

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### General Description

DA9121 is a power management unit (PMU) suitable for supplying CPUs, GPUs, DDR memory rails in single in-line pin package (SIPP) modules, smartphones, tablets, and other handheld applications.

DA9121 operates as a single-channel dual-phase buck converter, each phase requiring a small external 0.10  $\mu$ H inductor. It is capable of delivering up to 10 A output current at a 0.3 V to 1.9 V output voltage range. The 2.5 V to 5.5 V input voltage range is suitable for a wide variety of low-voltage systems, including, but not limited to, all Li-Ion battery supplied applications.

With remote sensing, the DA9121 guarantees the highest accuracy and supports multiple PCB routing scenarios without loss of performance.

The pass devices are fully integrated, so no external FETs or Schottky diodes are needed.

A programmable soft start-up can be enabled, which limits the inrush current from the input node and secures a slope-controlled rail activation.

The dynamic voltage control (DVC) supports adaptive adjustment of the supply voltage dependent on the processor load, via either a direct register write using the communication interface (I<sup>2</sup>C-compatible) or with a programmable input pin.

A configurable GPI allows multiple I<sup>2</sup>C address selection for multiple instances of DA9121 in the same application.

DA9121 has integrated over-temperature and over-current protection for increased system reliability, without the need for external sensing components.

### Key Features

- 2.5 V to 5.5 V input voltage
- 0.3 V to 1.9 V output voltage
- 4 MHz nominal switching frequency
- $\pm 1$  % accuracy (static)
- $\pm 5$  % accuracy (dynamic)
- I<sup>2</sup>C-compatible interface (FM+)
- Programmable GPIOs
- Programmable soft-start
- Voltage, current, and temperature supervision
- -40 °C to +85 °C ambient temperature range
- Package: 24WLCSP 2.5 mm x 1.7 mm (0.4 mm pitch)

### Applications

- SIPP modules (SoC, DRAM)
- Smartphones
- Tablet PCs
- Infotainment
- Ultrabooks™
- Wi-Fi Modules
- Game Consoles

## System Diagrams

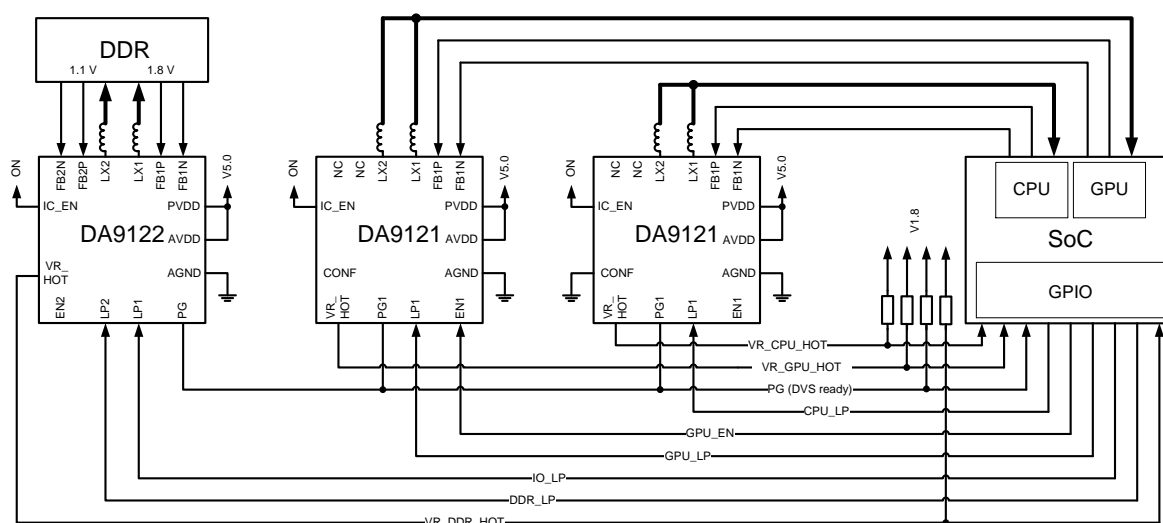


Figure 1: Typical Application Diagram (Port Control)

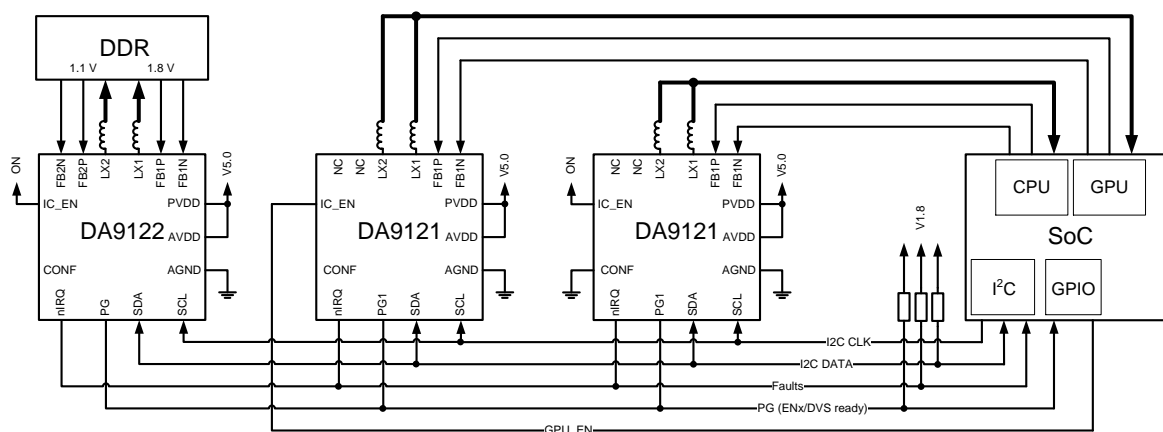


Figure 2: Typical Application Diagram (I²C Control)

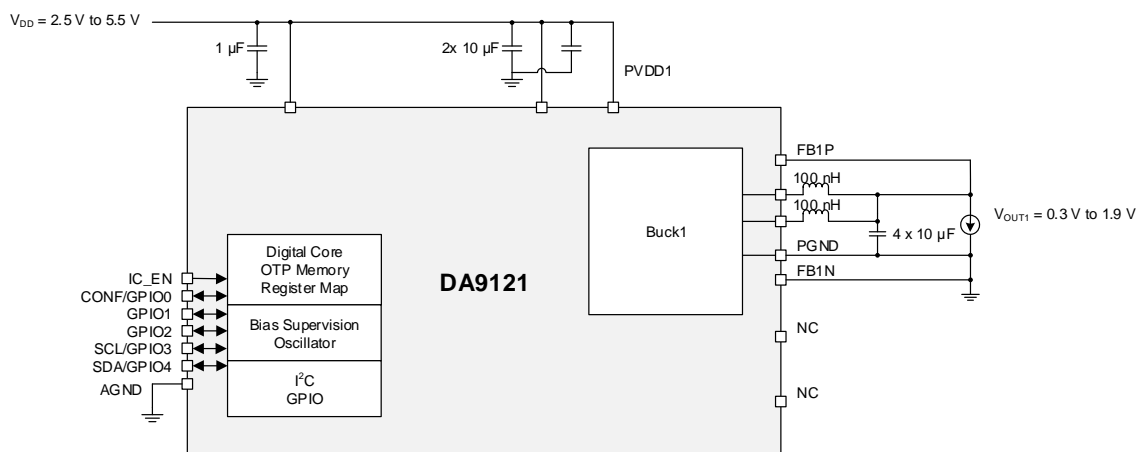


Figure 3: Simplified Schematic Diagram

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### Contents

<b>General Description .....</b>	<b>1</b>
<b>Key Features .....</b>	<b>1</b>
<b>Applications .....</b>	<b>1</b>
<b>System Diagrams .....</b>	<b>2</b>
<b>1 Terms and Definitions .....</b>	<b>5</b>
<b>2 Pinout .....</b>	<b>6</b>
<b>3 Characteristics .....</b>	<b>8</b>
3.1 Absolute Maximum Ratings .....	8
3.2 Recommended Operating Conditions .....	8
3.3 Thermal Characteristics .....	9
3.3.1 Thermal Ratings .....	9
3.3.2 Power Dissipation .....	9
3.4 ESD Characteristics .....	9
3.5 Buck Characteristics .....	10
3.6 Performance and Supervision Characteristics .....	11
3.7 Digital IO Characteristics .....	12
3.8 Timing Characteristics .....	13
3.9 Typical Performance .....	14
<b>4 Functional Description .....</b>	<b>18</b>
4.1 DC-DC Buck Converter .....	18
4.1.1 Switching Frequency .....	18
4.1.2 Operation Modes and Phase Selection .....	18
4.1.3 Output Voltage Selection .....	19
4.1.4 Soft Start-Up and Shutdown .....	19
4.1.5 Current Limit .....	19
4.1.6 Thermal Protection .....	20
4.2 Internal Circuits .....	21
4.2.1 IC_EN/Chip Enable/Disable .....	21
4.2.2 nIRQ/Interrupt .....	21
4.2.3 GPIO .....	24
4.3 Operating Modes .....	25
4.3.1 ON .....	25
4.3.2 OFF .....	25
4.4 I <sup>2</sup> C Communication .....	26
4.4.1 I <sup>2</sup> C Protocol .....	26
<b>5 Register Definitions .....</b>	<b>28</b>
5.1 Register Map .....	28
5.1.1 System .....	30
5.1.2 Buck1 .....	38
5.1.3 Serialization .....	42
<b>6 Package Information .....</b>	<b>43</b>
6.1 Package Outlines .....	43
6.2 Moisture Sensitivity Level .....	44
6.3 WLCSP Handling .....	44

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**High-Performance, 10 A, Dual-Phase DC-DC Converter**

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6.4	Soldering Information .....	44
<b>7</b>	<b>Ordering Information .....</b>	<b>45</b>
<b>8</b>	<b>Application Information .....</b>	<b>45</b>
8.1	Capacitor Selection .....	45
8.2	Inductor Selection .....	46

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**High-Performance, 10 A, Dual-Phase DC-DC Converter**

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**1 Terms and Definitions**

ATE	Automated test equipment
CPU	Central processing unit
DDR	Dual data rate
DVC	Dynamic voltage control
FET	Field effect transistor
FM+	Fast mode plus
GBD	Guaranteed by design
GBQ	Guaranteed by qualification
GBSPC	Guaranteed by statistical process characterization
GPI	General purpose input
GPIO	General purpose input/output
GPU	Graphics processing unit
IC	Integrated circuit
HW	Hardware
Li-Ion	Lithium-ion
OTP	One time programmable
PCB	Printed circuit board
PRS	Product requirements specification
SCL	Serial clock
SDA	Serial data
SIPP	Single in-line pin package
SW	Software

## High-Performance, 10 A, Dual-Phase DC-DC Converter

## 2 Pinout

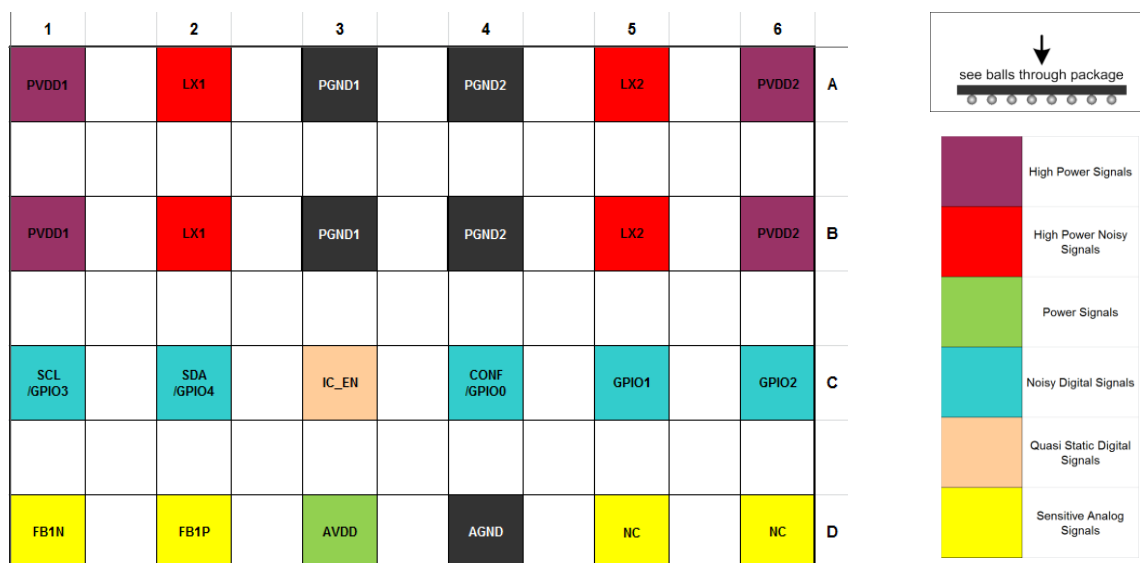


Figure 4: DA9121 Pinout Diagram (Top View)

Table 1: Pin Description

Pin No.	Pin Name	Type (Table 2)	Drive (mA)	Reset State	Description
A1, B1	PVDD1	PWR	5000		Supply voltage for buck power stage, decouple with 10 $\mu$ F and connect to same source as AVDD
A2, B2	LX1	AIO	5000		Switch node of buck, connect a 100 nH inductor between LX1 and output capacitor
A3, B3	PGND1	GND	5000		Buck power stage VSS rail
A4, B4	PGND2	GND	5000		Buck power stage VSS rail
A5, B5	LX2	AIO	5000		Switch node of buck, connect a 100 nH inductor between LX1 and output capacitor
A6, B6	PVDD2	PWR	5000		Supply voltage for buck power stage, decouple with 10 $\mu$ F and connect to same source as AVDD
C1	SCL/GPIO3	DIO	15		I <sup>2</sup> C clock or general purpose I/O
C2	SDA/GPIO4	DIO	15		I <sup>2</sup> C data or general purpose I/O
C3	IC_EN	AI	10		Powers up SW control interface and auxiliary circuitry (including bandgap, oscillator, and references).
C4	CONF/GPIO0	AI/DIO	10		Chip configuration or general purpose I/O
C5	GPIO1	DIO	10		General purpose I/O
C6	GPIO2	DIO	10		General purpose I/O
D1	FB1N	AI	10		Buck negative node of differential voltage feedback, connect to VSS at point of load
D2	FB1P	AI	10		Buck positive node of differential voltage feedback, connect to V <sub>OUT1</sub> at point of load
D3	AVDD	PWR	10		Supply rail for analog control circuitry, decouple with 1 $\mu$ F and connect to same source as PVDD

## High-Performance, 10 A, Dual-Phase DC-DC Converter

Pin No.	Pin Name	Type (Table 2)	Drive (mA)	Reset State	Description
D4	AGND	GND	10		Analog control and auxiliary circuitry VSS
D5	NC	AI			Not used
D6	NC	AI			Not used

Table 2: Pin Type Definition

Pin Type	Description	Pin Type	Description
DI	Digital input	AI	Analog input
DO	Digital output	AO	Analog output
DIO	Digital input/output	AIO	Analog input/output
PWR	Power	GND	Ground

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 3 Characteristics

#### 3.1 Absolute Maximum Ratings

Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, so functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specification are not implied. Exposure to Absolute Maximum Rating conditions for extended periods may affect device reliability.

