the IC as possible.
6	VDD5	<b>Output Pin for the Internal 5V LDO.</b> Bypass the VDD5 with a 1uF ceramic capacitor physically near the IC.
7	LG1	<b>Low Side Gate Driver Output.</b>
8	COMP	<b>Error Amplifier Output.</b> This is the output of the error amplifier (EA) and the non-inverting input of the PWM comparator.
9	CSP	<b>Current Sensing Input.</b>
10	VOUT	<b>Output Voltage Sensing.</b>
11	DM	<b>Negative Data Line for USB.</b>
12	DP	<b>Positive Data Line for USB.</b>
13	CC1	<b>Configuration Channel 1 for USB Type-C receptacle.</b> This pin is internally pulled high to VDD5 with a 10kΩ resistor.
14	CC2	<b>Configuration Channel 2 for USB Type-C receptacle.</b> This pin is internally pulled high to VDD5 with a 10kΩ resistor.
15	LX	<b>Power Switching Output to External Inductor.</b>
16	VIN	<b>Exposed Pad.</b> The exposed is connected to drain of the internal high-side MOSFET. Large PCB area is required for thermal dissipation.
17	GND	<b>Ground.</b>

**Functional Block Diagram**



**Functional Description**

**Power On Reset**

A power-on reset circuit monitors the input voltage at VCC pin. When the input voltage exceeds 8V, the converter will start operation. Once input voltage falls below 7V, the converter shuts down.

**Input Over Voltage Protection**

If the VCC pin voltage is higher than 32V (typical), the input OVP is triggered. The NT3885 turns off the switches and shuts down. The NT3885 resets itself and waits for another attachment after 1 second time delay when input OVP occurs.

**Waiting for Attachment**

Before power on reset, the CC1/CC2 are kept high impedance. After power on reset, the NT3885 connects CC1/CC2 to VDD5 by 10kΩ resistors and waits for attachment of an UFP. If and only if one of CC1/CC2 voltage is between 0.8V and 2.2V for 100ms, the NT3885 asserts attachment and initiates the soft start cycle. This will advertise the NT3885, as a DFP, can provide 3A output current.

**Soft Start**

When attached, the NT3885 initiates the soft-start cycle if the output voltage is lower than 0.45V (typical). The softstart function ramps up the output voltage from 0V to 5.2V within about 5ms. This effectively reduces the inrush current to charge the output capacitor. After softstart completes, the NT3885 enables output under voltage protection (UVP) which turns off the converter if output voltage is lower than 3.0V. The NT3885 resets itself and waits for another attachment after 1 second time delay when UVP occurs.

**Detachment Detection**

The NT3885 continuously monitors CC1/CC2 voltage for detachment detection during normal operation. The NT3885 asserts detachment of UFP and turns off the step-down converter if both CC1/CC2 voltages are higher than 2.7V for 15ms. An internal discharge circuit is turned on for 500ms to discharge the output voltage to a safe level, vSafe0V, within specified period. After the discharge expires, the NT3885 resets its interface configuration and resumes looking for a new UFP attachment.

**DM/DP Configuration**

The DM/DP have three configurations, mode 1 ~ mode 3, as shown in Figure 1 ~ Figure 3. The NT3885 automatically selects configurations according to the DP/DM status and pre-defined timing so that the attached portable devices can be quickly charged.

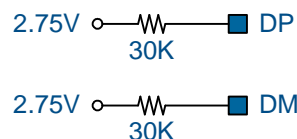


Figure 1. Mode 1 Configuration.

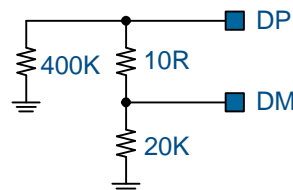


Figure 3. Mode 2 Configuration.

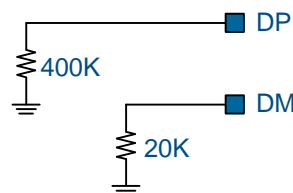


Figure 4. Mode 3 Configuration.

