AN11660

NXH5104 V_{AUX} - Auxiliary voltage supply

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Document information

Info	Content
Keywords	VAUX, Voltage supply, Pump charge, configurable
Abstract	The auxiliary supply (VAUX) is a configurable DC-to-DC supply. It is generated from the primary supply voltage (VDD) for supplying an external auxiliary component in the NXH5104, for example, an LED.

Revision history

Rev	Date	Description
1.0	20160928	Initial version

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1. Introduction

This application note describes the usage of the NXP NXH5104 serial Electrically Erasable and Programmable Read-Only Memory (EEPROM) auxiliary supply DC-to-DC converter. This converter generates an output voltage on the VAUX bump starting from the input voltage supplied on the V_{DD} bump.

This auxiliary supply is independent from the non-volatile storage. It can be used to supply other components in the application, for example an LED.

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2. Overview

The NXP NXH5104 is a 4 Mbit serial EEPROM. The device has been developed for low-power low-voltage applications and contains a Serial Peripheral Interface (SPI) compatible interface. As can be seen in Figure 1, a V_{AUX} voltage can be generated from the V_{DD} input.

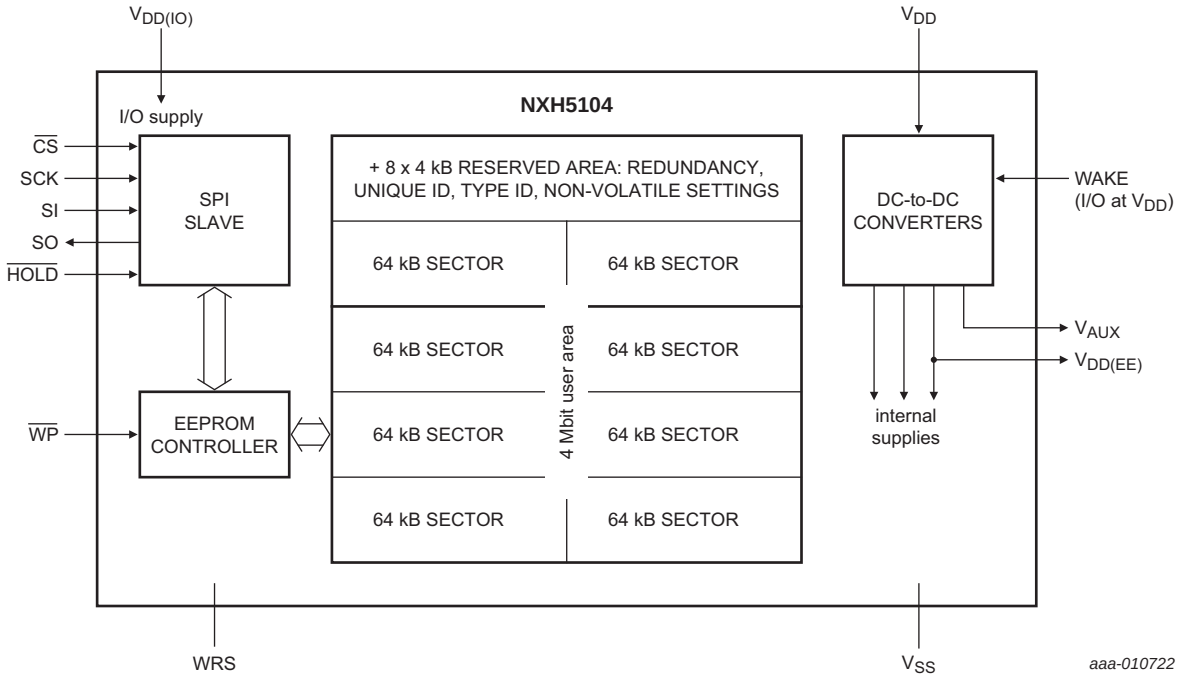

Fig 1. Block diagram

A more detailed view of the DC-to-DC generation circuit is shown in Figure 2.