**Table 3: Absolute Maximum Ratings**

Parameter	Description	Conditions	Min	Max	Unit
T <sub>STG</sub>	Storage temperature		-65	150	°C
T <sub>J</sub>	Junction temperature		-40	150	°C
V <sub>SYS</sub>	System supply voltage		-0.3	6.0	V
V <sub>PIN</sub>	Voltage on pins		-0.3	6.0	V

#### 3.2 Recommended Operating Conditions

**Table 4: Recommended Operating Conditions**

Parameter	Description	Conditions (Note 1)	Min	Typ	Max	Unit
V <sub>SYS</sub>	System supply voltage		2.5		5.5	V
V <sub>PIN</sub>	Voltage on pins		-0.3		V <sub>SYS</sub> + 0.3	V
T <sub>J</sub>	Junction temperature		-40		125	°C
T <sub>A</sub>	Ambient temperature		-40		85	°C

**Note 1** Within the specified limits, a lifetime of 10 years is guaranteed. If operating outside of these recommended conditions, please consult with Dialog Semiconductor.



## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 3.3 Thermal Characteristics

#### 3.3.1 Thermal Ratings

Table 5: Package Ratings

Parameter	Description	Conditions	Min	Typ	Max	Unit
$\theta_{JA}$	Package thermal resistance <a href="#">Note 1</a>			32.7		°C/W

**Note 1** Obtained from package thermal simulation, 2S2P4L board (JEDEC), influenced by PCB technology and layout.

#### 3.3.2 Power Dissipation

Table 6: Power Dissipation

Parameter	Description	Conditions	Min	Typ	Max	Unit
$P_D$	Power dissipation	Derating factor above $T_A = 70^\circ\text{C}$ : 30.6 mW/°C ( $1/\theta_{JA}$ )		2140		mW

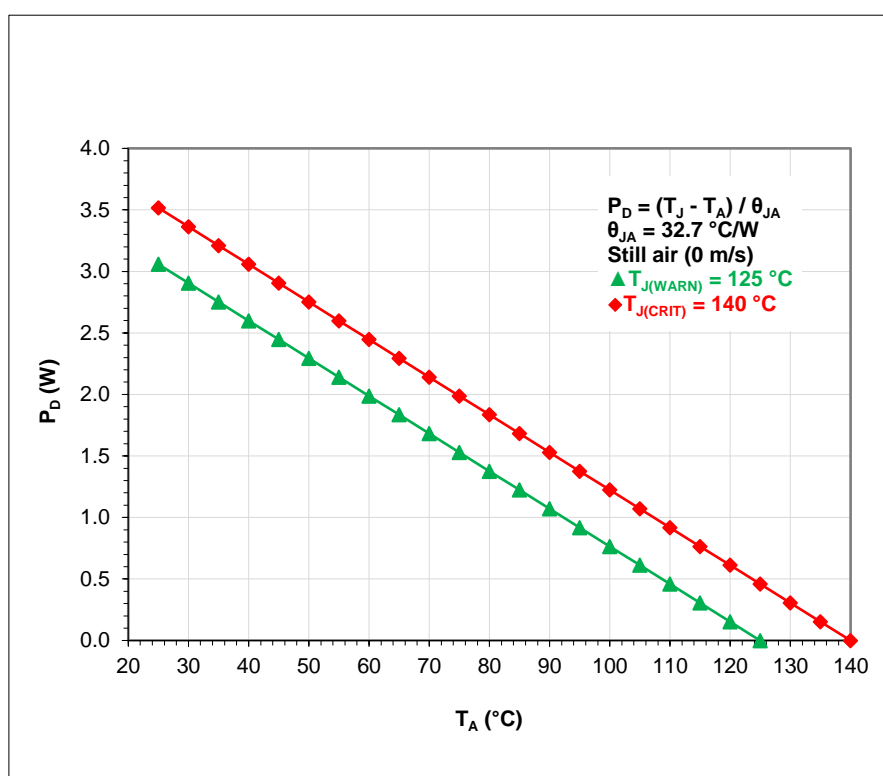


Figure 5: 24WLCSP Power Derating Curve

### 3.4 ESD Characteristics

Table 7: ESD Characteristics

Parameter	Description	Conditions	Min	Typ	Max	Unit
$V_{ESD\_HBM}$	ESD protection, human body model (HBM)				2	kV

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 3.5 Buck Characteristics

Unless otherwise noted, the following is valid for  $T_J = -40\text{ }^{\circ}\text{C}$  to  $+125\text{ }^{\circ}\text{C}$ ,  $V_{SYS} = 2.5\text{ V}$  to  $5.5\text{ V}$ .

**Table 8: Buck Electrical Characteristics**

Parameter	Description	Conditions	Min	Typ	Max	Unit
<b>External Electrical Conditions</b>						
$V_{IN}$	Input voltage	$V_{IN} = V_{SYS}$	2.5		5.5	V
$C_{OUT}$	Output capacitance, per phase, including voltage and temperature coefficient		-40 %	2 x 10	+30 %	$\mu\text{F}$
$ESR_{COUT}$	Output capacitor series resistance, per phase	$f > 100\text{ kHz}$		2		m $\Omega$
L	Inductor value, per phase, including current and temperature dependence		-50 %	0.1	+20 %	$\mu\text{H}$
$DCR_L$	Inductor DC resistance			30	50	m $\Omega$
<b>Electrical Performance</b>						
$V_{OUT}$	Output voltage, programmable in 10 mV steps	$I_{OUT} = 0\text{ mA}$ to $I_{MAX}$ $V_{IN} = 2.5\text{ V}$ to $5.5\text{ V}$	0.3		1.57	V
$V_{OUT\_LIM}$	Output voltage, programmable in 10 mV steps	$I_{OUT} = 0\text{ mA}$ to $I_{MAX}$ $V_{IN} = 3.0\text{ V}$ to $5.5\text{ V}$	0.3		1.9	V
$I_{LIM}$	Current limit, programmable per phase <a href="#">Note 1</a>	$CHx\_ILIM = 1010$	-20 %	8	+20 %	A
$V_{OUT\_ACC}$	Output voltage accuracy, including static line and load regulation	$V_{OUT} \geq 1\text{ V}$	-1		1	%
$V_{OUT\_ACC}$	Output voltage accuracy, including static line and load regulation	$V_{OUT} < 1\text{ V}$	-10		10	mV
$V_{THR\_PG\_RISE}$	Power good voltage threshold for rising	$V_{OUT} = V_{BUCK}$	-80	-50	-20	mV
$V_{THR\_PG\_DWN}$	Power good voltage threshold for falling	$V_{OUT} = V_{BUCK}$	-160	-130	-100	mV
$V_{THR\_HV}$	High $V_{OUT}$ voltage threshold	$V_{OUT} = V_{BUCK}$	100	150	200	mV
$V_{OUT\_TR\_LINE}$	Line transient response	$V_{IN} = 3\text{ V}$ to $3.6\text{ V}$ $I_{OUT} = 0.5 \cdot I_{MAX}$ $dt = 10\text{ }\mu\text{s}$		15		mV
$f_{SW}$	Switching frequency, post-trim			4		MHz

## High-Performance, 10 A, Dual-Phase DC-DC Converter

Parameter	Description	Conditions	Min	Typ	Max	Unit
t <sub>ON_MIN</sub>	Minimum turn-on pulse 0 % duty is also supported			20		ns
t <sub>BUCK_EN</sub>	Turn-on time	CH <sub>x</sub> _EN = high			20	µs
R <sub>PD</sub>	Output pull-down resistance for each phase at the LX node, see BUCK<x>_PD_DIS	V <sub>IN</sub> = 3.7 V V <sub>OUT</sub> = 0.5 V	100	150	200	Ω
R <sub>ON_P MOS</sub>	On resistance of switching PMOS, per phase	V <sub>IN</sub> = 3.7 V		36		mΩ
R <sub>ON_N MOS</sub>	On resistance of switching NMOS, per phase	V <sub>IN</sub> = 3.7 V		17		mΩ
<b>AUTO Mode</b>						
V <sub>OUT_TR_LD_2 PH</sub>	Load transient response, phase shedding enabled	V <sub>OUT</sub> = 1 V I <sub>OUT</sub> = 0 A to 10 A dI/dt = 10 A/µs		±5		%
<b>PFM Mode</b>						
I <sub>Q_PFM_2PH</sub>	Quiescent current in PFM	V <sub>IN</sub> = 3.7 V No load No switching		164		µA

**Note 1** t<sub>ON</sub> > 40 ns

### 3.6 Performance and Supervision Characteristics

**Table 9: Electrical Characteristics**

Parameter	Description	Conditions	Min	Typ	Max	Unit
<b>Electrical Performance</b>						
V <sub>THR_POR</sub>	Power-on-reset threshold	Threshold for AVDD falling		2.1	2.25	V
V <sub>THR_POR_HYS</sub>	Power-on-reset hysteresis			200		mV
T <sub>WARN</sub>	Thermal warning temperature threshold		115	125	135	°C
T <sub>CRIT</sub>	Thermal shutdown temperature threshold		130	140	150	°C
I <sub>IN_OFF</sub>	Supply current	OFF state T <sub>A</sub> = 27 °C IC_EN = 0		0.1	1	µA

## High-Performance, 10 A, Dual-Phase DC-DC Converter

Parameter	Description	Conditions	Min	Typ	Max	Unit
$I_{IN\_ON}$	Supply current	ON state $T_A = 27\text{ °C}$ $IC\_EN = 1$ Buck off	5	10	20	$\mu\text{A}$

### 3.7 Digital IO Characteristics

**Table 10: Digital I/O Electrical Characteristics**

Parameter	Description	Conditions	Min	Typ	Max	Unit
<b>Electrical Performance</b>						
$V_{IH\_EN}$	Input high voltage, IC enable		1.2		AVDD	V
$V_{IL\_EN}$	Input low voltage, IC enable				0.4	V
$t_{IC\_EN}$	IC enable time				1000	$\mu\text{s}$
$V_{IH\_GPIO\_SCL\_SDA}$	Input high voltage GPIO, SCL, SDA		1.2		AVDD	V
$V_{IL\_GPIO\_SCL\_SDA}$	Input low voltage GPIO, SCL, SDA				0.4	V
$V_{OH\_GPIO}$	Output high voltage GPIO	Push-pull mode $I_{OUT} = 1\text{ mA}$	$0.8 \cdot AVDD$		AVDD	V
$V_{OL\_GPIO}$	Output low voltage GPIO	Push-pull mode $I_{OUT} = 1\text{ mA}$			$0.2 \cdot AVDD$	V
$V_{OL\_SDA}$	Output low voltage SDA	$I_{OUT} = 3\text{ mA}$		0.24		V
$R_{PD}$	GPIO pull-down resistor		2	10	120	$k\Omega$
$R_{PU}$	GPIO pull-up resistor		2	10	120	$k\Omega$

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 3.8 Timing Characteristics

**Table 11: I2C Electrical Characteristics**

Parameter	Description	Conditions	Min	Typ	Max	Unit
<b>Electrical Performance</b>						
t <sub>BUS</sub>	Bus free time between a STOP and START condition		0.5			µs
C <sub>BUS</sub>	Bus line capacitive load				150	pF
f <sub>SCL</sub>	SCL clock frequency		20 Note 1		1000	kHz
t <sub>LO_SCL</sub>	SCL low time		0.5			µs
t <sub>HI_SCL</sub>	SCL high time		0.26			µs
t <sub>RISE</sub>	SCL and SDA rise time	Requirement for input			1000	ns
t <sub>FALL</sub>	SCL and SDA fall time	Requirement for input			300	ns
t <sub>SETUP_START</sub>	Start condition setup time		0.26			µs
t <sub>HOLD_START</sub>	Start condition hold time		0.26			µs
t <sub>SETUP_STOP</sub>	Stop condition setup time		0.26			µs
t <sub>DATA</sub>	Data valid time				0.45	µs
t <sub>DATA_ACK</sub>	Data valid acknowledge time				0.45	µs
t <sub>SETUP_DATA</sub>	Data setup time		50			ns
t <sub>HOLD_DATA</sub>	Data hold time		0			ns

**Note 1** Minimum clock frequency is limited to 20 kHz if I2C\_TIMEOUT is enabled

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 3.9 Typical Performance

Unless otherwise noted,  $V_{IN} = 3.7\text{ V}$ ,  $V_{OUT} = 1.0\text{ V}$ ,  $T_A = 25\text{ }^{\circ}\text{C}$ , 2.0 mm x 1.6 mm 0.1  $\mu\text{H}$  per-phase output inductors (DCR = typ. 11.5 m $\Omega$ ) and 4 x 10  $\mu\text{F}$  output capacitors.