**Mode 1 Configuration**

Mode 1 is the default configuration when output voltage is higher than 4.0V. The NT3885 leaves mode 1 and enters mode 2 if one of the three conditions is true: 1.)  $V_{DP-0} < V_{DP}$  for 2ms; 2.)  $V_{DM} < V_{DM-1}$  for 15ms or 3.)  $V_{DP} < V_{DP-1}$  for 15ms.

When entering mode 2, the NT3885 resets the internal 2-second counter.

**Mode 2 Configuration**

The NT3885 leaves mode 2 under two conditions:

- 1.) enters mode 3 if  $V_{DP-2} < V_{DP} < V_{DP-1}$  for 1.2 seconds.
- 2.) otherwise enters mode 1 when the 2-second counter expires.

**Mode 3 Configuration**

The NT3885 leaves mode 3 and enters mode 1 if  $V_{DP-2} > V_{DP}$  for 40ms.

At mode 3, the NT3885 keeps monitoring DM voltage. Once  $V_{DM} < V_{DM-2}$  for longer than 40ms, the NT3885 recognizes a Quick Charge supporting device is attached and adjusts the output voltage according to DP/DM voltage as illustrated in Table 1.

Functional Description

The NT3885 features a soft transition function when adjusting the output voltage. The output voltage slew rate is limited to 3.5V/ms. This effectively reduces the inrush current to charge the output capacitors.

Table 1.  $V_{OUT}$  vs. DP/DM voltages relationship

$V_{DP}$	$V_{DM}$	$V_{OUT}$
$V_{DP} < V_{DP-2}$	X	Enter mode 1
$V_{DP-2} < V_{DP}$	$V_{DM} < V_{DM-1}$	5.2V
$V_{DP-2} < V_{DP} < V_{DP-1}$	$V_{DM-2} < V_{DM} < V_{DM-1}$	12.0V
$V_{DP-2} < V_{DP} < V_{DP-1}$	$V_{DM} > V_{DM-1}$	Continuous mode
$V_{DP} > V_{DP-1}$	$V_{DM-2} < V_{DM} < V_{DM-1}$	9.0V
$V_{DP} > V_{DP-1}$	$V_{DM} > V_{DM-1}$	Keep last state

Incremental Output Voltage

When  $V_{DP-2} < V_{DP} < V_{DP-1}$  and  $V_{DM} > V_{DM-1}$ , the NT3885 enters continuous mode. Upon each DP positive pulse with 150us delay time, the NT3885 increases output voltage by 200mV as shown in Figure 5. Pulsewidth (both  $t_L$  and  $t_H$ ) shorter than 150us will be skipped. The maximum output voltage is limited at 12.0V.

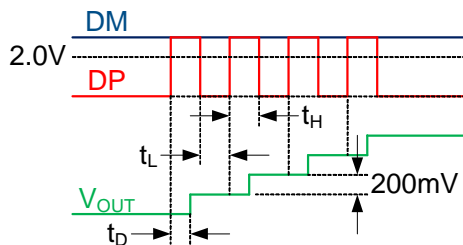


Figure 5. Incremental Output Voltage.

Decremental Output Voltage

Upon each DM negative pulse with 150us delay time, the NT3885 decreases output voltage by 200mV as shown in Figure 6. Pulsewidth (both  $t_L$  and  $t_H$ ) shorter than 150us will be skipped. The minimum output voltage is 3.6V.

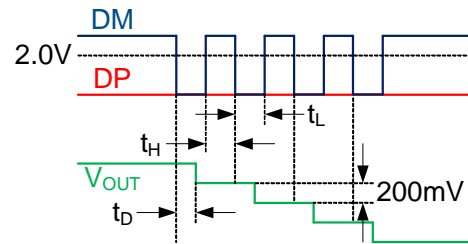


Figure 6. Decremental Output Voltage.