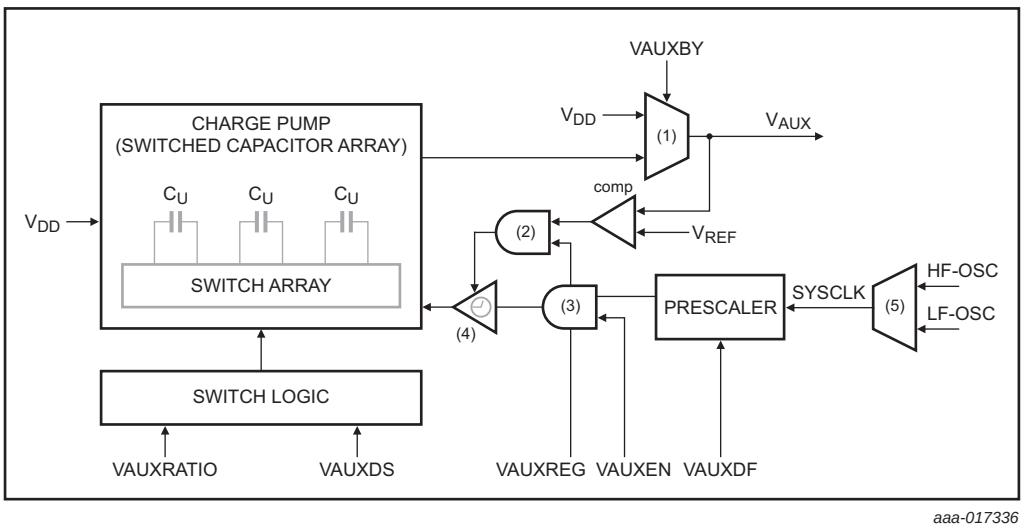

Fig 2. Auxiliary DC-to-DC: block diagram

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The input parameters, as seen in Figure 2, directly relate to the register fields of the VAUX register. See the SPI auxiliary supply configuration table in the NXH5104 *data sheet* for more details. See also Table 2.

3. Decoupling

To support the voltage conversion process, the DC-to-DC converter must dump its charge in an external capacitor. The type and value of this external capacitor is greatly dependent on the use case; maximum allowed voltage ripple and load. The design and validation of the auxiliary supply has been done for a capacitor of 470 nF.

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4. Example use cases

The following use cases demonstrate the usage of the auxiliary supply DC-to-DC converter:

- Generating an LED supply
- Generating a supply for feeding $V_{DD(IO)}$

4.1 Driving an LED

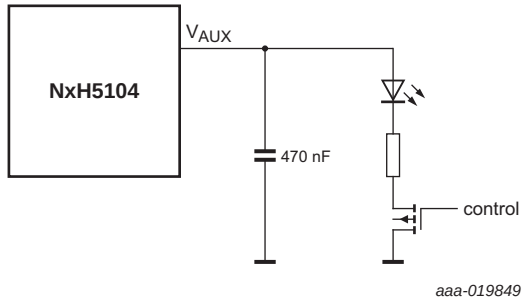

Fig 3. Application diagram for driving an LED

4.2 Auxiliary supply feeding $V_{DD(IO)}$

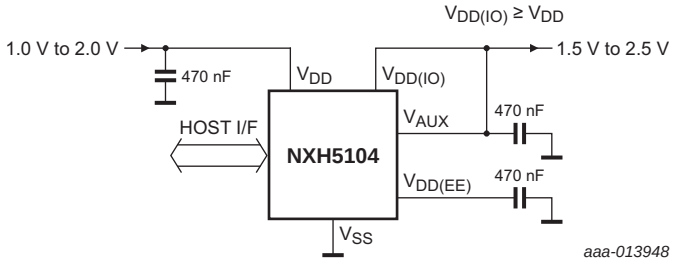

Fig 4. Auxiliary I/O supply

5. Control

Enabling/disabling and configuring the auxiliary supply generation can be performed through the SPI interface using the following three commands (for more information, see the *NXH5104 data sheet*):

- VAUXVW: volatile write of the auxiliary supply configuration register
- VAUXPW: persistent write of the auxiliary supply configuration register
- VAUXR: prepares a read of the auxiliary supply configuration register