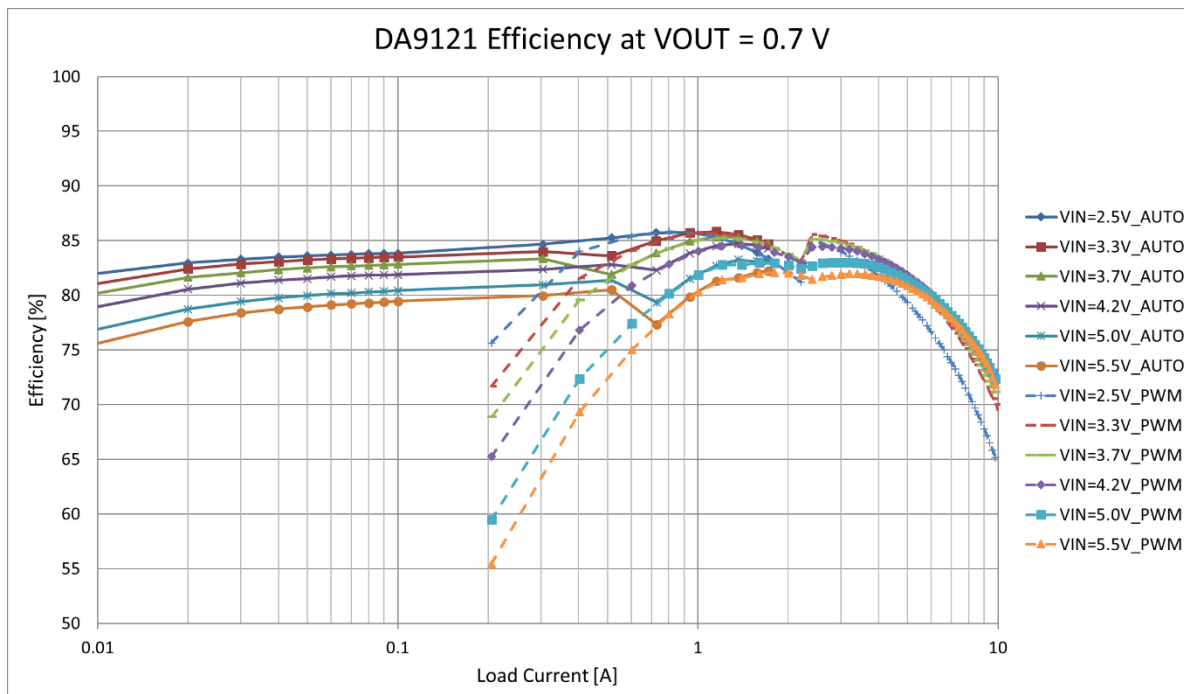


Figure 6: Efficiency v Load,  $V_{OUT} = 0.7\text{ V}$

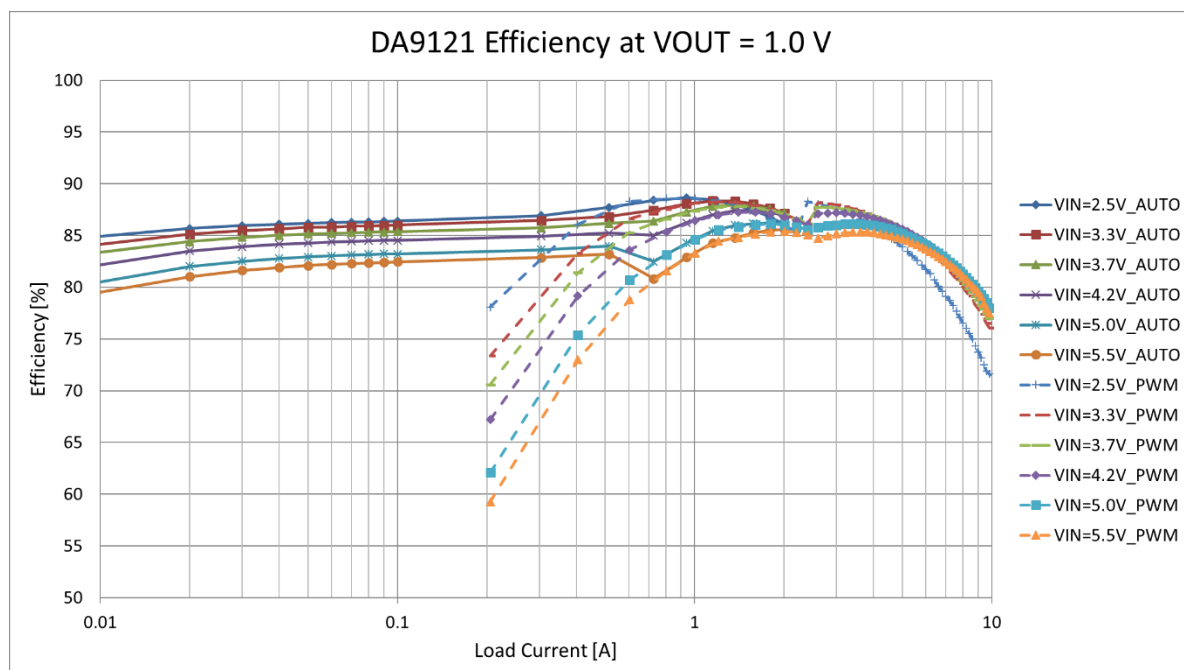
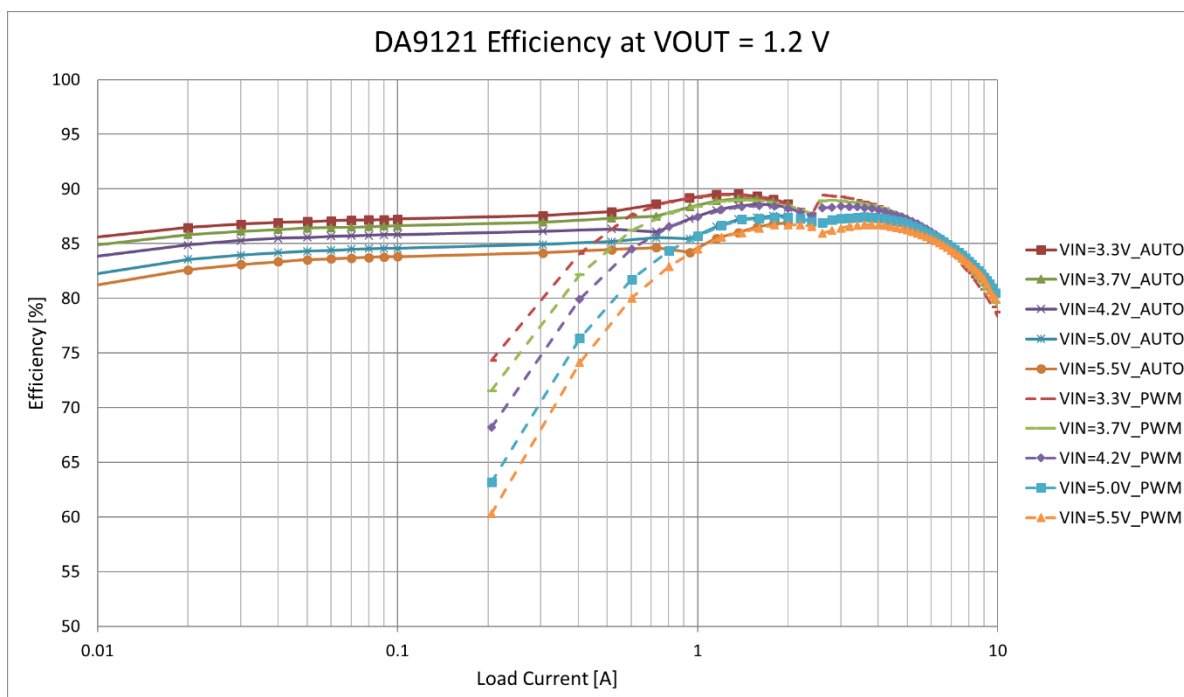
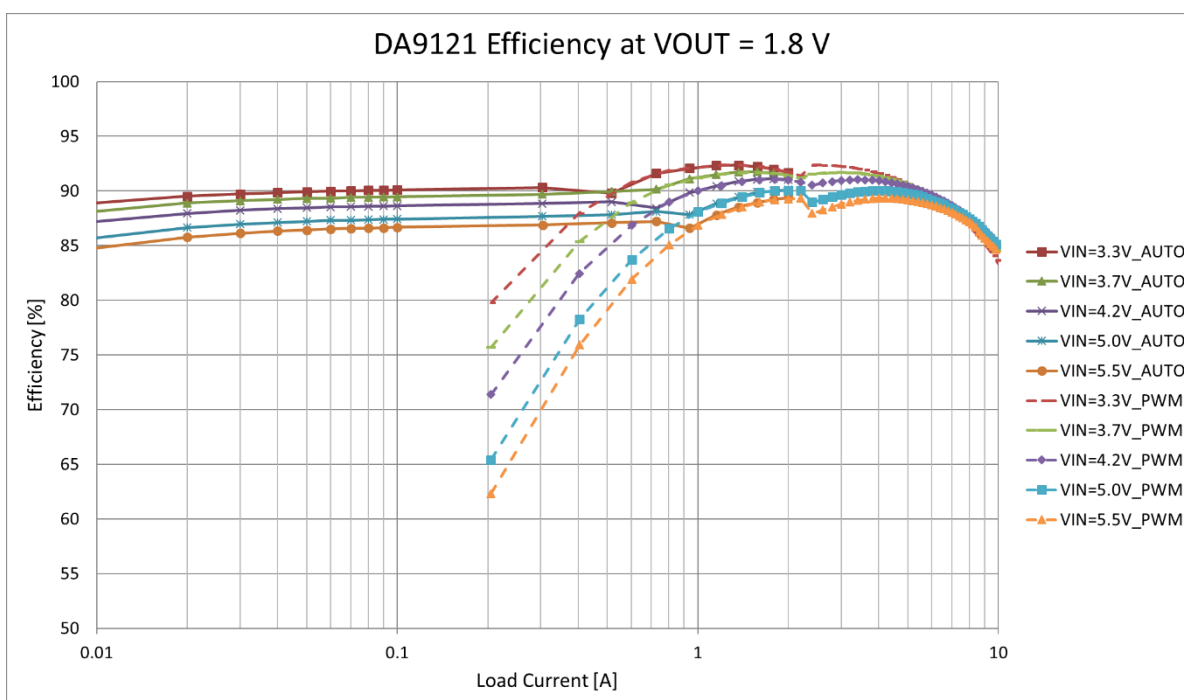
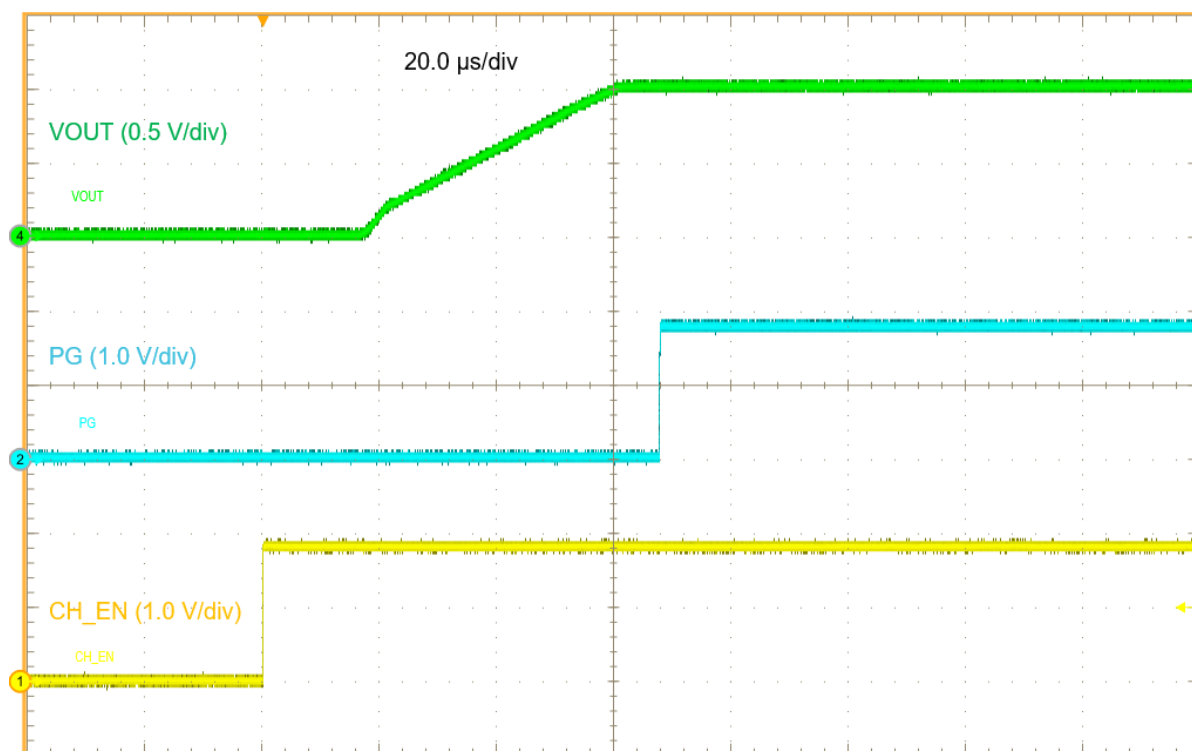
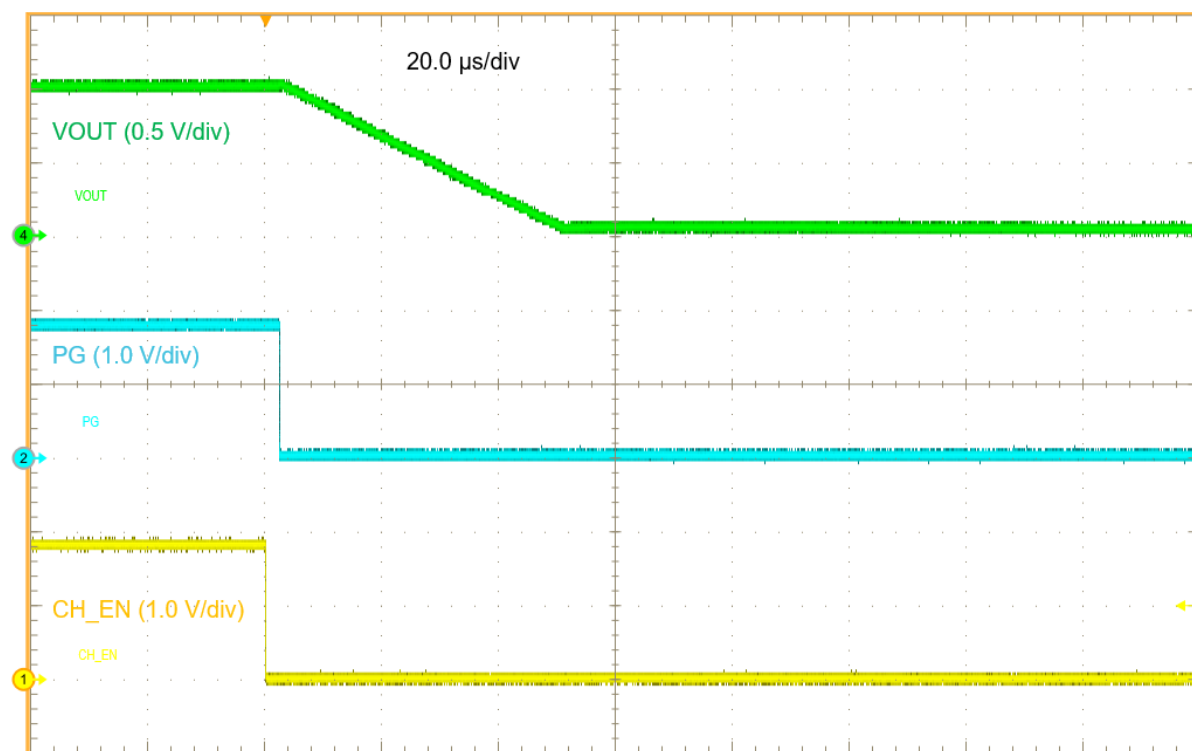