CV/CC/CP mode control

The NT3885 provides CV/CC/CP function to meet power profile requirement of Quick Charge™ 3.0. In the CV mode, the output voltage is controlled within  $\pm 1\%$ . In the CC mode, the output current variation is less than  $\pm 5\%$  of the nominal value which can be set up to 3A by the current sensing resistor as:

$$I_{OUT-N} = \frac{V_{ILIM}}{R_{CS}} = \frac{66mV}{R_{CS}}$$

The NT3885 enters CP mode (constant power) when output voltage is higher than 7.0V as shown Figure 7. The current limit is linearly decreased as output voltage increases and roughly keeps the output power constant.

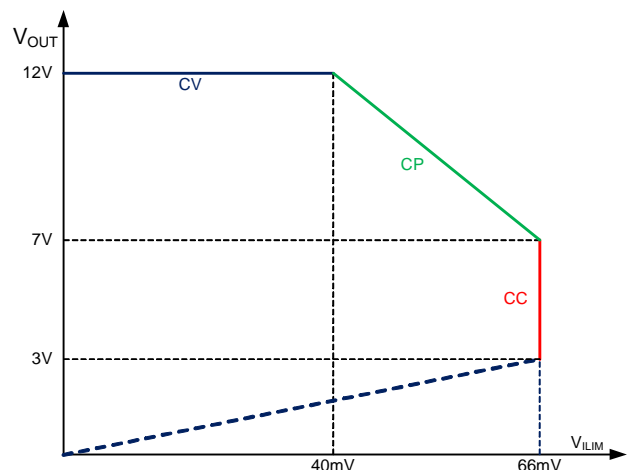


Figure 7. Power Profile.

Cycle-by-Cycle Current Limit

The NT3885 uses on-state resistance of the internal power MOSFET as a current sense element. Once the peak switch current through the power MOSFET is higher than current-limit threshold, the NT3885 turns off the power MOSFET immediately to limit the inductor current. The NT3885

resumes normal operation at next PWM clock.

#### Under Voltage Protection

When the load demands more current than CC level or cycle-by-cycle current limit level (CC mode operation or output short circuit), the output voltage will decrease. Once the output voltage is lower than 3.0V, the under voltage protection (UVP) will be triggered to shut down the converter.

The NT3885 resets itself and resumes normal operation with 1 second time delay.

#### Over Voltage Protection

The over voltage protection (OVP) is triggered when the output voltage is 15% higher than its target level. When OVP, the step-down converter stops switching immediately. The converter resumes normal operation when OVP disappears.

#### Over Temperature Protection

The over temperature protection (OTP) is triggered and shuts down the NT3885 when its junction temperature exceeds 160°C. Once the junction temperature cools down by approximately 40°C, the converter will resume normal operation.

#### Cable Compensation

In charger applications, the load current will cause considerable voltage drop along the output cable and current sensing resistor  $R_{CS}$ . The NT3885 automatically compensates the voltage drop so that the terminal voltage is kept constant over entire loading current range. The real output voltage is adjusted according to the current sensing voltage as:

$$V_{OUT} = V_{OUT-N} + 3 \cdot V_{CS}$$

where  $V_{OUT-N}$  is the target output voltage level set by DP/DM.

#### Output Voltage Discharge

The NT3885 turns on the internally discharge circuit for 500ms under the following conditions:

- 1.) UFP detachment is detected.
- 2.) Discrete output voltage decreasing command is received.

This will sink a 50mA current (at  $V_{OUT} = 5.2V$ ) to discharge the output voltage to a safe level within the specified requirement.