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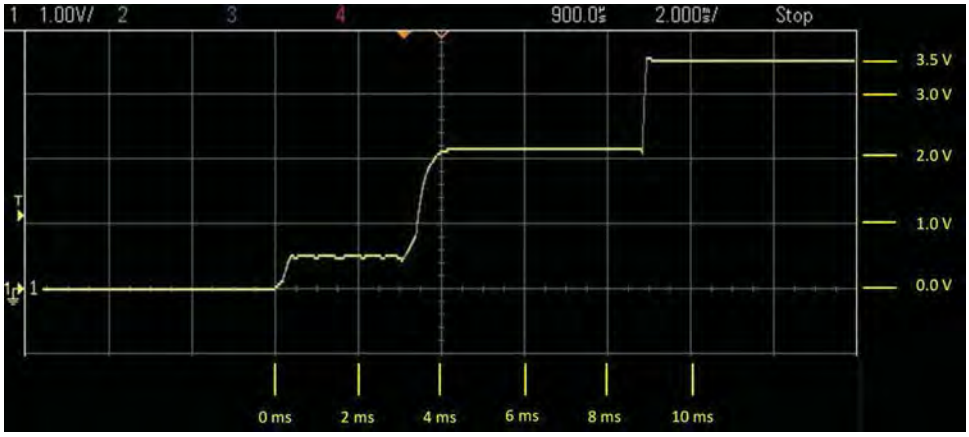
A volatile write configuration will be lost after a V_{DD} supply power cycle and after a return to Power-down mode. A persistent write is permanently stored in the device and automatically reloaded after a V_{DD} supply power cycle and after a return to Power-down mode.

Note: a persistent write of the auxiliary supply configuration register requires first a Write Enable (WREN) command, otherwise the VAUXPW is ignored.

6. Starting up/shutting down

Enabling and disabling the auxiliary supply DC-to-DC converter does not occur in one go. To be able to generate a safe start-up and shut-down, the NXP NXH5104 steps through different configurations before applying the final (user requested) configuration.

Note: the user should refrain from drawing currents during the start-up, otherwise correct operation cannot be guaranteed. Depending on the target output voltage, the start-up time takes typically 5 ms (V_{AUX} < 2 V) or 10 ms (V_{AUX} > 2 V. The following oscilloscope plot shows the start-up for a target V_{AUX} setting of 3.5 V.



aaa-024470

Fig 5. V_{AUX} start-up timing

7. Modes

The auxiliary supply generator has three main modes:

- OFF: No V_{AUX} voltage is present at the V_{AUX} output
- NORMAL: The DC-to-DC converter is active and up, or down, converts the V_{DD} unto the V_{AUX} output
- BYPASS: The auxiliary supply unit is bypassed. V_{DD} is connected to the V_{AUX} output

Important: Enabling the DC-to-DC converter and the BYPASS mode at the same time creates a short-circuit. The VAUXEN and VAUXBY fields in the auxiliary supply configuration register (see the NXH5104 *data sheet*) must not be set at the same time.

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8. Operation versus power modes

The auxiliary supply generation behaves differently depending on the operation mode of the NXP NXH5104 device;

- OFF: when there is no V_{DD} supplied, no V_{AUX} voltage is generated
- POWER DOWN: when NXH5104 is in this mode, no V_{AUX} voltage is generated, nor is the BYPASS enabled to connect V_{DD} to V_{AUX}
- SLEEP: when NXH5104 is in this mode, the auxiliary supply is in ACTIVE mode, however the V_{AUX} voltage depends on:
  - When the auxiliary supply is configured in NORMAL mode, when switching to SLEEP, the V_{AUX} is switched off
  - When the auxiliary supply is configured in BYPASS mode, when switching to SLEEP, the V_{AUX} is kept in BYPASS mode
- STANDBY: when NXH5104 is in this mode, the auxiliary supply is in ACTIVE mode. The configuration can either be NORMAL or BYPASS mode, depending on the programmed configuration

The following flowchart shows the V_{AUX} configuration regarding the power modes of NXH5104.