Figure 7: Efficiency vs Load,  $V_{OUT} = 1.0\text{ V}$

## High-Performance, 10 A, Dual-Phase DC-DC Converter

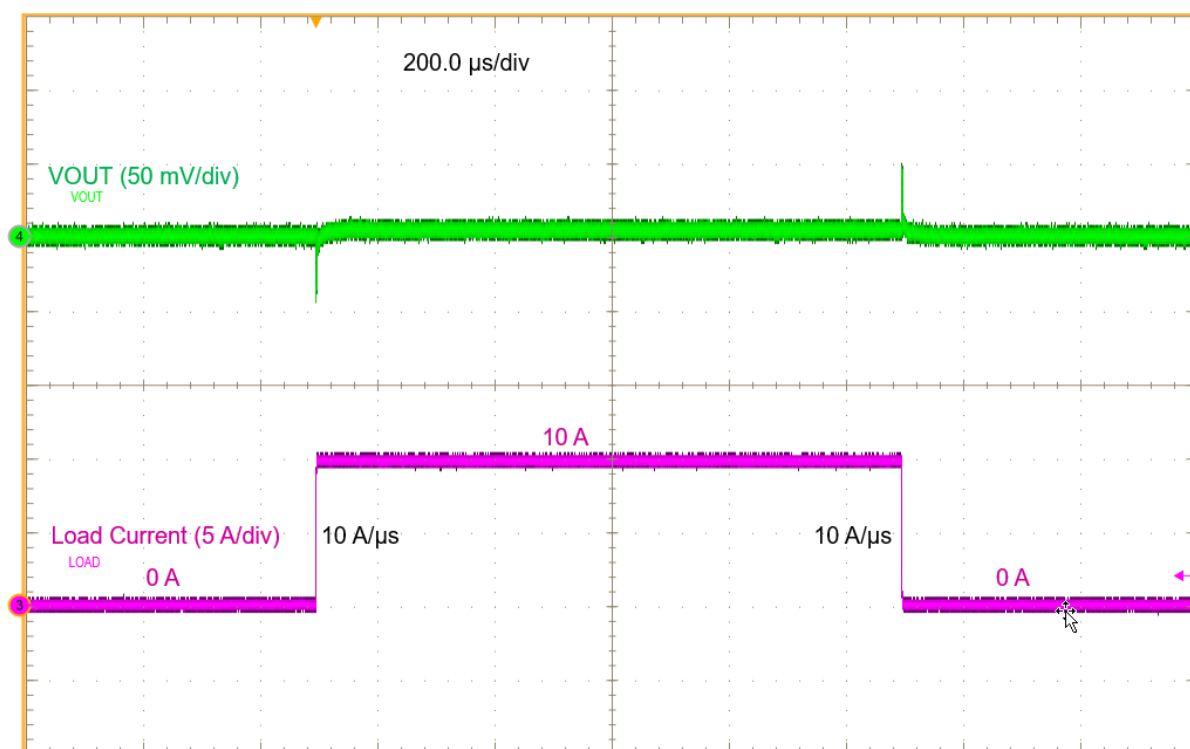
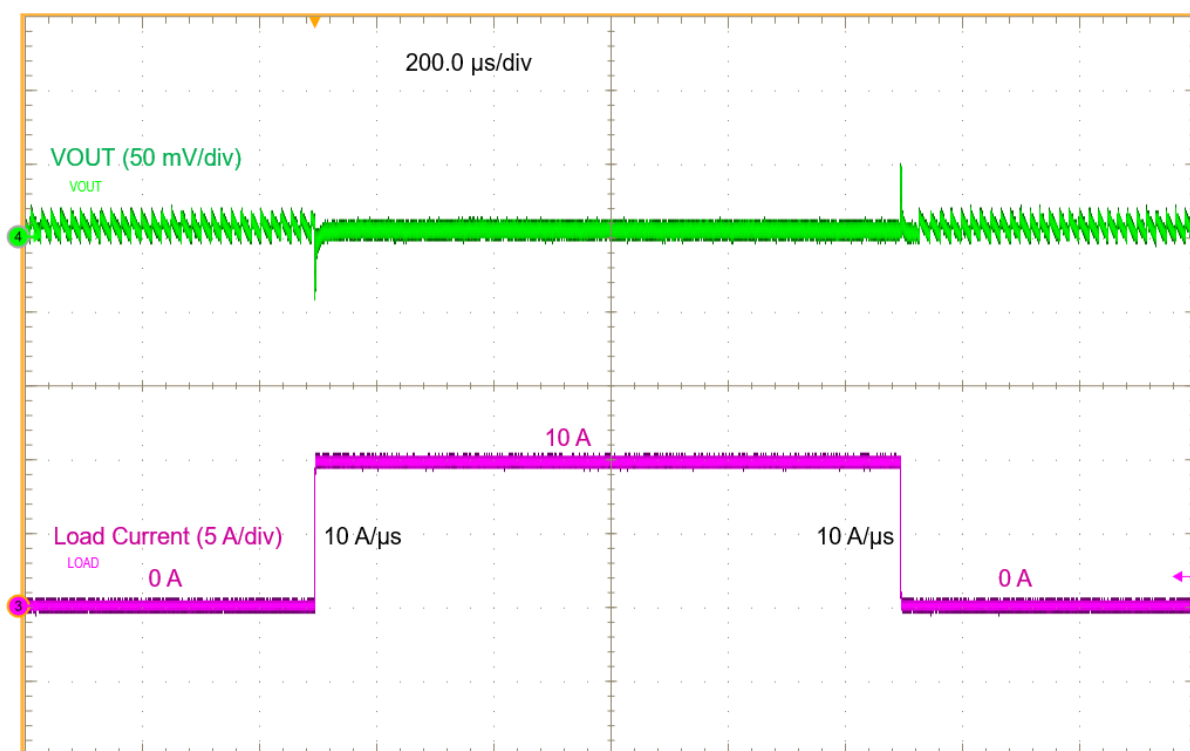
Figure 8: Efficiency vs Load,  $V_{OUT} = 1.2\text{ V}$ Figure 9: Efficiency vs Load,  $V_{OUT} = 1.8\text{ V}$

## High-Performance, 10 A, Dual-Phase DC-DC Converter

Figure 10: Buck Soft Start-up at 20 mV/ $\mu$ s Slew RateFigure 11: Buck Active Shutdown at 20 mV/ $\mu$ s Slew Rate



## High-Performance, 10 A, Dual-Phase DC-DC Converter

Figure 12: Buck Load Transient Response in PWM Mode, 0 A to 10 A at 10 A/ $\mu\text{s}$ Figure 13: Buck Load Transient Response in AUTO Mode, 0 A to 10 A at 10 A/ $\mu\text{s}$

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 4 Functional Description

#### 4.1 DC-DC Buck Converter

DA9121 operates as a single-channel dual-phase buck converter capable of delivering up to 10 A output current at a 0.3 V to 1.9 V output voltage range.

The buck converter has two voltage registers. One defines the normal output voltage, while the other offers an alternative retention voltage. In this way, different application power modes can easily be supported. The voltage selection can be operated either via GPI or via control interface to guarantee the maximum flexibility according to the specific host processor status in the application.

When a buck is enabled, its output voltage is monitored and a power good signal indicates that the buck output voltage has reached a level higher than the  $V_{THR\_PG\_RISE}$  threshold. The power good status is lost when the voltage drops below  $V_{THR\_PG\_DWN}$  or increases above  $V_{THR\_HV}$ . The status of the power good indicator can be read back via I<sup>2</sup>C from the PG1 status bit. It can be also individually assigned to any of the GPIOs by setting the GPIO mode registers to PG1 output.

The buck converter is capable of supporting DVC transitions that occur when:

- the active and selected A- or B-voltage is updated to a new target value
- the voltage selection is changed from the A- to B-voltage (or B- to A-voltage) using CH1\_VSEL

The DVC controller operates in pulse width modulation (PWM) mode with synchronous rectification.

The slew rate of the DVC transition is programmed at 10 mV per 8  $\mu$ s, 4  $\mu$ s, 2  $\mu$ s, 1  $\mu$ s, or 0.5  $\mu$ s in register bits CH1\_SR\_DVC.

A pull-down resistor (typically 150  $\Omega$ ) for each phase is always activated unless it is disabled by setting register bits CH1\_PD\_DIS to 1.

##### 4.1.1 Switching Frequency

The buck switching frequency can be tuned using register bit OSC\_TUNE. The internal 8 MHz oscillator frequency is tuned in  $\pm 160$  kHz steps. This impacts the buck converter frequency in steps of 80 kHz and helps to mitigate possible disturbances to other high frequency systems in the application.

##### 4.1.2 Operation Modes and Phase Selection

The buck converters can operate in PWM and PFM modes. The operating mode is selected using register bits CH1\_<A or B>\_MODE.

Phase shedding automatically changes between 1- and 2-phase operation at a typical current of 2.0 A.

If the automatic operation mode is selected on CH1\_<A or B>\_MODE, the buck converter automatically changes between synchronous PWM mode and PFM depending on the load current. This improves the efficiency across the whole range of output load currents.

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 4.1.3 Output Voltage Selection

The switching converter can be configured using the I<sup>2</sup>C interface.

Two output voltages can be pre-configured in registers CH1\_<A or B>\_VOUT. The output voltage can be selected by either toggling register bit CH1\_VSEL or by re-programming the selected voltage control register. Both changes will result in ramped voltage transitions. After being enabled, the buck converter will, by default, use the register settings in CH1\_A\_VOUT unless the output voltage selection is configured via the GPI port.

Registers CH1\_VMAX limit the output voltage that can be set for each of the respective buck converters.

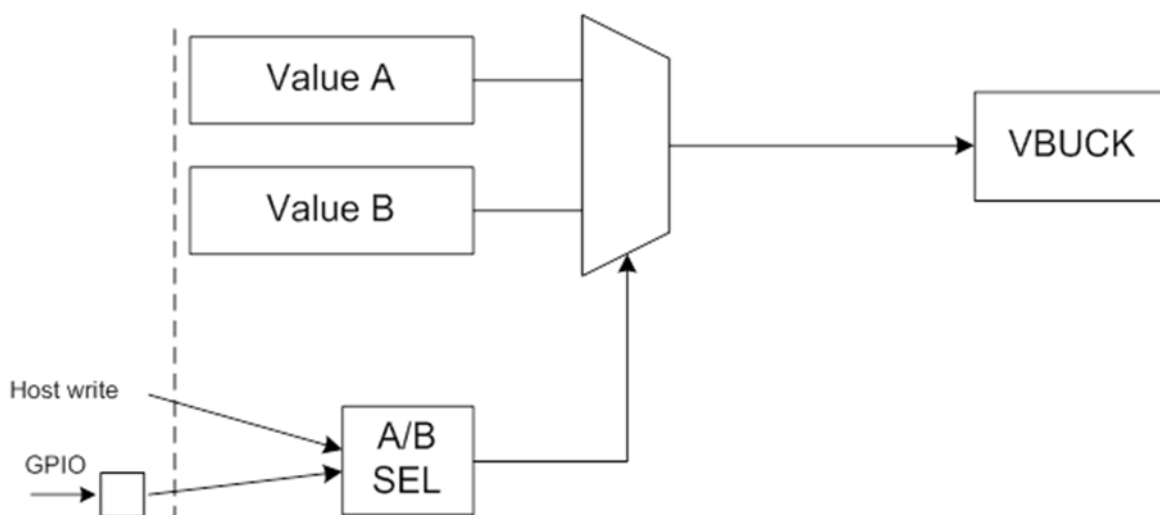


Figure 14: Buck Output Voltage Control Concept

### 4.1.4 Soft Start-Up and Shutdown

To limit in-rush current from V<sub>SYS</sub>, the buck converter can perform a soft-start after being enabled. The start-up behavior is a compromise between acceptable inrush current from the battery and turn-on time. Ramp times can be configured in register CH1\_SR\_STARTUP. Rates higher than 20 mV/μs may produce overshoot during the start-up phase, so it should be considered carefully.

A ramped power down can be selected in register bits CH1\_SR\_SHDN. When no ramp is selected (immediate power down), the output node will be discharged only by the pull-down resistor, if enabled in register CH1\_PD\_DIS.

### 4.1.5 Current Limit

The integrated current limit protects the power stages and external coil from excessive current. The buck current limit should be configured to at least 40 % higher than the required maximum output current.

When the current limit is reached, the buck converter generates an event and an interrupt to the host processor unless the interrupt has been masked using register M\_OC1 in SYS\_MASK\_1. Register bit OC\_DVC\_MASK is used to mask over-current events during DVC transitions.

## High-Performance, 10 A, Dual-Phase DC-DC Converter

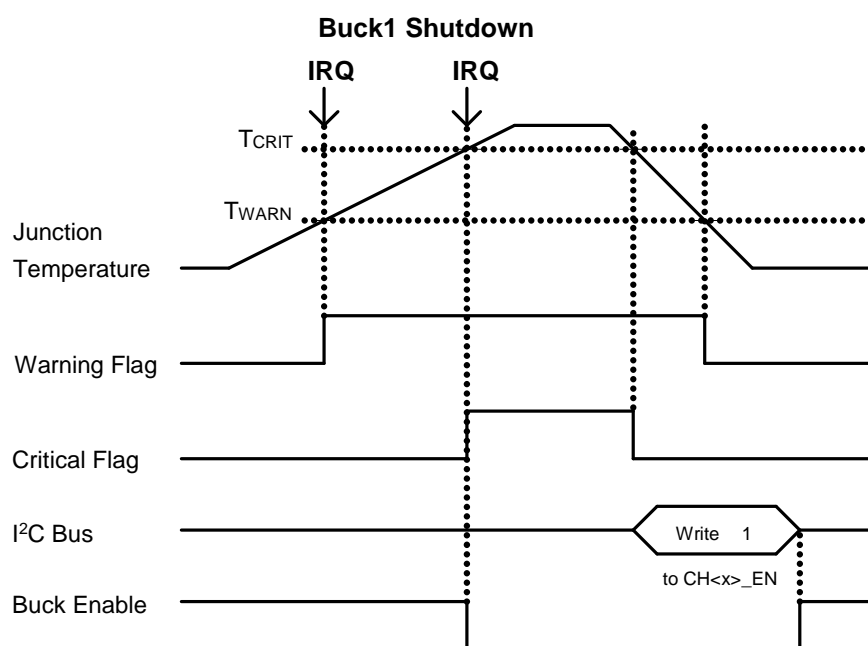
### 4.1.6 Thermal Protection

DA9121 is protected from internal overheating by thermal shutdown.

There are two kinds of flags concerning thermal protection, thermal warning and thermal critical. The warning flag is asserted when  $T_J > T_{WARN}$  and the critical flag is asserted when  $T_J > T_{CRIT}$ . When the critical flag is asserted, Buck1 is shut down immediately.

**Table 12: Thermal Protection Control Registers**

Category	Register name	Description
Status	TEMP_WARN	Asserted as long as the thermal warning threshold is reached
	TEMP_CRIT	Asserted as long as the thermal shutdown threshold is reached
IRQ event	E_TEMP_WARN	TEMP_WARN caused event
	E_TEMP_CRIT	TEMP_CRIT caused event
IRQ mask	M_TEMP_WARN	TEMP_WARN event IRQ mask
	M_TEMP_CRIT	TEMP_CRIT event IRQ mask
	M_VR_HOT	TEMP_WARN status IRQ mask



**Figure 15: Thermal Protection Operation**

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 4.2 Internal Circuits

#### 4.2.1 IC\_EN/Chip Enable/Disable

IC\_EN is chip enable/disable control input. When IC\_EN = 0, all blocks except for low I<sub>Q</sub> POR are powered-down and buck output is pulled-down.

#### 4.2.2 nIRQ/Interrupt

The interrupt triggers events. Trigger conditions and control registers for each interrupt event are listed in [Table 13](#).

Some of these events are categorized as fault events and affect device operation (for example, buck disable), see [Section 4.1.6](#).

**Table 13: Interrupt List**

Name	Polarity ( <a href="#">Note 1</a> )	Trigger	IRQ Status Register	IRQ Mask Register	Deglintch Period
Thermal warning (event)	N	T <sub>J</sub> rising above T <sub>WARN</sub>	E_TEMP_WARN	M_TEMP_WARN	0 s
Thermal critical (event)	N	T <sub>J</sub> rising above T <sub>CRIT</sub>	E_TEMP_CRIT	M_TEMP_CRIT	0 s
Buck1 power-good (event)	P	Buck1 V <sub>OUT</sub> is in power-good voltage range (not under- or over-voltage)	E_PG1	M_PG1	0 s
Buck1 over-voltage (event)	N	Buck1 V <sub>OUT</sub> rising above over-voltage threshold (target voltage + 150 mV)	E_OV1	M_OV1	Rise: 8 µs Fall: 8 µs
Buck1 under-voltage (event)	N	Buck1 V <sub>OUT</sub> falling below under-voltage threshold (target voltage - V <sub>TH_PG</sub> )	E_UV1	M_UV1	0 s
Buck1 over-current (event)	N	Buck1 current rising above over-current threshold	E_OC1	M_OC1	0 s
Buck1 power-good (status) ( <a href="#">Note 2</a> )	P	Buck1 V <sub>OUT</sub> is in power-good voltage range (not under- or over-voltage)	PG1	M_PG1_STAT ( <a href="#">Note 3</a> )	0 s
Thermal warning (status) ( <a href="#">Note 2</a> )	N	T <sub>J</sub> rising above T <sub>WARN</sub>	TEMP_WARN	M_VR_HOT ( <a href="#">Note 3</a> )	0 s
GPIO0 change (event)	N	Detect GPIO0 change for active trigger selected GPIO0_TRIG register	E_GPIO0	M_GPIO0	100 µs/ 1 ms/ 10 ms/ 100 ms
GPIO1 change (event)	N	Detect GPIO1 change for active trigger selected GPIO1_TRIG register	E_GPIO1	M_GPIO1	

## High-Performance, 10 A, Dual-Phase DC-DC Converter

Name	Polarity (Note 1)	Trigger	IRQ Status Register	IRQ Mask Register	Deglitch Period
GPIO2 change (event)	N	Detect GPIO2 change for active trigger selected GPIO2_TRIG register	E_GPIO2	M_GPIO2	

**Note 1** Polarity at the source of the flag: P = active-high, N = active-low.

General rule is: normal system state is high, and abnormal system state is low (for example, PG = high means power-good, TEMP\_CRIT = low when TEMP critical state).

**Note 2** Interrupt outputs the status as is. I<sup>2</sup>C write is not required for interrupt clear.

**Note 3** OTP load value defined by CONF pin setting if CONF\_EN = 1.

**Table 14: Interrupt Registers Except for Power Good Status**

Register	Description
E_<name>	Read-only interrupt event register 0: No interrupt 1: Interrupt occurred <b>Cleared after being written to I<sup>2</sup>C.</b> Set until IRQ is removed.
M_<name>	Interrupt mask register 0: Not masked 1: Masked. No IRQ signal sent. Event register (E_<name>) is updated.

**Table 15: Interrupt Registers for Power Good and Temp Warning Status**

Register	Description
PG<x>	Buck<x> power good status. Asserted as long as the buck<x> output voltage is in range (under-voltage threshold < buck output voltage < over-voltage threshold) 0: Not power good 1: Power good
M_PG<x>_STAT	Power good status interrupt mask register 0: Not masked 1: Masked. No IRQ signal sent. Power good status register (PG<x>) is updated
TEMP_WARN	Asserted as long as the thermal warning threshold (T <sub>WARN</sub> ) is reached 0: Junction temperature is below T <sub>WARN</sub> 1: Junction temperature is above T <sub>WARN</sub>
M_VR_HOT	Temperature warning status (TEMP_WARN) interrupt mask register 0: Not masked 1: Masked. No IRQ signal sent. Temperature warning status register (TEMP_WARN) is updated

## High-Performance, 10 A, Dual-Phase DC-DC Converter

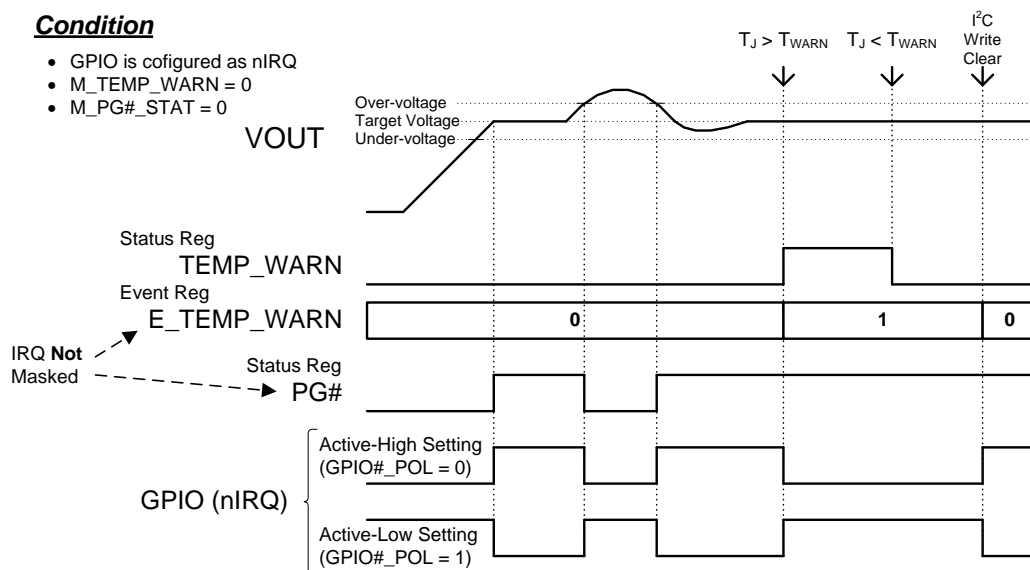


Figure 16: Interrupt Operation Example

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 4.2.3 GPIO

#### 4.2.3.1 GPIO Pin Assignment

The DA9121 provides up to five GPIO pins, three if the I<sup>2</sup>C is enabled, see [Table 16](#). These registers are OTP programmable. When CONF\_EN = 1 GPIO0 can be used for chip configuration.

Any register settings for GPIO3 and GPIO4 are ignored and GPIO3 and GPIO4 function as SCL and SDA respectively if I2C\_EN = 1.

**Table 16: GPIO Pin Assignment**

OTP Option		GPIO Pin					Available GPIOs
I2C_EN	CONF_EN	CONF/ GPIO0	GPIO1	GPIO2	SCL/ GPIO3	SDA/ GPIO4	
1'b0	1'b0	GPIO0	GPIO1	GPIO2	GPIO3	GPIO4	5
	1'b1	CONF	GPIO1	GPIO2	GPIO3	GPIO4	4
1'b1	1'b0	GPIO0	GPIO1	GPIO2	SCL	SDA	3
	1'b1	CONF	GPIO1	GPIO2	SCL	SDA	2

#### 4.2.3.2 GPIO Function

The GPIOs pins are configurable as the following functions in register GPIO<x>\_MODE (x = 0 to 4):

- Buck1 enable input (EN1)
- Buck1 DVC control input (DVC1)
- Buck1 OTP setting reload input (RELOAD)
- Buck1 power good output (PG1)
- Interrupt output (nIRQ)

**Table 17: GPIO Function Configuration**

GPIO<x>_MODE[3:0]	Function	IO Condition
4'h0	GPIO disable	HiZ
4'h1	EN1	In
4'h2	Reserved	In
4'h3	Reserved	In
4'h4	DVC1	In
4'h5	Reserved	In
4'h6	Reserved	In
4'h7	RELOAD	In
4'h8	PG1	Out
4'h9	Reserved	Out
4'hA	Reserved	Out
4'hB	Reserved	Out
4'hC	nIRQ	Out
4'hD	Reserved	HiZ
4'hE	Low level	Out
4'hF	High level	Out



## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 4.2.3.3 Chip Configuration Select (CONF)

GPIO0 functions as chip configuration select (CONF) input when CONF\_EN = 1.

Three different chip configurations can be selected according to the CONF pin level, whether it is HIGH, LOW, or Hi-Z.

**Table 18: GPIO0-Configurable Registers when CONF\_EN = 1**

Register Name	Description
IF_SLAVE_ADDR[6:0]	I2C slave address
CH1_A_MODE[1:0]	CH1_A Operation mode select
CH1_B_MODE[1:0]	CH1_B Operation mode select
CH1_VSEL	CH1 output voltage and operation selection
CH1_EN	CH1 enable
CH1_A_VOUT[7:0]	CH1 output voltage setting A
CH1_B_VOUT[7:0]	CH1 output voltage setting B
M_PG1_STAT	IRQ mask setting for CH1 power good status
M_VR_HOT	IRQ mask setting for temp warning status
GPIO1_MODE[3:0]	GPIO1 mode setting
GPIO2_MODE[3:0]	GPIO2 mode setting
GPIO1_OBUF	GPIO1 output buffer select
GPIO2_OBUF	GPIO2 output buffer select
GPIO1_TRIG[1:0]	GPIO1 input trigger select
GPIO1_POL	GPIO1 polarity select
GPIO1_PUPD	GPIO1 pull-up/pull-down enable
GPIO1_DEB[1:0]	GPIO1 input debounce time setting
GPIO1_DEB_RISE	GPIO1 input debounce rising edge enable
GPIO1_DEB_FALL	GPIO1 input debounce falling edge enable
GPIO2_TRIG[1:0]	GPIO2 input trigger select
GPIO2_POL	GPIO2 polarity select
GPIO2_PUPD	GPIO2 pull-up/pull-down enable
GPIO2_DEB[1:0]	GPIO2 input debounce time setting
GPIO2_DEB_RISE	GPIO2 input debounce rising edge enable
GPIO2_DEB_FALL	GPIO2 input debounce falling edge enable

## 4.3 Operating Modes

### 4.3.1 ON

DA9121 is ON when the IC\_EN port is higher than  $V_{IH\_EN}$  and the supply voltage is higher than  $V_{THR\_POR}$ . Once enabled, the host processor can start communicating with DA9121 using the control interface, after the  $t_{IC\_EN}$  delay.

### 4.3.2 OFF

DA9121 is OFF when the IC\_EN port is lower than  $V_{IL\_EN}$ . In OFF, the bucks are always disabled and LX nodes are pulled down by (typically 150  $\Omega$ ) internal pull-down resistors.

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 4.4 I<sup>2</sup>C Communication

All features of DA9121 can be controlled with the I<sup>2</sup>C interface which is enabled or disabled in register I2C\_EN.

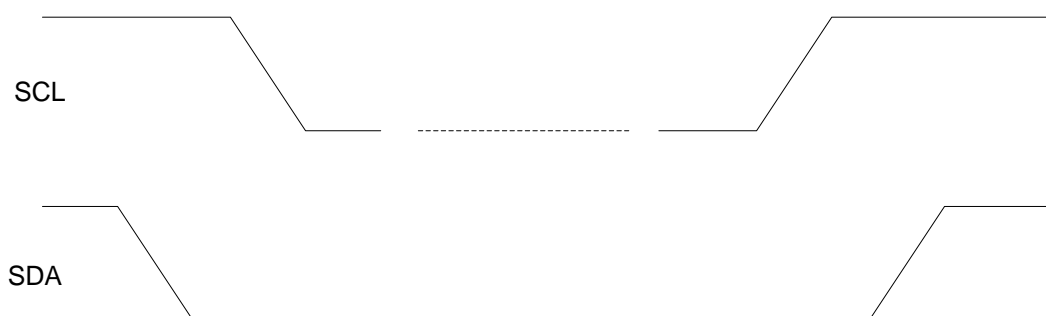
I2C_EN	Description
0	I <sup>2</sup> C disable: SCL/GPIO3 and SDA/GPIO4 pins can be used as GPIO
1	I <sup>2</sup> C enable: SCL/GPIO3 and SDA/GPIO4 pins are used as I <sup>2</sup> C clock input and I <sup>2</sup> C data input/output.

GPIO3 functions as the I<sup>2</sup>C clock and GPIO4 carries all the power manager bidirectional I<sup>2</sup>C data. The I<sup>2</sup>C interface is open-drain supporting multiple devices on a single line. The bus lines have to be pulled high by external pull-up resistors (2 kΩ to 20 kΩ). The standard frequency of the I<sup>2</sup>C bus is 1 MHz in fast-mode plus (FM+), 400 kHz in fast-mode, or 100 kHz in standard mode.

#### 4.4.1 I<sup>2</sup>C Protocol

All data is transmitted across the I<sup>2</sup>C bus in eight-bit groups. To send a bit, the SDA line is driven towards the intended state while the SCL is low (a low SDA indicates a zero bit). Once the SDA has settled, the SCL line is brought high and then low. This pulse on SCL clocks the SDA bit into the receiver's shift register.

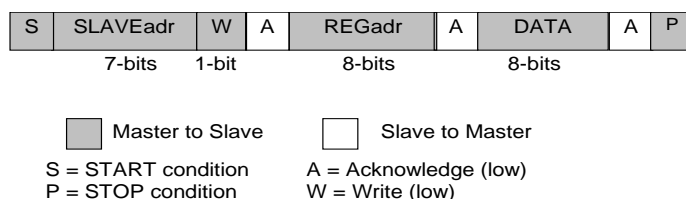
A two-byte serial protocol is used containing one byte for address and one byte data. Data and address transfer are transmitted MSB first for both read and write operations. All transmissions begin with the START condition from the master while the bus is in idle state (the bus is free). It is initiated by a high to low transition on the SDA line while the SCL is in the high state (a STOP condition is indicated by a low to high transition on the SDA line while the SCL is in the high state).



**Figure 17: I<sup>2</sup>C START and STOP Condition Timing**

The I<sup>2</sup>C bus is monitored for a valid slave address whenever the interface is enabled. It responds immediately when it receives its own slave address. The acknowledge is done by pulling the SDA line low during the following clock cycle (white blocks marked with A in [Figure 18](#) and [Figure 19](#)).

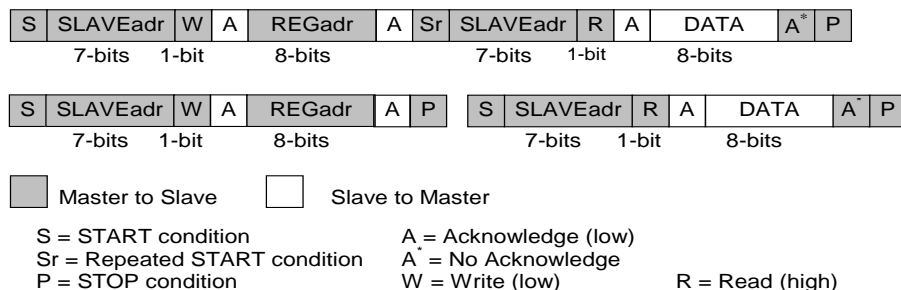
The protocol for a register write from master to slave consists of a START condition, a slave address with read/write bit, and the eight-bit register address followed by eight bits of data, terminated by a STOP condition. DA9121 responds to all bytes with acknowledge (A), see [Figure 18](#).



**Figure 18: I<sup>2</sup>C Byte Write (SDA Line)**

## High-Performance, 10 A, Dual-Phase DC-DC Converter

When the host reads data from a register it first has to write to DA9121 with the target register address and then read from DA9121 with a repeated START, or alternatively a second START, condition. After receiving the data, the host sends no acknowledge (A\*) and terminates the transmission with a STOP condition, see [Figure 19](#).



**Figure 19: I²C Byte Read (SDA Line) Examples**

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 5 Register Definitions

#### 5.1 Register Map

Table 19: Register Map

Addr	Register	7	6	5	4	3	2	1	0
<b>System Module</b>									
<b>System</b>									
0x0001	<a href="#">SYS_STATUS_0</a>	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	TEMP_CRIT	TEMP_WARN
0x0002	<a href="#">SYS_STATUS_1</a>	Reserved	Reserved	Reserved	Reserved	PG1	OV1	UV1	OC1
0x0003	<a href="#">SYS_STATUS_2</a>	Reserved	Reserved	Reserved	Reserved	Reserved	GPIO2	GPIO1	GPIO0
0x0004	<a href="#">SYS_EVENT_0</a>	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	E_TEMP_CRIT	E_TEMP_WARN
0x0005	<a href="#">SYS_EVENT_1</a>	Reserved	Reserved	Reserved	Reserved	E_PG1	E_OV1	E_UV1	E_OC1
0x0006	<a href="#">SYS_EVENT_2</a>	Reserved	Reserved	Reserved	Reserved	Reserved	E_GPIO2	E_GPIO1	E_GPIO0
0x0007	<a href="#">SYS_MASK_0</a>	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	M_TEMP_CRIT	M_TEMP_WARN
0x0008	<a href="#">SYS_MASK_1</a>	Reserved	Reserved	Reserved	Reserved	M_PG1	M_OV1	M_UV1	M_OC1
0x0009	<a href="#">SYS_MASK_2</a>	Reserved	Reserved	Reserved	Reserved	Reserved	M_GPIO2	M_GPIO1	M_GPIO0
0x000A	<a href="#">SYS_MASK_3</a>	Reserved	Reserved	Reserved	Reserved	M_VR_HOT	Reserved	Reserved	M_PG1_STAT
0x000B	<a href="#">SYS_CONFIG_0</a>	Reserved				Reserved			
0x000C	<a href="#">SYS_CONFIG_1</a>	Reserved				Reserved			
0x000D	<a href="#">SYS_CONFIG_2</a>	Reserved	OC_LATCHOFF<1:0>		OC_DVC_MASK	PG_DVC_MASK<1:0>		Reserved	Reserved
0x000E	<a href="#">SYS_CONFIG_3</a>	Reserved	OSC_TUNE<2:0>			Reserved	Reserved	I2C_TIMEOUT	Reserved
0x0010	<a href="#">SYS_GPIO0_0</a>	Reserved	Reserved	Reserved	GPIO0_MODE<3:0>				GPIO0_OBUF
0x0011	<a href="#">SYS_GPIO0_1</a>	GPIO0_D EB_FALL	GPIO0_D EB_RISE	GPIO0_DEB<1:0>		GPIO0_P UPD	GPIO0_POL	GPIO0_TRIG<1:0>	
0x0012	<a href="#">SYS_GPIO1_0</a>	Reserved	Reserved	Reserved	GPIO1_MODE<3:0>				GPIO1_OBUF
0x0013	<a href="#">SYS_GPIO1_1</a>	GPIO1_D EB_FALL	GPIO1_D EB_RISE	GPIO1_DEB<1:0>		GPIO1_P UPD	GPIO1_POL	GPIO1_TRIG<1:0>	
0x0014	<a href="#">SYS_GPIO2_0</a>	Reserved	Reserved	Reserved	GPIO2_MODE<3:0>				GPIO2_OBUF
0x0015	<a href="#">SYS_GPIO2_1</a>	GPIO2_D EB_FALL	GPIO2_D EB_RISE	GPIO2_DEB<1:0>		GPIO2_P UPD	GPIO2_POL	GPIO2_TRIG<1:0>	

## High-Performance, 10 A, Dual-Phase DC-DC Converter

Addr	Register	7	6	5	4	3	2	1	0
Buck Control									
Buck1									
0x0020	BUCK_BUCK1_0	Reserved	CH1_SR_DVC_DWN<2:0>			CH1_SR_DVC_UP<2:0>			CH1_EN
0x0021	BUCK_BUCK1_1	Reserved	CH1_SR_SHDN<2:0>			CH1_SR_STARTUP<2:0>			CH1_PD_DIS
0x0022	BUCK_BUCK1_2	Reserved	Reserved	Reserved	Reserved	CH1_ILIM<3:0>			
0x0023	BUCK_BUCK1_3	CH1_VMAX<7:0>							
0x0024	BUCK_BUCK1_4	Reserved	Reserved	Reserved	CH1_VSEL	CH1_B_MODE<1:0>		CH1_A_MODE<1:0>	
0x0025	BUCK_BUCK1_5	CH1_A_VOUT<7:0>							
0x0026	BUCK_BUCK1_6	CH1_B_VOUT<7:0>							
0x0027	BUCK_BUCK1_7	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	
Serialization									
0x0048	OTP_DEVICE_ID	DEV_ID<7:0>							
0x0049	OTP_VARIANT_ID	MRC<3:0>				VRC<3:0>			
0x004A	OTP_CUSTOMER_ID	CUST_ID<7:0>							
0x004B	OTP_CONFIG_ID	CONFIG_REV<7:0>							

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 5.1.1 System

**Table 20: SYS\_STATUS\_0 (0x0001)**

Bit	Symbol	Description
[1]	TEMP_CRIT	Asserted as long as the thermal shutdown threshold is reached
[0]	TEMP_WARN	Asserted as long as the thermal warning threshold is reached

**Table 21: SYS\_STATUS\_1 (0x0002)**

Bit	Symbol	Description
[3]	PG1	Asserted as long as the Buck1 output voltage is in range
[2]	OV1	Asserted as long as Buck1 hitting over-voltage
[1]	UV1	Asserted as long as Buck1 hitting under-voltage
[0]	OC1	Asserted as long as Buck1 hitting over-current

**Table 22: SYS\_STATUS\_2 (0x0003)**

Bit	Symbol	Description
[2]	GPIO2	GPIO2 status
[1]	GPIO1	GPIO1 status
[0]	GPIO0	GPIO0 status

**Table 23: SYS\_EVENT\_0 (0x0004)**

Bit	Symbol	Description
[1]	E_TEMP_CRIT	TEMP_CRIT caused event. Writing 1 action clear this bit into 0 if event source has been released.
[0]	E_TEMP_WARN	TEMP_WARN caused event. Writing 1 action clear this bit into 0 if event source has been released.

**Table 24: SYS\_EVENT\_1 (0x0005)**

Bit	Symbol	Description
[3]	E_PG1	PG1 caused event. Writing 1 action clear this bit into 0 if event source has been released.
[2]	E_OV1	OV1 caused event. Writing 1 action clear this bit into 0 if event source has been released.
[1]	E_UV1	UV1 caused event. Writing 1 action clear this bit into 0 if event source has been released.
[0]	E_OC1	OC1 caused event. Writing 1 action clear this bit into 0 if event source has been released.

## High-Performance, 10 A, Dual-Phase DC-DC Converter

**Table 25: SYS\_EVENT\_2 (0x0006)**

Bit	Symbol	Description
[2]	E_GPIO2	GPIO2 event. Writing 1 action clear this bit into 0 if event source has been released.
[1]	E_GPIO1	GPIO1 event. Writing 1 action clear this bit into 0 if event source has been released.
[0]	E_GPIO0	GPIO0 event. Writing 1 action clear this bit into 0 if event source has been released.

**Table 26: SYS\_MASK\_0 (0x0007)**

Bit	Symbol	Description
[1]	M_TEMP_CRIT	TEMP_CRIT IRQ mask
[0]	M_TEMP_WARN	TEMP_WARN IRQ mask

**Table 27: SYS\_MASK\_1 (0x0008)**

Bit	Symbol	Description
[3]	M_PG1	PG1 event IRQ mask
[2]	M_OV1	OV1 event IRQ mask
[1]	M_UV1	UV1 event IRQ mask
[0]	M_OC1	OC1 event IRQ mask

**Table 28: SYS\_MASK\_2 (0x0009)**

Bit	Symbol	Description
[2]	M_GPIO2	GPIO2 IRQ mask
[1]	M_GPIO1	GPIO1 IRQ mask
[0]	M_GPIO0	GPIO0 IRQ mask

**Table 29: SYS\_MASK\_3 (0x000A)**

Bit	Symbol	Description
[3]	M_VR_HOT	Temp warning status IRQ mask. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1
[0]	M_PG1_STAT	PG1 status IRQ mask. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1

## High-Performance, 10 A, Dual-Phase DC-DC Converter

**Table 30: SYS\_CONFIG\_2 (0x000D)**

Bit	Symbol	Description										
[6:5]	OC_LATCHOFF	<p>Over-current latch-off setting. BUCK shut-down after OCP for 8 <math>\mu</math>s/1 ms/3 ms unless disable setting. IRQ is generated unless IRQ is masked.</p> <table><thead><tr><th>Value</th><th>Description</th></tr></thead><tbody><tr><td>0x0</td><td>Latch off disable</td></tr><tr><td>0x1</td><td>Latch off after 8 <math>\mu</math>s of OCP signal</td></tr><tr><td>0x2</td><td>Latch off after 1 ms of OCP signal</td></tr><tr><td>0x3</td><td>Latch off after 3 ms of OCP signal</td></tr></tbody></table>	Value	Description	0x0	Latch off disable	0x1	Latch off after 8 $\mu$ s of OCP signal	0x2	Latch off after 1 ms of OCP signal	0x3	Latch off after 3 ms of OCP signal
Value	Description											
0x0	Latch off disable											
0x1	Latch off after 8 $\mu$ s of OCP signal											
0x2	Latch off after 1 ms of OCP signal											
0x3	Latch off after 3 ms of OCP signal											
[4]	OC_DVC_MASK	Over-current event (IRQ and latch-off feature) mask during DVC ramp-up and ramp-down										
[3:2]	PG_DVC_MASK	<p>Power-good mask during DVC</p> <table><thead><tr><th>Value</th><th>Description</th></tr></thead><tbody><tr><td>0x0</td><td>No mask</td></tr><tr><td>0x1</td><td>Mask as not power good during DVC</td></tr><tr><td>0x2</td><td>Mask as power good during DVC</td></tr><tr><td>0x3</td><td>Reserved</td></tr></tbody></table>	Value	Description	0x0	No mask	0x1	Mask as not power good during DVC	0x2	Mask as power good during DVC	0x3	Reserved
Value	Description											
0x0	No mask											
0x1	Mask as not power good during DVC											
0x2	Mask as power good during DVC											
0x3	Reserved											

**Table 31: SYS\_CONFIG\_3 (0x000E)**

Bit	Symbol	Description
[6:4]	OSC_TUNE	Tune oscillator frequency, tuned frequency = Current + OSC_TUNE * 160 kHz
		<b>Value</b> <b>Description</b>
		0x33
		0x22
		0x11
		<b>0x00</b> <b>0</b>
		0x7-1
		0x6-2
		0x5-3
		0x4-4
[1]	I2C_TIMEOUT	Enable automatic reset of 2-wire interface (if SDA stays low for >50 ms).



## High-Performance, 10 A, Dual-Phase DC-DC Converter

Table 32: SYS\_GPIO0\_0 (0x0010)

Bit	Symbol	Description
[4:1]	GPIO0_MODE	GPIO function mode select
		<b>Value      Description</b>
		<b>0x0      GPIO disable</b>
		0x1      EN1 input
		0x2      Reserved
		0x3      Reserved
		0x4      DVC1 input
		0x5      Reserved
		0x6      Reserved
		0x7      RELOAD input
		0x8      PG1 output
		0x9      Reserved
		0xA      Reserved
		0xB      Reserved
		0xC      nIRQ output
		0xD      Reserved
		0xE      Low output
		0xF      High output
[0]	GPIO0_OBUF	GPIO output buffer select
		<b>Value      Description</b>
		<b>0x0      open-drain output</b>
		0x1      push-pull output

Table 33: SYS\_GPIO0\_1 (0x0011)

Bit	Symbol	Description
[7]	GPIO0_DEB_FALL	GPI debounce falling edge
[6]	GPIO0_DEB_RISE	GPI debounce rising edge
[5:4]	GPIO0_DEB	GPI debounce time
		<b>Value      Description</b>
		<b>0x0      100 <math>\mu</math>s debounce</b>
		0x1      1 ms debounce
		0x2      10 ms debounce
		0x3      100 ms debounce

## High-Performance, 10 A, Dual-Phase DC-DC Converter

Bit	Symbol	Description
[3]	GPIO0_PUPD	GPIO pull-up/pull-down enable <b>Value      Description</b> <b>0x0      GPI: pull-down disabled, GPO: pull-up to AVDD disabled</b> 0x1      GPI: pull-down enabled, GPO: pull-up to AVDD enabled
[2]	GPIO0_POL	GPIO polarity <b>Value      Description</b> <b>0x0      GPIO is active-high</b> 0x1      GPIO is active-low
[1:0]	GPIO0_TRIG	GPI trigger type <b>Value      Description</b> <b>0x0      Dual-edge triggered</b> 0x1      Pos-edge triggered 0x2      Neg-edge triggered 0x3      Reserved (No trigger)

Table 34: SYS\_GPIO1\_0 (0x0012)

Bit	Symbol	Description
[4:1]	GPIO1_MODE	GPIO function mode select. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1 <b>Value      Description</b> <b>0x0      GPIO disable</b> 0x1      EN1 input 0x2      Reserved 0x3      Reserved 0x4      DVC1 input 0x5      Reserved 0x6      Reserved 0x7      RELOAD input 0x8      PG1 output 0x9      Reserved 0xA      Reserved 0xB      Reserved 0xC      nIRQ output 0xD      Reserved 0xE      Low output 0xF      High output

## High-Performance, 10 A, Dual-Phase DC-DC Converter

Bit	Symbol	Description						
[0]	GPIO1_OBUF	<div>GPIO output buffer select. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1</div> <table><tr><th>Value</th><th>Description</th></tr><tr><td>0x0</td><td>open-drain output</td></tr><tr><td>0x1</td><td>push-pull output</td></tr></table>	Value	Description	0x0	open-drain output	0x1	push-pull output
Value	Description							
0x0	open-drain output							
0x1	push-pull output							

**Table 35: SYS\_GPIO1\_1 (0x0013)**

Bit	Symbol	Description										
[7]	GPIO1_DEB_FALL	GPI debouce falling edge. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1										
[6]	GPIO1_DEB_RISE	GPI debounce rising edge. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1										
[5:4]	GPIO1_DEB	<div>GPI debounce time. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1</div> <table><tr><th>Value</th><th>Description</th></tr><tr><td>0x0</td><td>100 μs debouce</td></tr><tr><td>0x1</td><td>1 ms debouce</td></tr><tr><td>0x2</td><td>10 ms debounce</td></tr><tr><td>0x3</td><td>100 ms debounce</td></tr></table>	Value	Description	0x0	100 μs debouce	0x1	1 ms debouce	0x2	10 ms debounce	0x3	100 ms debounce
Value	Description											
0x0	100 μs debouce											
0x1	1 ms debouce											
0x2	10 ms debounce											
0x3	100 ms debounce											
[3]	GPIO1_PUPD	<div>GPIO pull-up/pull-down enable. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1</div> <table><tr><th>Value</th><th>Description</th></tr><tr><td>0x0</td><td><b>GPI: pull-down disabled, GPO: pull-up to AVDD disabled</b></td></tr><tr><td>0x1</td><td>GPI: pull-down enabled, GPO: pull-up to AVDD enabled</td></tr></table>	Value	Description	0x0	<b>GPI: pull-down disabled, GPO: pull-up to AVDD disabled</b>	0x1	GPI: pull-down enabled, GPO: pull-up to AVDD enabled				
Value	Description											
0x0	<b>GPI: pull-down disabled, GPO: pull-up to AVDD disabled</b>											
0x1	GPI: pull-down enabled, GPO: pull-up to AVDD enabled											
[2]	GPIO1_POL	<div>GPIO polarity. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1</div> <table><tr><th>Value</th><th>Description</th></tr><tr><td>0x0</td><td><b>GPIO is active-high</b></td></tr><tr><td>0x1</td><td>GPIO is active-low</td></tr></table>	Value	Description	0x0	<b>GPIO is active-high</b>	0x1	GPIO is active-low				
Value	Description											
0x0	<b>GPIO is active-high</b>											
0x1	GPIO is active-low											
[1:0]	GPIO1_TRIG	<div>GPI trigger type. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1</div> <table><tr><th>Value</th><th>Description</th></tr><tr><td>0x0</td><td><b>Dual-edge triggered</b></td></tr><tr><td>0x1</td><td>Pos-edge triggered</td></tr><tr><td>0x2</td><td>Neg-edge triggered</td></tr><tr><td>0x3</td><td>Reserved (No trigger)</td></tr></table>	Value	Description	0x0	<b>Dual-edge triggered</b>	0x1	Pos-edge triggered	0x2	Neg-edge triggered	0x3	Reserved (No trigger)
Value	Description											
0x0	<b>Dual-edge triggered</b>											
0x1	Pos-edge triggered											
0x2	Neg-edge triggered											
0x3	Reserved (No trigger)											

## High-Performance, 10 A, Dual-Phase DC-DC Converter

**Table 36: SYS\_GPIO2\_0 (0x0014)**

Bit	Symbol	Description
[4:1]	GPIO2_MODE	GPIO function mode select. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1
		<b>Value      Description</b>
		<b>0x0      GPIO disable</b>
		0x1      EN1 input
		0x2      Reserved
		0x3      Reserved
		0x4      DVC1 input
		0x5      Reserved
		0x6      Reserved
		0x7      RELOAD input
		0x8      PG1 output
		0x9      Reserved
		0xA      Reserved
		0xB      Reserved
		0xC      nIRQ output
		0xD      Reserved
		0xE      Low output
		0xF      High output
[0]	GPIO2_OBUF	GPIO output buffer select. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1
		<b>Value      Description</b>
		<b>0x0      open-drain output</b>
		0x1      push-pull output

**Table 37: SYS\_GPIO2\_1 (0x0015)**

Bit	Symbol	Description
[7]	GPIO2_DEB_FALL	GPI debounce falling edge. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1
[6]	GPIO2_DEB_RISE	GPI debounce rising edge. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1
[5:4]	GPIO2_DEB	GPI debounce time. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1
		<b>Value      Description</b>
		<b>0x0      100 µs debounce</b>
		0x1      1 ms debounce
		0x2      10 ms debounce
		0x3      100 ms debounce

## High-Performance, 10 A, Dual-Phase DC-DC Converter

Bit	Symbol	Description										
[3]	GPIO2_PUPD	<p>GPIO pull-up/pull-down enable. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1</p> <table><thead><tr><th>Value</th><th>Description</th></tr></thead><tbody><tr><td>0x0</td><td><b>GPI: pull-down disabled, GPO: pull-up to AVDD disabled</b></td></tr><tr><td>0x1</td><td>GPI: pull-down enabled, GPO: pull-up to AVDD enabled</td></tr></tbody></table>	Value	Description	0x0	<b>GPI: pull-down disabled, GPO: pull-up to AVDD disabled</b>	0x1	GPI: pull-down enabled, GPO: pull-up to AVDD enabled				
Value	Description											
0x0	<b>GPI: pull-down disabled, GPO: pull-up to AVDD disabled</b>											
0x1	GPI: pull-down enabled, GPO: pull-up to AVDD enabled											
[2]	GPIO2_POL	<p>GPIO polarity. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1</p> <table><thead><tr><th>Value</th><th>Description</th></tr></thead><tbody><tr><td>0x0</td><td><b>GPIO is active-high</b></td></tr><tr><td>0x1</td><td>GPIO is active-low</td></tr></tbody></table>	Value	Description	0x0	<b>GPIO is active-high</b>	0x1	GPIO is active-low				
Value	Description											
0x0	<b>GPIO is active-high</b>											
0x1	GPIO is active-low											
[1:0]	GPIO2_TRIG	<p>GPI trigger type. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1</p> <table><thead><tr><th>Value</th><th>Description</th></tr></thead><tbody><tr><td>0x0</td><td><b>Dual-edge triggered</b></td></tr><tr><td>0x1</td><td>Pos-edge triggered</td></tr><tr><td>0x2</td><td>Neg-edge triggered</td></tr><tr><td>0x3</td><td>Reserved (No trigger)</td></tr></tbody></table>	Value	Description	0x0	<b>Dual-edge triggered</b>	0x1	Pos-edge triggered	0x2	Neg-edge triggered	0x3	Reserved (No trigger)
Value	Description											
0x0	<b>Dual-edge triggered</b>											
0x1	Pos-edge triggered											
0x2	Neg-edge triggered											
0x3	Reserved (No trigger)											

## High-Performance, 10 A, Dual-Phase DC-DC Converter

## 5.1.2 Buck1

Table 38: BUCK\_BUCK1\_0 (0x0020)

Bit	Symbol	Description
[6:4]	CH1_SR_DVC_DWN	Voltage slew-rate for DVC ramp-down
		<b>Value</b> <b>Description</b>
		0x0      10 mV/8 $\mu$ s
		0x1      10 mV/4 $\mu$ s
		0x2      10 mV/2 $\mu$ s
		0x3      10 mV/ $\mu$ s
		<b>0x4      20 mV/<math>\mu</math>s</b>
		0x5      Reserved
		0x6      Reserved
		0x7      Reserved
[3:1]	CH1_SR_DVC_UP	Voltage slew-rate for DVC ramp-up
		<b>Value</b> <b>Description</b>
		0x0      10 mV/8 $\mu$ s
		0x1      10 mV/4 $\mu$ s
		0x2      10 mV/2 $\mu$ s
		0x3      10 mV/ $\mu$ s
		<b>0x4      20 mV/<math>\mu</math>s</b>
		0x5      40 mV/ $\mu$ s
		0x6      Reserved
		0x7      Reserved
[0]	CH1_EN	Channel enable. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1

Table 39: BUCK\_BUCK1\_1 (0x0021)

Bit	Symbol	Description
[6:4]	CH1_SR_SHDN	Voltage slew-rate during shut-down
		<b>Value</b> <b>Description</b>
		0x0      10 mV/8 $\mu$ s
		0x1      10 mV/4 $\mu$ s
		0x2      10 mV/2 $\mu$ s
		0x3      10 mV/ $\mu$ s
		<b>0x4      20 mV/<math>\mu</math>s</b>
		0x5      Reserved
		0x6      Reserved
		0x7      Immediate power-down

## High-Performance, 10 A, Dual-Phase DC-DC Converter

Bit	Symbol	Description
[3:1]	CH1_SR_STARTUP	Voltage slew-rate during startup
		<b>Value      Description</b>
		0x0      10 mV/8 $\mu$ s
		0x1      10 mV/4 $\mu$ s
		0x2      10 mV/2 $\mu$ s
		0x3      10 mV/ $\mu$ s
		<b>0x4      20 mV/<math>\mu</math>s</b>
		0x5      40 mV/ $\mu$ s
		0x6      Reserved
		0x7      Reserved
[0]	CH1_PD_DIS	Pull-down while buck is disabled. 0: enable, 1: disable

**Table 40: BUCK\_BUCK1\_2 (0x0022)**

Bit	Symbol	Description
[3:0]	CH1_ILIM	Select OCP threshold (A)
		<b>Value      Description</b>
		0x0      Reserved
		0x1      3.5
		0x2      4.0
		0x3      4.5
		0x4      5.0
		0x5      5.5
		0x6      6.0
		0x7      6.5
		0x8      7.0
		<b>0x9      7.5</b>
		0xA      8.0
		0xB      8.5
		0xC      9.0
		0xD      9.5
		0xE      10.0
		0xF      Disable

## High-Performance, 10 A, Dual-Phase DC-DC Converter

**Table 41: BUCK\_BUCK1\_3 (0x0023)**

Bit	Symbol	Description
[7:0]	CH1_VMAX	VOUT max setting (V): From 0.30 V (0x1E) to 1.90 V (0xBE) in 10 mV steps. This is a read-only register.
		<b>Value</b> <b>Description</b>
		0x1E      0.3
		0x1F      0.31
		0x20      0.32
		Continuing through...
		0x99      1.53
		To...
		0xBD      1.89
		<b>0xBE</b> <b>1.9</b>

**Table 42: BUCK\_BUCK1\_4 (0x0024)**

Bit	Symbol	Description										
[4]	CH1_VSEL	Output voltage and operation selection: 0: A, 1: B. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1										
[3:2]	CH1_B_MODE	Operation mode selection. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1 <table><tr><th>Value</th><th>Description</th></tr><tr><td>0x0</td><td>Force PFM operation</td></tr><tr><td>0x1</td><td>Force PWM operation (full phase)</td></tr><tr><td>0x2</td><td>Force PWM operation (with phase shedding)</td></tr><tr><td>0x3</td><td>Auto mode</td></tr></table>	Value	Description	0x0	Force PFM operation	0x1	Force PWM operation (full phase)	0x2	Force PWM operation (with phase shedding)	0x3	Auto mode
Value	Description											
0x0	Force PFM operation											
0x1	Force PWM operation (full phase)											
0x2	Force PWM operation (with phase shedding)											
0x3	Auto mode											
[1:0]	CH1_A_MODE	Operation mode selection. Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1 <table><tr><th>Value</th><th>Description</th></tr><tr><td>0x0</td><td>Force PFM operation</td></tr><tr><td>0x1</td><td>Force PWM operation (full phase)</td></tr><tr><td>0x2</td><td>Force PWM operation (with phase shedding)</td></tr><tr><td>0x3</td><td>Auto mode</td></tr></table>	Value	Description	0x0	Force PFM operation	0x1	Force PWM operation (full phase)	0x2	Force PWM operation (with phase shedding)	0x3	Auto mode
Value	Description											
0x0	Force PFM operation											
0x1	Force PWM operation (full phase)											
0x2	Force PWM operation (with phase shedding)											
0x3	Auto mode											



## High-Performance, 10 A, Dual-Phase DC-DC Converter

**Table 43: BUCK\_BUCK1\_5 (0x0025)**

Bit	Symbol	Description
[7:0]	CH1_A_VOUT	Output voltage setting A: Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1 From 0.30 V (0x1E) to 1.90 V (0xBE) in steps of 10 mV (default 1.0 V) Write-protected when value is written below 0.30 V or above 1.90 V
		<b>Value</b> <b>Description</b>
		0x1E      0.3
		0x1F      0.31
		0x20      0.32
		Continuing through...
		<b>0x64</b> <b>1</b>
		To...
		0xBC      1.88
		0xBD      1.89
0xBE      1.9		

**Table 44: BUCK\_BUCK1\_6 (0x0026)**

Bit	Symbol	Description
[7:0]	CH1_B_VOUT	Output voltage setting B: Initial value is determined by CONF pin setting at the start-up in CONF_EN = 1 From 0.30 V (0x1E) to 1.90 V (0xBE) in steps of 10 mV (default 1.0 V) Write-protected when value is written below 0.30 V or above 1.90 V
		<b>Value</b> <b>Description</b>
		0x1E      0.3
		0x1F      0.31
		0x20      0.32
		Continuing through...
		<b>0x64</b> <b>1</b>
		To...
		0xBC      1.88
		0xBD      1.89
0xBE      1.9		

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**High-Performance, 10 A, Dual-Phase DC-DC Converter**

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**5.1.3 Serialization****Table 45: OTP\_DEVICE\_ID (0x0048)**

Bit	Symbol	Description
[7:0]	DEV_ID	Device ID

**Table 46: OTP\_VARIANT\_ID (0x0049)**

Bit	Symbol	Description
[7:4]	MRC	Mask Revision Code
[3:0]	VRC	Chip Variant Code

**Table 47: OTP\_CUSTOMER\_ID (0x004A)**

Bit	Symbol	Description
[7:0]	CUST_ID	Customer ID

**Table 48: OTP\_CONFIG\_ID (0x004B)**

Bit	Symbol	Description
[7:0]	CONFIG_REV	OTP Variant

High-Performance, 10 A, Dual-Phase DC-DC Converter

6 Package Information

6.1 Package Outlines

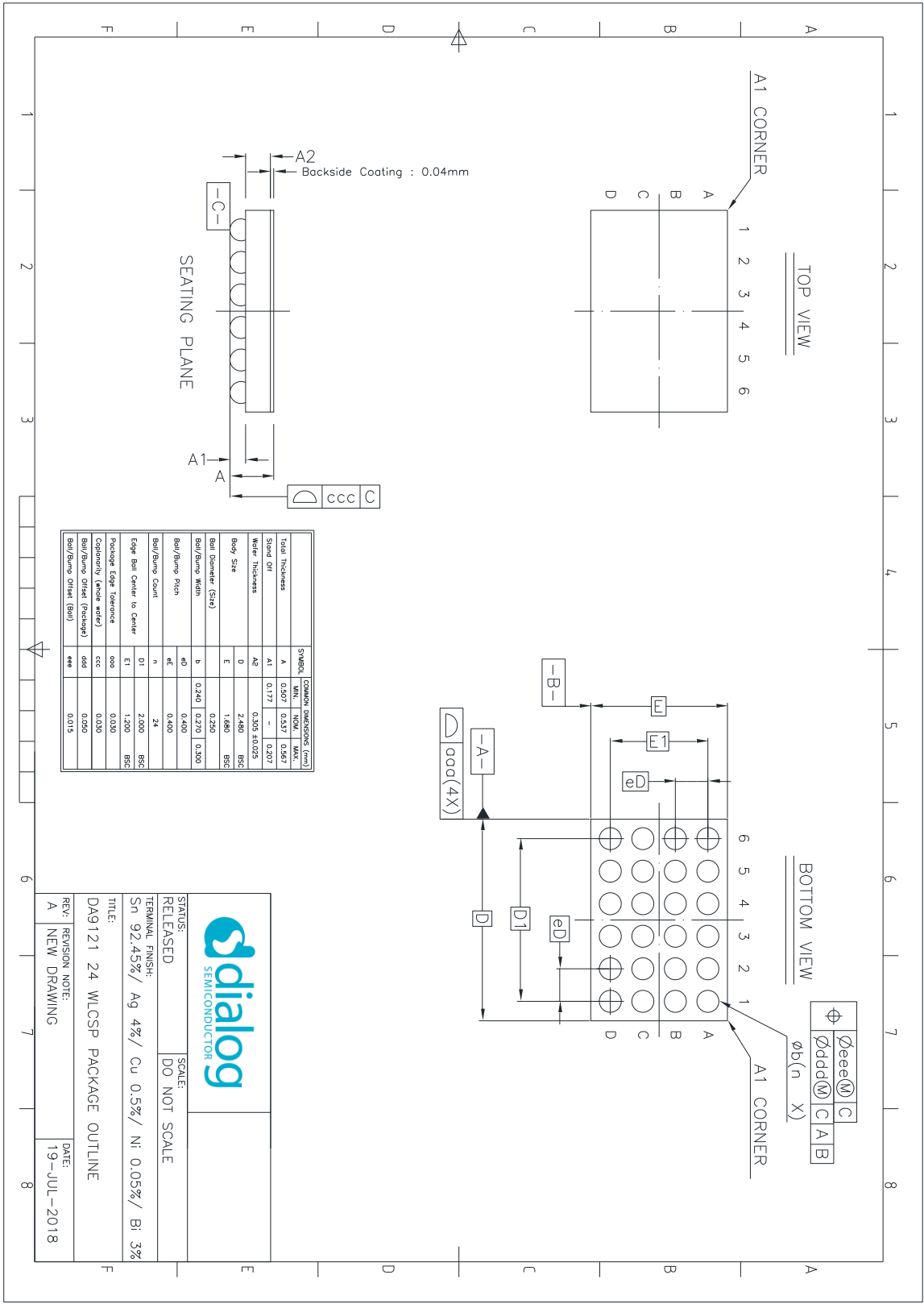


Figure 20: Package Outline Drawing

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 6.2 Moisture Sensitivity Level

The moisture sensitivity level (MSL) is an indicator for the maximum allowable time period (floor lifetime) in which a moisture sensitive plastic device, once removed from the dry bag, can be exposed to an environment with a specified maximum temperature and a maximum relative humidity before the solder reflow process. The MSL classification is defined in [Table 49](#).

For detailed information on MSL levels refer to the IPC/JEDEC standard J-STD-020, which can be downloaded from <http://www.jedec.org>.

The DA9121 package is qualified for MSL1.

**Table 49: MSL Classification**

MSL Level	Floor Lifetime	Conditions
MSL 1	Unlimited	≤30 °C / 85 % RH

### 6.3 WLCSP Handling

Manual handling of WLCSP packages should be reduced to the absolute minimum. In cases where it is still necessary, a vacuum pick-up tool should be used. In extreme cases plastic tweezers could be used, but metal tweezers are not acceptable, since contact may easily damage the silicon chip.

Removal of a WLCSP package will cause damage to the solder balls. Therefore a removed sample cannot be reused.

WLCSP packages are sensitive to visible and infrared light. Precautions should be taken to properly shield the chip in the final product.

### 6.4 Soldering Information

Refer to the IPC/JEDEC standard J-STD-020 for relevant soldering information. This document can be downloaded from <http://www.jedec.org>.

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 7 Ordering Information

The ordering number consists of the part number followed by a suffix indicating the packing method. For details and availability, please consult Dialog Semiconductor's [customer support portal](#) or your local sales representative.

**Table 50: Ordering Information**

Part Number	Package	Size (mm)	Shipment Form	Pack Quantity
DA9121-xxV72	24 WLCSP	2.5 x 1.7	T&R	4500
DA9121-xxV76	24 WLCSP	2.5 x 1.7	Waffle Tray	140
DA9121-B0V72 Standard OTP Variant $V_{OUT1} = 1.0\text{ V}$	24 WLCSP	2.5 x 1.7	T&R	4500
DA9121-B0V76 Standard OTP Variant $V_{OUT1} = 1.0\text{ V}$	24 WLCSP	2.5 x 1.7	Waffle Tray	140

### 8 Application Information

The following recommended components are examples selected from requirements of a typical application.

#### 8.1 Capacitor Selection

Ceramic capacitors are used as bypass capacitors at all VDD and output rails. When selecting a capacitor, especially for types with high capacitance at smallest physical dimension, the DC bias characteristic has to be taken into account.

**Table 51: Recommended Capacitor Types**

Application	Value	Size	Temp. Char.	Tol. (%)	V-Rate	Type
VOUT output bypass	10 $\mu\text{F}$	0402	X5R $\pm 15\%$	$\pm 20$	6.3 V	Murata GRM155R60J106ME15
PVDDx bypass	10 $\mu\text{F}$	0603	X5R $\pm 15\%$	$\pm 20$	25 V	Murata GRM188R61E106MA73
AVDD bypass	1 $\mu\text{F}$	0402	X5R $\pm 15\%$	$\pm 10$	10 V	Murata GRM155R61A105KE15

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### 8.2 Inductor Selection

Inductors should be selected based on the following parameters:

- Rated maximum current  
Usually a coil provides two current limits: ISAT specifies the maximum current at which the inductance drops by 30 % of the nominal value, and IMAX is defined by the maximum power dissipation and is applied to the effective current.
- DC resistance  
Critical for the converter efficiency and should therefore be minimized.

**Table 52: Recommended Inductor Types**

Value (μH)	Size (mm)	I <sub>MAX</sub> (DC) (A)	I <sub>SAT</sub> (A)	Tol. (%)	DC Resistance (mΩ)	Type
0.1	2.0 x 1.6 x 1.0	6.5	9.0	±20	11.5	Cyntec HTEN20161T-R10MDR
0.11	2.0 x 1.2 x 1.0	6.3	11	±20	8	Murata DFE201210S-R11M=P2
0.1	1.6 x 0.8 x 1.0	5.2	6.5	±20	17	Taiyo Yuden MEKK1608TR10M
0.1	1.6 x 0.8 x 0.8	4.1	9.4	±20	19	Taiyo Yuden MCHK1608TR10MJN
0.1	2.0 x 1.2 x 0.65	4.6	8.7	±20	11	Taiyo Yuden MCFE2012TR10MJN
0.1	2.5 x 2.0 x 1.2	12	13	±20	4	TDK TFM252012ALMAR10MT
0.1	1.6 x 0.8 x 0.95	3.8	4.3	±20	15	Tokyo Coil Engineering TFP160810M-R10N
0.11	2.0 x 1.6 x 0.6	3.0	6.0	±20	24	Würth Elektronik WE-PMMI 744 799 771 11

## High-Performance, 10 A, Dual-Phase DC-DC Converter

### Status Definitions

Revision	Datasheet Status	Product Status	Definition
1.<n>	Target	Development	This datasheet contains the design specifications for product development. Specifications may be changed in any manner without notice.
2.<n>	Preliminary	Qualification	This datasheet contains the specifications and preliminary characterization data for products in pre-production. Specifications may be changed at any time without notice in order to improve the design.
3.<n>	Final	Production	This datasheet contains the final specifications for products in volume production. The specifications may be changed at any time in order to improve the design, manufacturing and supply. Major specification changes are communicated via Customer Product Notifications. Datasheet changes are communicated via <a href="http://www.dialog-semiconductor.com">www.dialog-semiconductor.com</a> .
4.<n>	Obsolete	Archived	This datasheet contains the specifications for discontinued products. The information is provided for reference only.

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