**Absolute Maximum Rating**

(Note1)

Supply Input Voltage, $V_{IN}$ -----	-0.3V to +40V
BST to LX -----	+0.3V to +7V
LX to GND -----	-1V to $V_{IN}+1V$
Other Pins -----	-0.3V to +7V
Storage Temperature Range -----	-65°C to +150°C
Operation Temperature Range -----	-40°C to +150°C
Lead Temperature Range (Soldering 10sec) -----	260°C

ESD Rating (Note2)

MM (Machine Mode) -----	200V
MM (Machine Mode), DP/DM Pins -----	800V
HBM (Human Body Mode) -----	2kV
HBM (Human Body Mode), DP/DM Pins -----	8kV

**Thermal Information**

Package Thermal Resistance (Note3)

WDFN5x6-14L $q_{JA}$ -----	50°C/W
WDFN5x6-14L $q_{JC}$ -----	5°C/W

Power Dissipation,  $P_D$  @  $T_A = 25^\circ\text{C}$

WDFN5x6-14L -----	2W
-------------------	----

**Note 1.** Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

**Note 2.** Devices are ESD sensitive. Handling precaution recommended.

**Note 3.**  $q_{JA}$  is measured in the natural convection at  $T_A = 25^\circ\text{C}$  on a high effective thermal conductivity test board of JEDEC 51-7 thermal measurement standard.

**Electrical Characteristics**

 ( $V_{IN} = 14V$ ,  $T_A = +25^{\circ}C$  unless otherwise specified.)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
<b>Supply Input</b>						
Supply Voltage Range	$V_{IN}$		9	--	30	V
Supply Input Current	$I_{IN-SD}$	CC1, CC2 open.	--	0.6	1.2	mA
	$I_{IN-Q}$	No load.	--	1.5	3.0	
VDD5 Output Voltage	$V_{DD5}$	$V_{IN} = 9V \sim 30V$	5.1	5.25	5.4	V
<b>Power On Reset</b>						
$V_{IN}$ POR Threshold	$V_{IN-POR}$	$V_{IN}$ rising,	7.5	8.0	8.5	V
$V_{IN}$ POR Hysteresis	$V_{IN-HYS}$	$V_{IN}$ Falling	--	1.0	--	V
$V_{IN}$ Over Voltage Protection	$V_{IN-OVP}$		30	32	34	V
<b>Oscillator</b>						
Normal PWM Frequency	$f_{OSC}$		--	125	--	kHz
		$T_A = -25^{\circ}C$ to $125^{\circ}C$	110	--	140	
Minimum On-Time	$t_{ON-MIN}$		--	500	--	ns
Maximum Duty Cycle	$D_{MAX}$		95	--	--	%
<b>Output Voltage</b>						
Output Voltage	$V_{OUT}$	Default	5.15	5.20	5.25	V
		9V mode	8.6	9.0	9.4	
		12V mode	11.4	12.0	12.6	
Incremental/Decremental Step			150	200	250	mV
$V_{OUT}$ Load Compensator		$V_{CS} = 60mV$	160	180	200	mV
<b>PWM Error Amplifier</b>						
Error Amplifier Transconductance	GM		--	500	--	$\mu A/V$
COMP Source Current		$V_{COMP} = 4V$	--	36	--	$\mu A$
COMP Sink Current		$V_{COMP} = 1V$	--	36	--	$\mu A$
<b>Current Sense Amplifier</b>						
Current Limit Level	$V_{ILIM}$	$V_{OUT} = 4.5 \sim 6.5V$	62	66	70	mV
		$V_{OUT} = 12V$	36	40	44	
Current Limit Breaking Point			--	7.0	--	V
<b>Protection</b>						
Over Voltage Protection Level	$V_{OVP}$	Percentage of target level.	112	115	118	%
Over Voltage Protection Hysteresis		$V_{OUT}$ falling.	--	5	--	%
Under Voltage Protection Level	$V_{UVP}$	$V_{OUT}$ falling.	2.9	3.0	3.1	V
Current Limit	$I_{LIM}$		4.0	5.0	6.0	A
Over Temperature Shutdown			--	160	--	$^{\circ}C$
Over Temperature Hysteresis			--	40	--	$^{\circ}C$