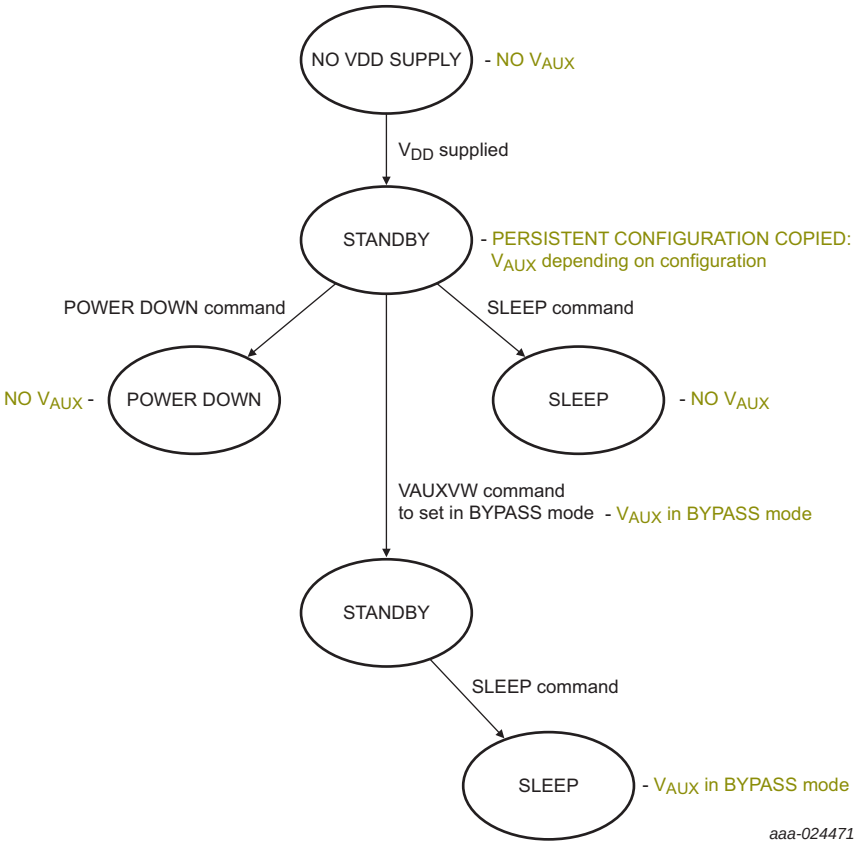

Fig 6. Power mode flowchart

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9. Settings

The following table gives an overview of the auxiliary supply generation unit settings:

Table 1. Auxiliary supply generation unit settings

Field	Setting
VAUXEN	enabling/disabling the auxiliary supply generation
VAUXBY	bypass the auxiliary supply generation
VAUXRATIO	conversion ratio (2× or 3×)
VAUXDS	drive strength
VAUXDF	division factor
VAUXREG	loop mode
VAUXV	target output voltage

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Table 2. SPI auxiliary supply configuration

Bits	Access	Field	Value	Description
31:17	-	-	-	(reserved)
16	R/W/P	VAUXEN	(0b)	auxiliary supply enable.
		VAUXEN_DIS	0b	disabled.
		VAUXEN_EN	1b	enabled.
15	R/W/P	VAUXBY	(0b)	auxiliary supply bypass mode.
		VAUXBY_DIS	0b	disabled.
		VAUXBY_EN	1b	enabled.
14	R/W/P	VAUXRATIO	(0b)	auxiliary supply ratio setting.
			0b	ratio 2
			1b	ratio 3
13	-	-	-	(reserved)
12:11	R/W/P	VAUXDS	(00b)	auxiliary supply drive strength.
			00b	1/4 of drive strength.
			01b	2/4 of drive strength.
			10b	3/4 of drive strength.
			11b	4/4 of drive strength.
10:8	R/W/P	VAUXDF	(000b)	auxiliary supply clock divider.
			000b	maximum clock speed
			001b	clock divided by 2
			010b	clock divided by 4
			011b	clock divided by 8
			100b	clock divided by 16
			101b	clock divided by 32
			110b	clock divided by 64
			111b	clock divided by 128
7	R/W/P	VAUXREG	(0b)	auxiliary supply enable voltage regulation
			0b	disabled (open loop).
			1b	enabled (closed loop).
6:0	R/W/P	VAUXV	(0b)	auxiliary supply comparator mode.
			00h	minimum (1.5 V)
			7Fh	maximum (3.3 V)

9.1 Drive strength

The output drive strength of the auxiliary supply generation can be set in the VAUXDS field. The power consumption can be optimized by setting the drive strength only 1 step higher than required. For example, when requiring 600 μA, it is best to set the drive strength to 1.0 mA.