**Electrical Characteristics**

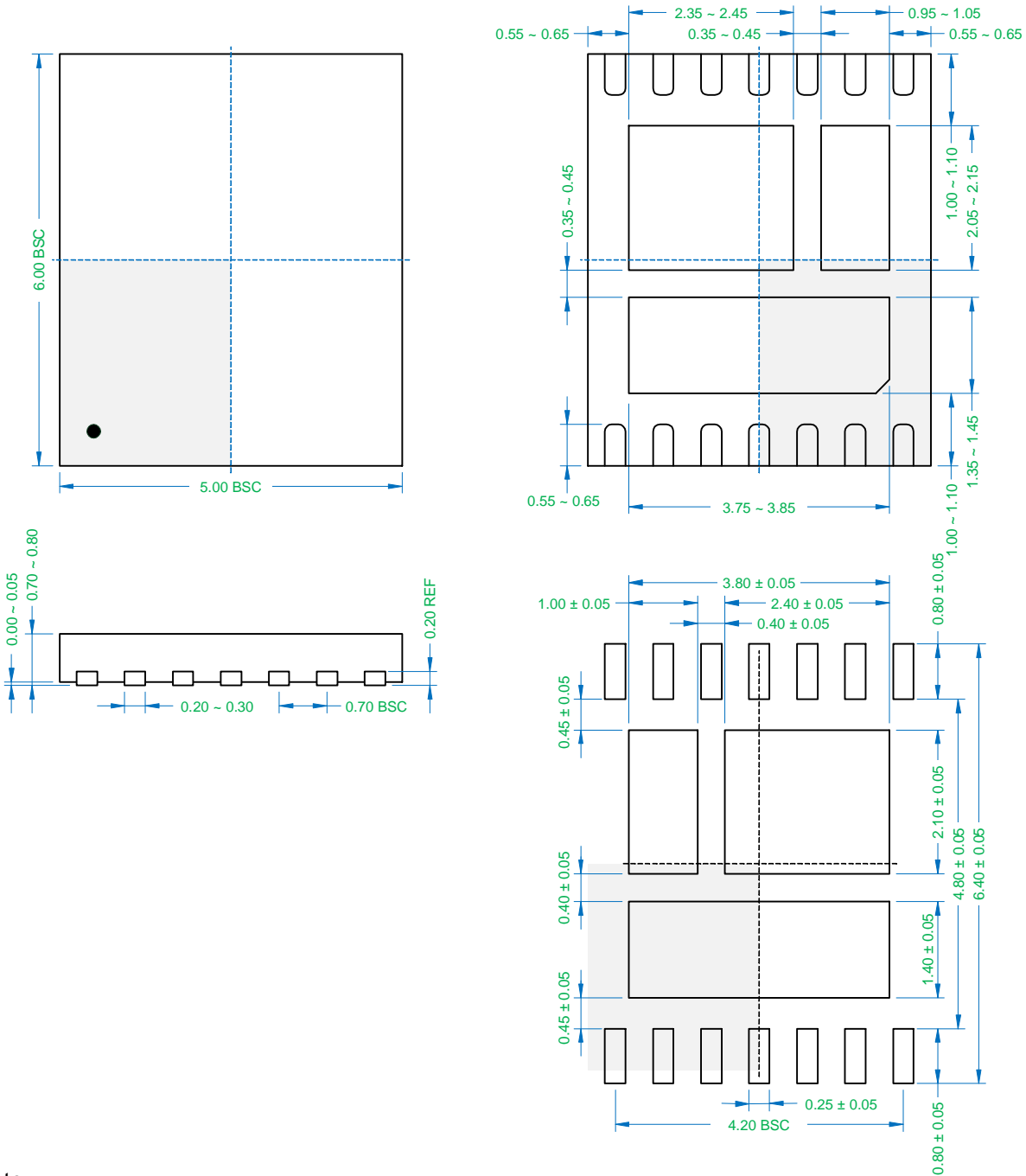
Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
<b>DP/DM Threshold Levels</b>						
DP/DM Threshold Levels	$V_{DP-0}$	Delta from initial $V_{DP}$	100	125	150	mV
	$V_{DM-1}$	$V_{DM}$ : $V_{DP}$ rising	1.95	2.05	2.15	V
	$V_{DP-1}$	$V_{DM-1}/V_{DP-1}$ hysteresis	--	100	--	mV
	$V_{DM-2}$	$V_{DM}$ : $V_{DP}$ rising	0.325	0.35	0.375	V
	$V_{DP-2}$	$V_{DM-2}/V_{DP-2}$ hysteresis	--	50	--	mV
	<b>DP/DM at Mode 1</b>					
DP Floating Voltage	$V_{DP}$		2.65	2.75	2.85	V
DM Floating Voltage	$V_{DM}$		2.65	2.75	2.85	V
DP Pin Output Impedance	$Z_{DP}$		24	30	36	kW
DM Pin Output Impedance	$Z_{DM}$		24	30	36	kW
Debounce Time for Exiting Mode 1		$V_{DP} > V_{DP-0}$	1.6	2.0	2.4	ms
		$V_{DM} < V_{DM-1}$ or $V_{DP} < V_{DP-1}$	12	15	18	ms
<b>DP/DM at Mode 2</b>						
DP and DM Short Circuit Switch			--	10	20	W
DM Pull Low Resistance			16	20	24	kW
DP Pull Low Resistance			320	400	480	kW
Recycle Time for Entering Mode 1			1.6	2.0	2.4	s
Debounce Time for Entering Mode 3			1.0	1.2	1.5	s
<b>DP/DM at Mode 3</b>						
DP Pull Low Resistance			320	400	480	kW
DM Pull Low Resistance			16	20	24	kW
Debounce Time for DM Low			32	40	48	ms
Debounce Time for DP Low			32	40	48	ms
Deglitch Time for DM/DP Change		Quick Charge 2.0 mode	32	40	48	ms
		Quick Charge 3.0 mode	100	150	200	us
Duration for Voltage Step		Quick Charge 2.0 Mode	48	60	72	us
Output Voltage Incremental/ Decremental Step			--	200	--	mV