- VAUXDS = 0: minimum 0.5 mA
- VAUXDS = 1: minimum 1.0 mA
- VAUXDS = 2: minimum 1.5 mA
- VAUXDS = 3: minimum 2.0 mA

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9.2 VAUXRATIO

The conversion ratio of the auxiliary supply generation can be set in the VAUXRATIO field:

- VAUXRATIO = 0: 2x ratio
- VAUXRATIO = 1: 3x ratio

The achievable unloaded VAUX output voltage depends on the selected conversion ratio and the VDD input supply level. The other way around, a certain VAUX output voltage with selected conversion ratio requires a minimum VDD input supply level.

The exact levels are difficult to define for every possible use case. As a rule of thumb:

$V_{DD} \times \text{ratio} \times 0.85 > V_{AUX}$

Some examples are shown in Table 3.

Table 3. VAUX conversion ratio examples

Input	Output											
V_{DD} [V]	V_{AUX} [V]	Ratio	Drive strength	Clock division	Target	VAUXEN	VAUXBY	VAUXRATIO	VAUXDS	VAUXDF	VAUXREG	VAUXV
0.9	1.2	3	2	1	0x0F	1	0	1	3	0	1	0x0F
0.9	1.8	3	4	1	0x24	1	0	1	3	0	1	0x24
1.2	1.8	2	4	1	0x24	1	0	0	3	0	1	0x24
1.2	2.5	3	4	1	0x3B	1	0	1	3	0	1	0x3B
1.8	3.3	2	4	1	0x58	1	0	0	3	0	1	0x58

When the ratio is chosen too low for the target output voltage, the DC-to-DC goes into open loop mode. The target output voltage may still not be reached and a high current is drawn from V_{DD}.

When the ratio is chosen too high for the target output voltage, the overall efficiency is lower than with a correctly set ratio. Also, ripple on the output voltage is higher.

9.3 Output voltage

The output voltage in Closed-loop mode and when the current load does not exceed the configured performance of the auxiliary supply generation, is defined by setting the VAUXV field.

Each sample is trimmed in production for supplying a V_{AUX} of 2.500 V with accuracy [–0 mV / +30 mV] for setting (decimal) 62.

When incrementing VAUXV by 1, V_{AUX} increases by 28.510 mV with incremental accuracy [–1 mV / +1 mV]. When decrementing VAUXV with 1, V_{AUX} decreases with 28.510 mV with incremental accuracy [–1 mV / +1 mV].

A full table for VAUXV versus the generated V_{AUX} output voltage can be found in the appendix. The maximum allowed output voltage is V_{AUX} = 3.5 V.

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Note: the minimum allowed VAUXV setting is 15. Configuring a lower value might generate a high V_{AUX} output voltage.

9.3.1 Load and minimum input supply

The following table shows the minimum input supply $V_{i(min)}$ to generate a stable VAUX output voltage, while sustaining a load I_{AUX} of up to 2 mA. depending on the set ratio (2× or 3×). The last column indicates the typical current I_{DD} being drawn from the input supply at $V_{i(min)}$ while sustaining a load of 2 mA at the target set V_{AUX}.

Table 4. Minimum input supply

VAUXV Setting	V_{AUX} [V]	I_{AUX} [mA]	Ratio	$V_{i(min)}$ [V]	typical I_{DD} [mA]
62	2.5	2.0	2×	1.45	6.4
	2.5	2.0	3×	1.30	9.5
78	3.0	2.0	2×	1.75	6.5
	3.0	2.0	3×	1.55	9.1
88	3.3	2.0	2×	1.85	6.5
	3.3	2.0	3×	1.65	9.9

9.4 Open loop mode

The auxiliary supply generation can be run in Closed loop mode and in Open loop mode. The input supply voltage on VDD and the ratio (2× or 3×) mainly define the output voltage in Open loop mode. Therefore, any change on V_{DD} impacts directly V_{AUX}. Use the Closed loop mode only where VAUXV defines the output voltage V_{AUX}.

10. Bypass mode

In the bypass mode, an internal switch between V_{DD} and V_{AUX} is closed. Therefore, enabling the DC-to-DC converter and the BYPASS mode at the same time creates a short-circuit. The VAUXEN and VAUXBY fields in the auxiliary supply configuration register (see the NXH5104 *data sheet*) may not be set at the same time.

Note: depending on the requested configuration, when switching the DC-to-DC converter to Bypass mode, be aware of a high voltage on the V_{AUX} capacitor being connected to the V_{DD} input. When $V_{AUX} > V_{DD}$, current flows from V_{AUX} to V_{DD}. For example, V_{DD} is 1.8 V and V_{AUX} is configured to output 3.3 V. When the auxiliary supply bypass switch is closed, the 470 nF capacitor at 3.3 V is connected to V_{DD} at 1.8 V causing a current to flow from V_{AUX} into V_{DD}.

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11. Appendix - VAUXV

Table 5 shows the minimum, average and maximum V_{AUX} output voltage versus the setting of the VAUXV field of the auxiliary supply configuration register. The output is decoupled with 470 nF but without load.

Table 5. Output voltage

VAUXV setting	V_{AUX} (V)		
	Minimum	Average	Maximum
15	1.08	1.15	1.19
16	1.11	1.18	1.21
17	1.14	1.21	1.24
18	1.17	1.24	1.27
19	1.20	1.27	1.30
20	1.23	1.30	1.33
21	1.27	1.33	1.36
22	1.30	1.36	1.39
23	1.32	1.38	1.42
24	1.35	1.41	1.45
25	1.38	1.44	1.48
26	1.41	1.47	1.51
27	1.45	1.50	1.54
28	1.48	1.53	1.57
29	1.51	1.56	1.60
30	1.54	1.59	1.63
31	1.57	1.62	1.66
32	1.60	1.65	1.69
33	1.63	1.68	1.72
34	1.66	1.71	1.75
35	1.69	1.74	1.78
36	1.72	1.77	1.81
37	1.75	1.80	1.84
38	1.78	1.83	1.87
39	1.81	1.86	1.90
40	1.84	1.89	1.93
41	1.87	1.92	1.96
42	1.90	1.95	1.99
43	1.94	1.98	2.02
44	1.96	2.01	2.05
45	2.00	2.04	2.08
46	2.03	2.07	2.10
47	2.06	2.09	2.13
48	2.09	2.12	2.16
49	2.12	2.15	2.19

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Table 5. Output voltage *…continued*

VAUXV setting	V_{AUX} (V)		
	Minimum	Average	Maximum
50	2.15	2.18	2.22
51	2.18	2.21	2.26
52	2.21	2.24	2.29
53	2.24	2.27	2.32
54	2.27	2.30	2.34
55	2.30	2.33	2.37
56	2.33	2.36	2.40
57	2.36	2.39	2.43
58	2.39	2.42	2.47
59	2.42	2.45	2.50
60	2.45	2.48	2.53
61	2.48	2.51	2.56
62	2.51	2.53	2.58
63	2.54	2.56	2.61
64	2.56	2.59	2.64
65	2.59	2.62	2.67
66	2.62	2.65	2.71
67	2.65	2.68	2.73
68	2.68	2.71	2.76
69	2.70	2.74	2.79
70	2.73	2.77	2.82
71	2.76	2.80	2.85
72	2.79	2.83	2.88
73	2.81	2.85	2.91
74	2.84	2.88	2.94
75	2.87	2.92	2.97
76	2.90	2.95	3.00
77	2.93	2.97	3.03
78	2.96	3.00	3.06
79	2.98	3.03	3.09
80	3.01	3.06	3.12
81	3.04	3.09	3.15
82	3.07	3.12	3.18
83	3.10	3.15	3.21
84	3.13	3.18	3.24
85	3.15	3.21	3.27
86	3.18	3.24	3.30
87	3.21	3.27	3.33
88	3.24	3.30	3.36
89	3.26	3.33	3.39

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Table 5. Output voltage *…continued*

VAUXV setting	V_{AUX} (V)		
	Minimum	Average	Maximum
90	3.29	3.36	3.42
91	3.32	3.39	3.45
92	3.35	3.42	3.48
93	3.38	3.45	3.51
94	3.40	3.47	3.54
95	3.43	3.50	3.57
96	3.46	3.53	3.60
97	3.49	3.56	3.63
98	3.52	3.59	3.66

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12. Abbreviations

Table 6. Abbreviations

Acronym	Description
EEPROM	Electrically Erasable and Programmable Read-Only Memory
SPI	Serial Peripheral Interface

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