**Electrical Characteristics**

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
<b>CC1/CC2</b>						
CC1/CC2 Open Circuit Voltage			--	5.2	--	V
CC1/CC2 Pull High Resistance			--	10	--	kΩ
Upper Bound for Attachment		CC1/CC2 falling	--	2.2	--	V
		CC1/CC2 rising	--	2.7	--	V
Lower Bound for Attachment			--	0.8	--	V
Debounce Time for Attachment			--	100	--	ms
Debounce Time for Detachment			--	15	--	ms
<b>Soft Start</b>						
Soft Start Time	$t_{SS}$		--	5.0	--	ms
Recycle Time			--	1000	--	ms
<b>Discharge Function</b>						
Discharge Period			--	500	--	ms
Discharge Current		$V_{OUT} = 5.15V$	--	50	--	mA
<b>High/Low Side Switches</b>						
High Side Switch On-Resistance	$R_{DS(ON)}$	$I_L = 0.1A$	--	30	--	mΩ
Low Side Switch On-Resistance	$R_{DS(ON)}$	$I_L = 0.1A$	--	30	--	mΩ
LX Rising Time		$I_L = 1A$	--	30	--	ns
LX Falling Time		$I_L = 1A$	--	50	--	ns

Package Information

WDFN5x6-14L



Note

1. Package Outline Unit Description:

BSC: Basic. Represents theoretical exact dimension or dimension target

MIN: Minimum dimension specified.

MAX: Maximum dimension specified.

REF: Reference. Represents dimension for reference use only. This value is not a device specification.

TYP: Typical. Provided as a general value. This value is not a device specification.

2. Dimensions in Millimeters.

3. Drawing not to scale.

4. These dimensions do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm.