MP5991

16V, 50A, 1mΩ $R_{DS(ON)}$, Hot-Swap Intelli-Fuse Solution

DESCRIPTION

The MP5991 is an integrated, monolithic controller and switch with a power MOSFET and other circuitry that allows it to work in standalone operation or to be controlled via a hot-swap controller. The device can drive up to 50A of continuous output current (I_{OUT}) per device at room temperature, and up to 60A of continuous I_{OUT} with air flow.

The device limits the backplane voltage drop by limiting the inrush current to the load while a circuit card is inserted into a live backplane power source. It limits the internal MOSFET current (I_{FET}) by controlling the gate voltage (V_{GATE}) via the current limit (I_{LIMIT}) reference input and soft-start ramp.

The MP5991 provides many features to simplify system design, such as an integrated current mirror to monitor I_{OUT} and the integrated on-die temperature sense. This eliminates the need for an external current-sense power resistor, power MOSFET, and temperature-sense device.

The IC detects the power MOSFET's gate, source, and drain short conditions. It also provides feedback to the hot-swap controller via the fault-reporting output (GOK). The MP5991 can operate in parallel for high-current applications. During start-up, all of the devices in parallel actively share current.

The MP5991 is available in an LGA-32 (5mmx5mm) package.

FEATURES

- 4V to 16V Operating Input Voltage (V_{IN}) Range
- Up to 50A Continuous Output Current (I_{OUT})
- Up to 60A Continuous I_{OUT} with Air Flow
- Integrated Power MOSFET with 1mΩ $R_{DS(ON)}$
- IMON Reporting (±1% Accuracy)
- Built-In MOSFET Driver
- 3.3V LDO Output
- Integrated Current Sense with Sense Output
- Configurable Over-Current Limit
- Configurable Short-Circuit Current Limit
- Built-In Insertion Delay
- Configurable Soft Start (SS)
- Output Short-Circuit Protection (SCP)
- Over-Temperature Protection (OTP)
- Built-In Fuse Health Reporting
- Fault Signal Output (GOK)
- Fault Type Indication (FLT_TYPE)
- Supports Parallel Operation for High-Current Applications
- Integrated Intelli-Fuse Temperature Sense
- Available in an LGA-32 (5mmx5mm) Package

APPLICATIONS

- Hot Swap
- PC Cards
- Disk Drives
- Servers
- Networking

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TYPICAL APPLICATION

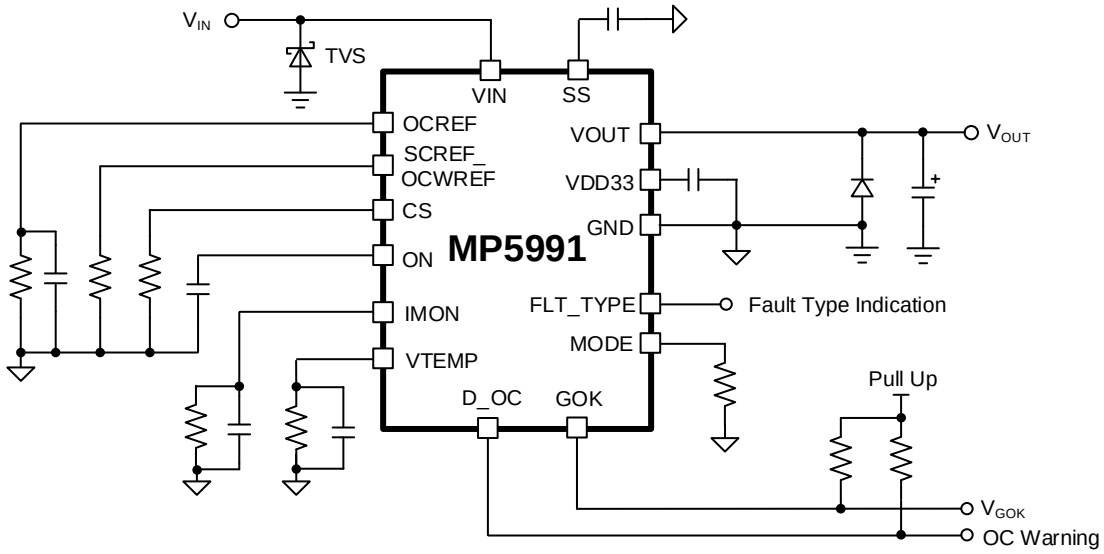

Figure 1: MP5991 Standalone Operation (R_{IMON} ≥ R_{CS})

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TYPICAL APPLICATION *(continued)*

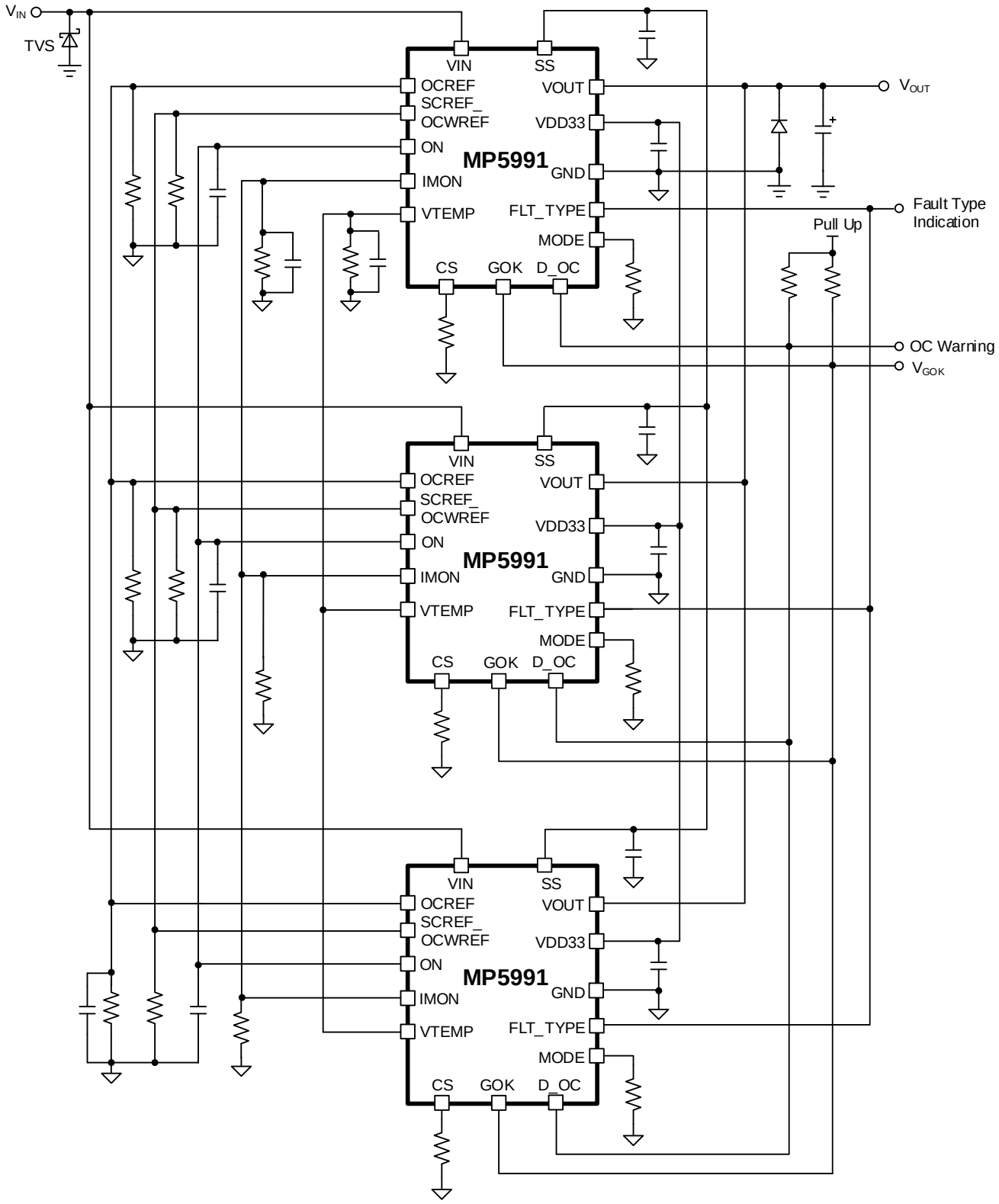

Figure 2: MP5991 3-Phase Parallel Operation

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TYPICAL APPLICATION *(continued)*

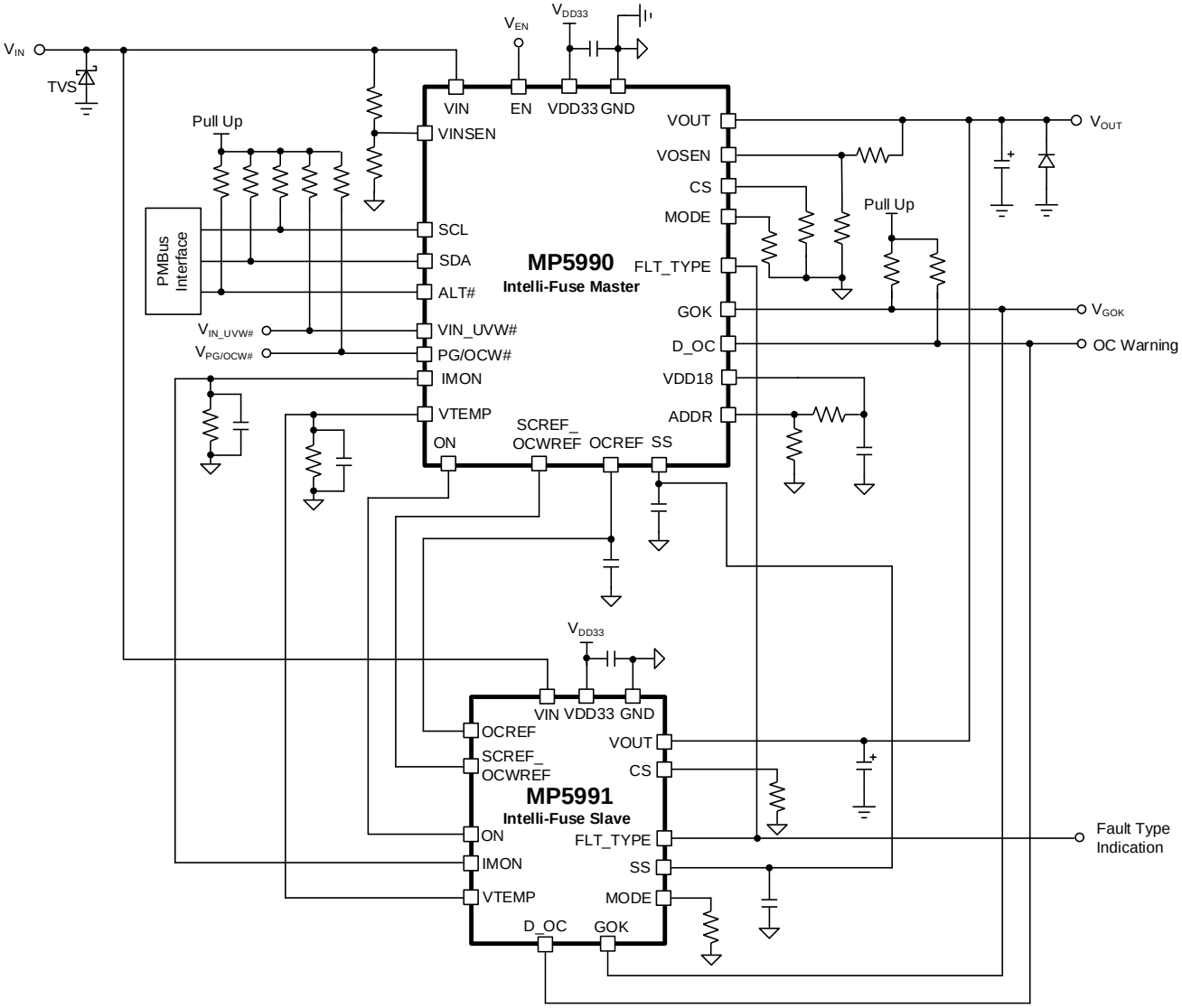

Figure 3: MP5990 and MP5991 Parallel Operation

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TYPICAL APPLICATION *(continued)*

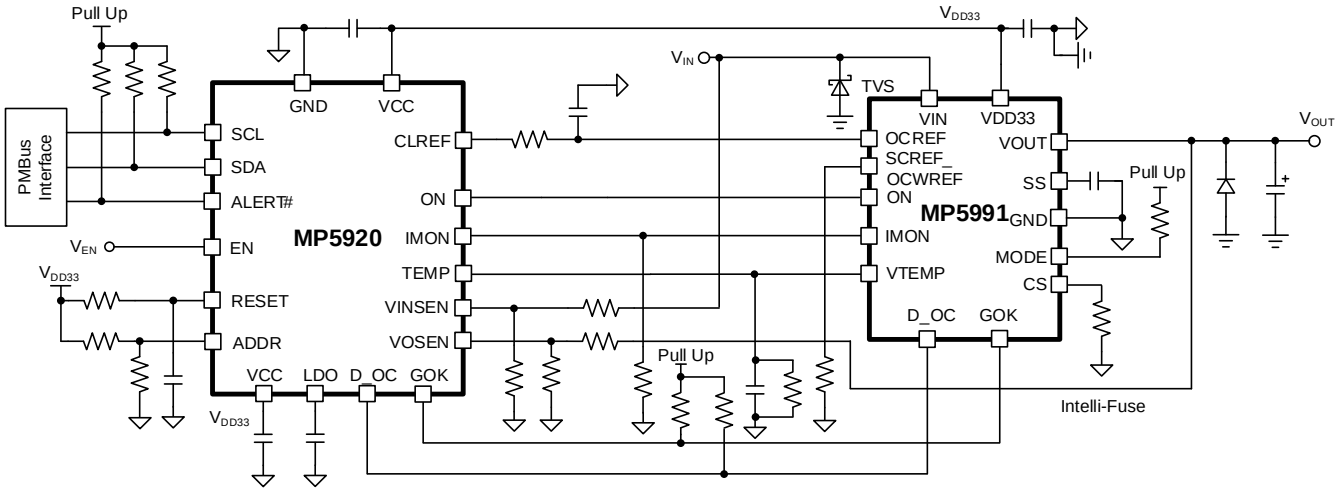

Figure 4: MP5991 Controlled via a Hot-Swap Controller (e.g. MP5920)

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ORDERING INFORMATION

Part Number*	Package	Top Marking	MSL Rating
MP5991GLU	LGA-32 (5mmx5mm)	*See Below*	3

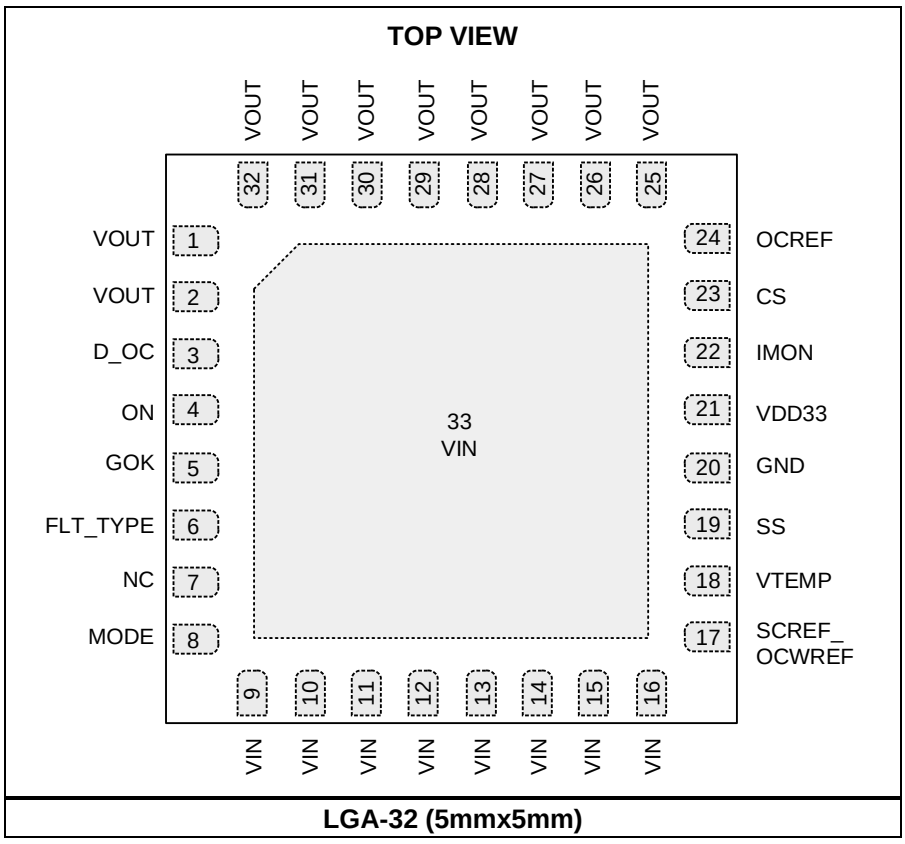
* For Tape & Reel, add suffix -Z (e.g. MP5991GLU-Z).

TOP MARKING

MPSYYWW
MP5991
LLLLLLL

MPS: MPS prefix
YY: Year code
WW: Week code
MP5991: Part number
LLLLLLL: Lot number

PACKAGE REFERENCE



LGA-32 (5mmx5mm)

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PIN FUNCTIONS

Pin #	Name	Description
1, 2, 25, 26, 27, 28, 29, 30, 31, 32	VOUT	**Output voltage.** The VOUT pin is connected to the source of the integrated power MOSFET.
3	D_OC	**Over-current indication digital output.** The D_OC pin is an open-drain output. In standalone mode, D_OC is pulled low once the CS voltage (V_{CS}) exceeds 85% of the OCREF voltage (V_{OCREF}). In slave mode, D_OC is pulled low once V_{CS} exceeds the OCWREF voltage (V_{OCWREF}).
4	ON	**MOSFET on/off control.** Pull the ON pin above 1.4V to turn the power MOSFET on; pull ON below 1.2V to turn it off. Do not float ON.
5	GOK	**Intelli-Fuse fault reporting output.** The GOK pin is an open-drain output. If a fault occurs, then GOK is pulled low and latches. The following faults that can trigger GOK: an input over-voltage (OV) fault, an output over-current (OC) fault, a short circuit (SC) fault, an over-temperature (OT) fault, or a MOSFET health fault.
6	FLT_TYPE	**Intelli-Fuse fault type indication output.** If a fault occurs, then the FLT_TYPE pin indicates a voltage level based on the fault type.
7	NC	**Not connected.** Float the NC pin.
8	MODE	**Mode selection.** Connect a resistor between the MODE and GND pins to select the operation mode (latch-off mode, hiccup mode, or slave mode).
9, 10, 11, 12, 13, 14, 15, 16, 33	VIN	**System input power supply.** The VIN pin is connected to the drain of the MOSFET.
17	SCREF_ OCWREF	**Multifunctional (short-circuit current limit and over-current warning reference in slave mode).** The SCREF_OCWREF pin is a multifunctional pin. To select the short-circuit current limit (I_{LIMIT_SC}), the MP5991 samples the SCREF voltage (V_{SCREF}) during the MOSFET turn-on insertion delay time (t_{ON_DELAY}). Then the device can set I_{LIMIT_SC} to 40A, 60A, 80A, 100A, or 120A. SCREF_OCWREF is also used as the OC warning reference in slave mode.
18	VTEMP	**Junction temperature sense output.** Place a ≤1nF capacitor and a ≥10kΩ resistor in parallel on the VTEMP pin.
19	SS	**Soft-start time setting.** An external capacitor connected to the SS pin sets the soft-start time (t_{SS}). The internal circuitry controls the output voltage (V_{OUT}) slew rate during start-up.
20	GND	**Signal ground.**
21	VDD33	**Internal 3.3V LDO output.** Place a ≥1µF decoupling capacitor close to the VDD33 and GND pins.
22	IMON	**Current monitor output.** The IMON pin reports the current flowing through the power device. Connect a resistor between the IMON and GND pins to generate the IMON voltage (V_{IMON}). Place a 2.2nF to 100nF capacitor in parallel to reduce noise and maintain a smooth voltage.
23	CS	**Current-sense output.** V_{CS} is compared to V_{OCREF} to determine the OC limit. The CS pin is also used to assert D_OC. If V_{CS} exceeds 85% of V_{OCREF} in standalone mode, then D_OC is pulled low. If V_{CS} exceeds V_{OCWREF} in slave mode, then D_OC is pulled low. Connect a resistor between the CS and GND pins to generate V_{CS}.
24	OCREF	**Current-limit reference voltage input.** Connect a 1nF to 10nF capacitor between the OCREF and GND pins to reduce noise and maintain a smooth voltage.

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ABSOLUTE MAXIMUM RATINGS (1)

V_{IN} (DC).....-0.3V to +20V
V_{IN} (1µs)..... 24V
V_{IN} (25ns)..... 29V
V_{OUT} .....-0.3V to +20V
All other pins .....-0.3V to +4.2V
Continuous power dissipation (T_A = 25°C) (2)
..... 5.68W
Junction temperature .....150°C
Lead temperature .....260°C
Storage temperature..... -65°C to +155°C

ESD Ratings (3)

Human body model (HBM) .....Class 1C
Charged device model (CDM).....Class C2B

Recommended Operating Conditions (4)

Operating input voltage (V_{IN}).....4V to 16V
Operating junction temp (T_J).... -40°C to +125°C

Thermal Resistance (5) θ_{JA} θ_{JC}

LGA-32 (5mmx5mm) ..... 22.....10.8 . °C/W

Notes:

1) Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature T_J (MAX), the junction-to-ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P_D (MAX) = (T_J (MAX) - T_A) / θ_{JA}. Exceeding the maximum allowable power dissipation can produce an excessive die temperature, which may cause the device to go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) Followed ANSI/ESDA/JEDEC JS-001 for HBM and ANSI/ESDA/JEDEC JS-002 for CDM.
4) The device is not guaranteed to function outside of its operating conditions.
5) Measured on JESD51-7, 4-layer PCB.

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ELECTRICAL CHARACTERISTICS

V_{IN} = 12V, R_{CS} = 2kΩ, R_{IMON} = 2kΩ, T_A = 25°C, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Supply Current						
Quiescent current	I_Q	Intelli-Fuse is on, no load		2.5	2.9	mA
		Fault protection, latch-off mode		2.3	2.7	mA
		Intelli-Fuse is off, V_{ON} = 0V, V_{IN} = 12V		2.3	2.7	mA
		Intelli-Fuse is off, V_{ON} = 0V, V_{IN} = 16V		2.3	2.7	mA
VDD33 Regulator and Under-Voltage Lockout (UVLO) Protection						
VDD33 regulator output voltage	V_{DD33}	I_{VDD33} = 0mA	3.2	3.3	3.4	V
		I_{VDD33} = 25mA	3.17	3.27	3.37	V
		I_{VDD33} = 40mA	3.16	3.26	3.36	V
VDD33 under-voltage lockout (UVLO) rising threshold	$V_{DD33_UVLO_RISING}$		2.55	2.7	2.85	V
VDD33 UVLO falling threshold	$V_{DD33_UVLO_FALLING}$		2.15	2.3	2.45	V
VDD33 UVLO hysteresis	$V_{DD33_UVLO_HYS}$			400		mV
V_{IN} UVLO Protection and Over-Voltage Protection (OVP)						
V_{IN} UVLO rising threshold	$V_{IN_UVLO_RISING}$		3.05	3.2	3.35	V
V_{IN} UVLO falling threshold	$V_{IN_UVLO_FALLING}$		2.55	2.7	2.95	V
Over-voltage protection	V_{OVP}		17	18.5	20	V
OVP hysteresis	V_{OVP_HYS}	Auto-retry		1		V
Power MOSFET						
On resistance	$R_{DS(ON)}$	T_J = 25°C, I_{FET} = 2A		1	1.25	mΩ
		T_J = 125°C, I_{FET} = 2A		1.35	1.7	mΩ
Off-state leakage current	I_{OFF}	V_{IN} = 16V, MOSFET is off			1	μA
MOSFET On/Off Control (ON)						
Internal ON current	I_{ON}		3.2	4.2	5.2	μA
ON input rising threshold	V_{ON_RISING}	V_{ON} is rising	1.3	1.4	1.5	V
ON input falling threshold	$V_{ON_FALLING}$	V_{ON} is falling	1.1	1.2	1.3	V
MOSFET turn-on hysteresis	V_{ON_HYS}			200		mV
MOSFET turn-on insertion delay time	t_{ON_DELAY}	V_{DD33} > $V_{DD33_UVLO_RISING}$, V_{IN} > $V_{IN_UVLO_RISING}$	0.8	1.3	1.8	ms
ON blanking time	t_{ON_BLANK}	V_{ON} recycling	0.7	1	1.5	ms
Current Monitor Output (IMON)						
IMON sense gain	g_{IMON}	I_{IMON} / I_{OUT}, I_{OUT} > 4A,	9.9	10	10.1	μA/A
IMON sense offset		I_{OUT} > 4A	-0.6		+0.6	μA
Current-Sense Output (CS)						
Current-sense gain	g_{CS}	I_{CS} / I_{OUT}, I_{OUT} > 4A	9.6	10	10.4	μA/A
Current-sense gain offset		I_{OUT} > 4A	-1		+1	μA

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ELECTRICAL CHARACTERISTICS *(continued)*

V_{IN} = 12V, R_{CS} = 2kΩ, R_{IMON} = 2kΩ, T_A = 25°C, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Over-Current (OC) Limit Reference (OCREF)						
Internal OCREF current	I_{OCREF}	Standalone mode	9	10	11	µA
		Slave mode		0		µA
OCREF clamp voltage	V_{OCREF_CLAMP}	V_{SS_CLAMP} at V_{OUT} < 80% of V_{IN}, T_J = 25°C	570	635	699	mV
		V_{SS_CLAMP} at V_{OUT} < 80% of V_{IN}, T_J = 125°C	340	440	570	mV
		V_{OUT} ≥ 80% of V_{IN}	1.9	2	2.1	V
OCREF operating voltage (6)	V_{OCREF}		0.3		1.8	V
OCREF OC regulation timer	t_{OC_REG}	V_{OUT} ≥ 90% of V_{IN}, V_{OCREF} ≥ 0.3V		220		µs
Short-Circuit Current Limit Reference (SCREF)						
Internal SCREF current	I_{SCREF}	Standalone mode, T_A = 25°C	9	10	11	µA
		Standalone mode, T_A = -40 to +125°C	9	10	11	µA
		Slave mode		0		µA
Short-circuit current limit SCREF voltage range	V_{SCREF}	I_{LIMIT_SC} = 40A		0	0.16	V
		I_{LIMIT_SC} = 60A	0.24	0.3	0.36	V
		I_{LIMIT_SC} = 80A	0.48	0.6	0.72	V
		I_{LIMIT_SC} = 120A	0.96	1.2	1.44	V
		I_{LIMIT_SC} = 100A	1.68			V
Short-circuit current limit (6)	$I_{LIMIT\ SC}$	V_{SCREF} > 1.6V		100		A
Short-circuit protection (SCP) response time (6)	t_{SCP}			200		ns
Short-circuit start-up protection timer	t_{SC_TIMER}	V_{OUT} < 1/8 x V_{IN}, I_{FET} is regulated by V_{SS_CLAMP}		2.1	3.2	ms
Temperature Sense (VTEMP)						
Temperature sense gain (6)				8.7		mV/°C
Temperature sense output (6)		T_J = 25°C		370		mV
Soft Start (SS)						
SS current	I_{SS}	V_{IN} = 12V, I_{SS} is dependent on V_{IN}, R_{SS} = 0.8MΩ	13	15	17	µA
SS low voltage	V_{SS_LOW}	SS is pull low internally via R_{SS}, I_{SINK} = 10mA			0.2	V
SS leakage current	I_{LKG_SS}	V_{ON} = 0V, V_{SS} = 3.3V, MOSFET is off			1	µA
GOK Output and Comparator						
Output low voltage	V_{GOK_LOW}	I_{SINK} = 10mA			0.3	V
GOK leakage current	I_{LKG_GOK}	V_{GOK} = 3.3V			1	µA
GOK internal pull-up resistor	R_{GOK}			370		kΩ
GOK comparator falling threshold	$V_{GOK_FALLING}$	Fault status	1.05	1.16	1.3	V
GOK comparator hysteresis	V_{GOK_HYS}			900		mV
GOK fault delay time			1	3	5	µs

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ELECTRICAL CHARACTERISTICS *(continued)*

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Parameters	Symbol	Condition	Min	Typ	Max	Units
D_OC Output						
Output low voltage	$V_{D_OC_LOW}$	I_{SINK} = 10mA			0.3	V
D_OC leakage current	$I_{LKG_D_OC}$	V_{D_OC} = 3.3V			1	μA
D_OC high to low threshold (OC warning)	$V_{D_OC_TH}$	Standalone mode, V_{OUT} ≥ 90% of V_{IN}, 0.3V ≤ V_{OCREF} ≤ 1.8V	0.8	0.85	0.9	V_{CS} / V_{OCREF}
		Slave mode, V_{OUT} ≥ 90% of V_{IN}, 0.3V ≤ V_{OCWREF} ≤ 1.8V	0.95	1	1.05	V_{CS} / V_{OCWREF}
MOSFET Short Detection						
MOSFET drain-to-source (DS) short entry threshold	$V_{OUT_DS_ENTRY}$	Measured at V_{OUT} during start-up	85	90	95	% of V_{IN}
MOSFET DS short recovery threshold	$V_{OUT_DS_RECOVERY}$	Measured at V_{OUT} during start-up	65	70	75	% of V_{IN}
Gate-to-source (GS) short protection delay time (6)	t_{GS_DELAY}	V_{SS} > V_{CC} - 0.7V	200	250	300	ms
Fault Type Indication Output (FLT_TYPE) (6 Indication Types)						
Short-circuit FLT_TYPE voltage (6)	$V_{FLT_TYPE\ SC}$	SCP		1.5		V
OC fault FLT_TYPE voltage	$V_{FLT_TYPE\ OC}$	OCP during SS or normal operation	1.16	1.2	1.24	V
OT/OV fault FLT_TYPE voltage	$V_{FLT_TYPE\ OT/OV}$	V_{IN} OVP and OTP	0.865	0.9	0.935	V
MOSFET DS/GS short FLT_TYPE voltage	$V_{FLT_TYPE\ DS/GS}$	MOSFET DS/GS short	0.57	0.6	0.63	V
GOK fault FLT_TYPE voltage	$V_{FLT_TYPE\ GOK}$	GOK fault	0.275	0.3	0.325	V
FLT_TYPE voltage for other conditions	$V_{FLT_TYPE\ OTHER}$		0.08	0.1	0.12	V
Thermal Shutdown						
Thermal shutdown threshold (6)	T_{SD}			145		°C
Mode Selection (MODE)						
MODE current	I_{MODE}		9	10	11	μA
Hiccup mode with 250ms auto-retry delay	V_{MODE1}	R_{MODE} = 30kΩ, t_{RETRY} = 250ms	0.24	0.3	0.36	V
Hiccup mode with 500ms auto-retry delay	V_{MODE2}	R_{MODE} = 0Ω, t_{RETRY} = 500ms		0	0.16	V
Hiccup mode with 1s auto-retry delay	V_{MODE3}	R_{MODE} = 60kΩ, t_{RETRY} = 1s	0.48	0.6	0.72	V
Slave mode	V_{MODE4}	R_{MODE} = 120kΩ	0.96	1.2	1.44	V
Latch-off mode	V_{MODE5}	MODE is pulled up to VDD33	1.68			V

Notes:

6) Guaranteed by design.

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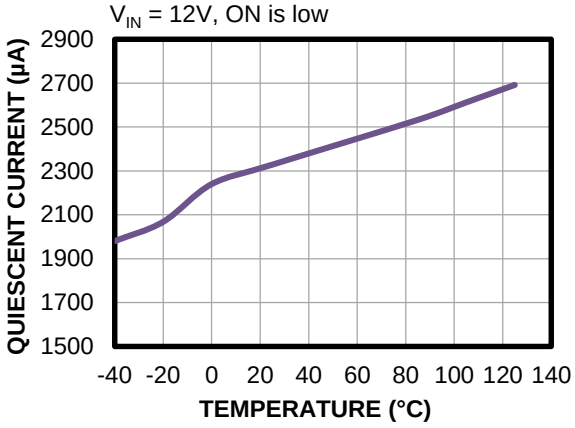
TYPICAL CHARACTERISTICS

V_{IN} = 12V, R_{CS} = R_{IMON} = 2kΩ, T_A = 25°C, unless otherwise noted.

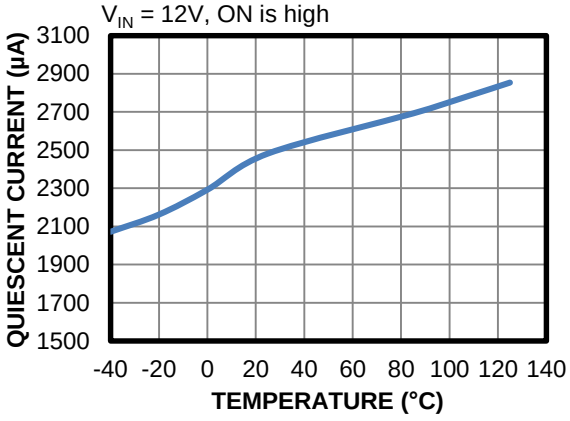
Quiescent Current vs. Temperature

V_{IN} = 12V, ON is low



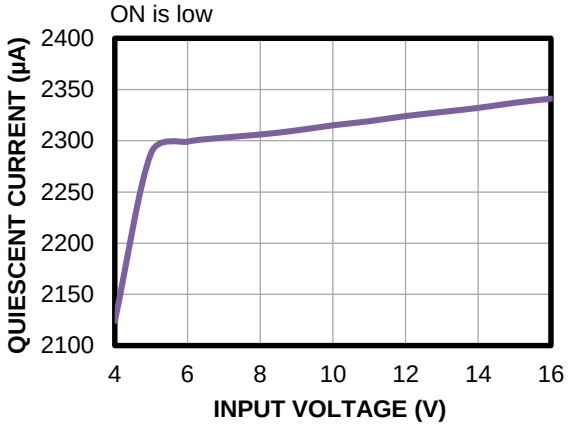
Quiescent Current vs. Temperature

V_{IN} = 12V, ON is high



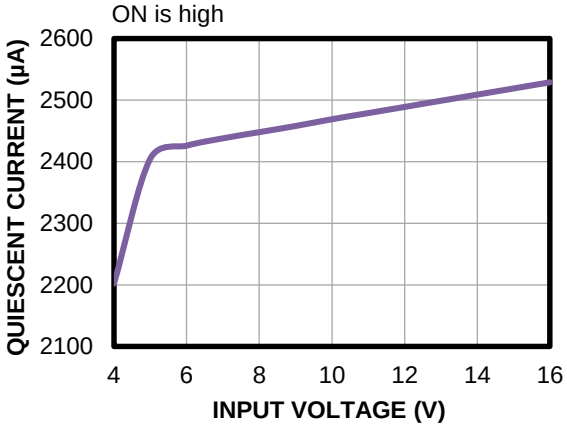
Quiescent Current vs. Input Voltage

ON is low

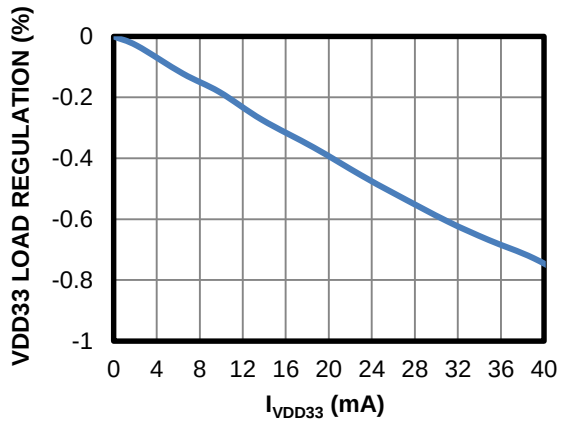


Quiescent Current vs. Input Voltage

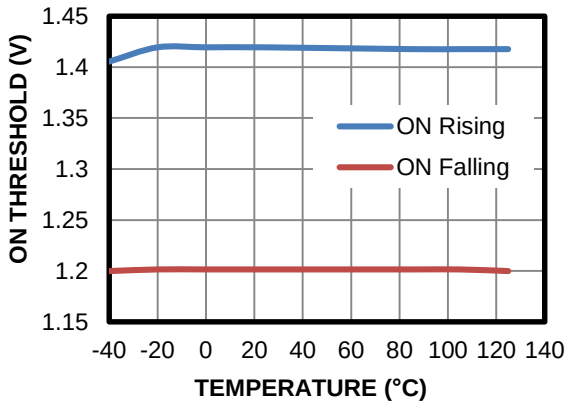
ON is high



VDD33 Load Regulation



ON Threshold vs. Temperature



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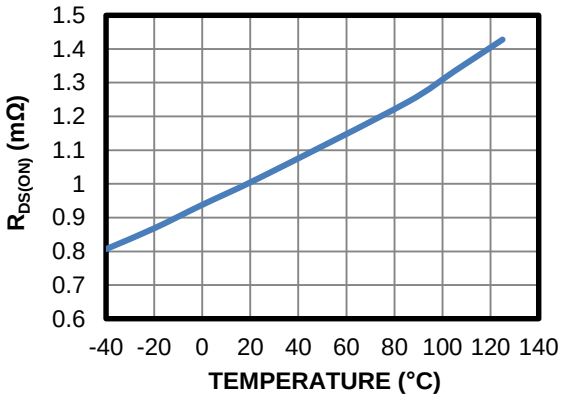
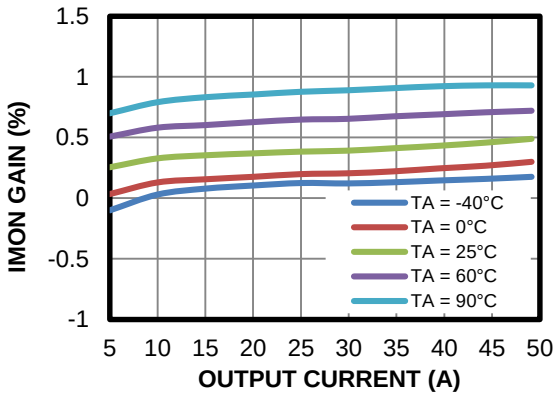
TYPICAL CHARACTERISTICS *(continued)*

V_{IN} = 12V, R_{CS} = R_{IMON} = 2kΩ, T_A = 25°C, unless otherwise noted.

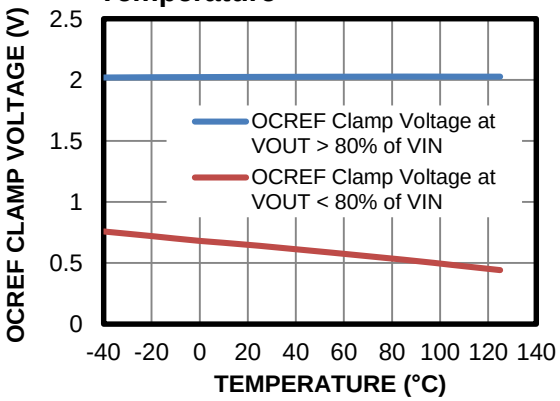
$R_{DS(ON)}$ vs. Temperature



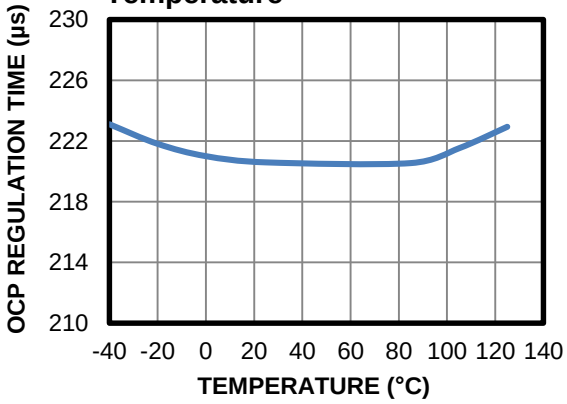
IMON Gain vs. Output Current



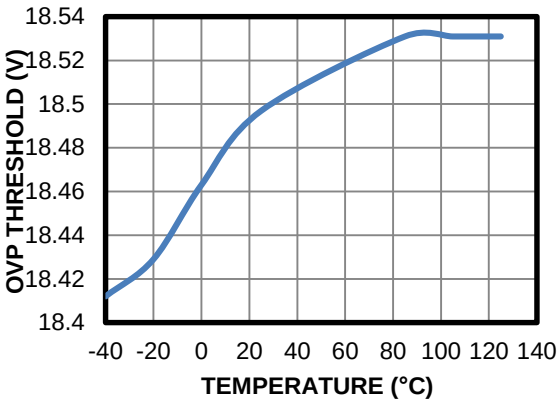
OCREF Clamp Voltage vs. Temperature



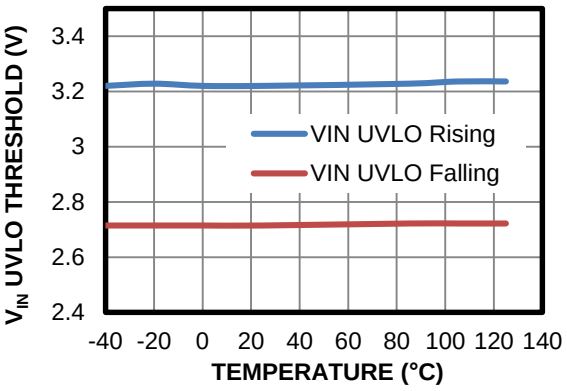
OCP Reguation Time vs. Temperature



OVP Threshold vs. Temperature



V_{IN} UVLO Threshold vs. Temperature



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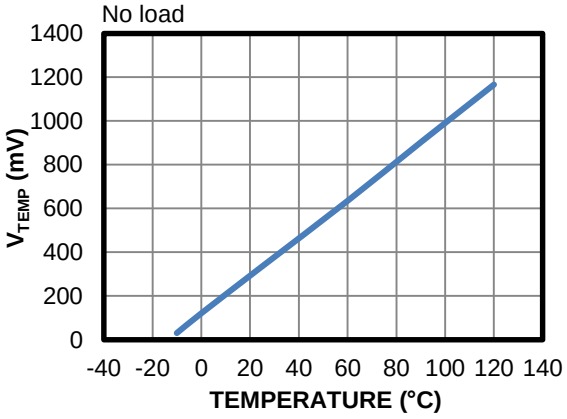
TYPICAL CHARACTERISTICS *(continued)*

V_{IN} = 12V, R_{CS} = R_{IMON} = 2kΩ, T_A = 25°C, unless otherwise noted.

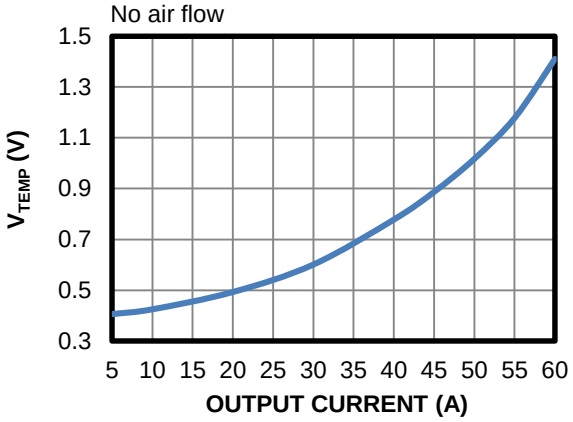
V_{TEMP} vs. Temperature

No load

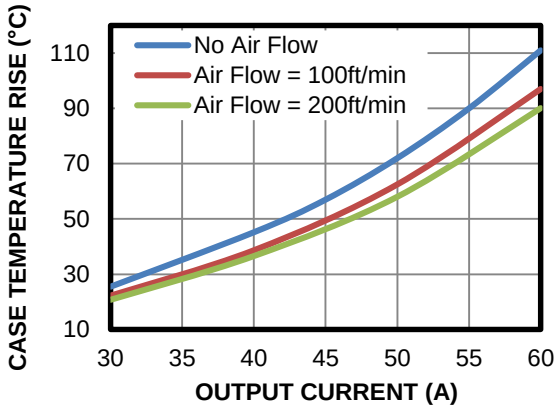


V_{TEMP} vs. Output Current

No air flow

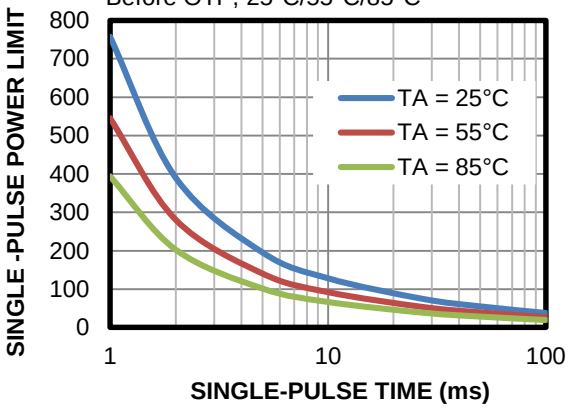


Case Temperature Rise



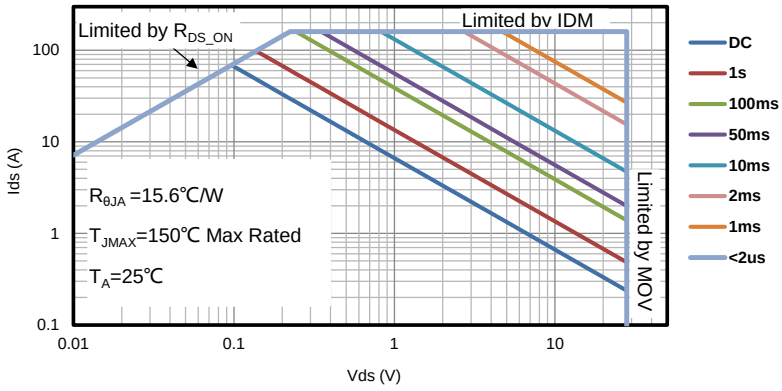
Single-Pulse Power Limit vs. Single-Pulse Time

Before OTP, 25°C/55°C/85°C



Safe Operation Area (SOA)

Tested on the EV5991-V-4PHASE-00A (11cmx15cm), 4-layer PCB, 2oz per layer



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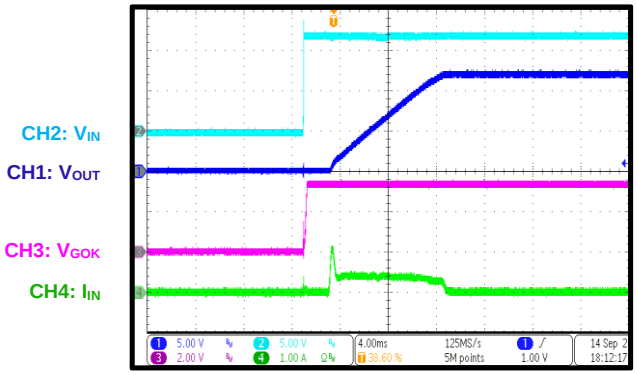
TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 12V, C_{OUT} = 330µF, R_{CS} = R_{IMON} = 2kΩ, T_A = 25°C, unless otherwise noted.

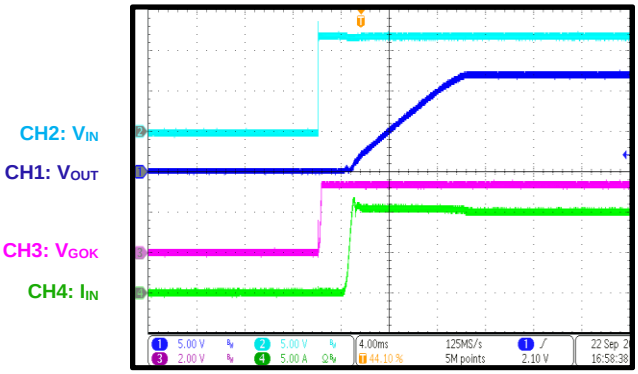
VIN Hot Plug

I_{OUT} = 0A



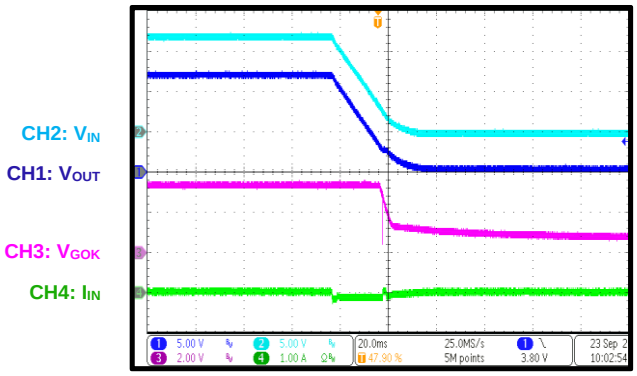
VIN Hot Plug

I_{OUT} = 10A



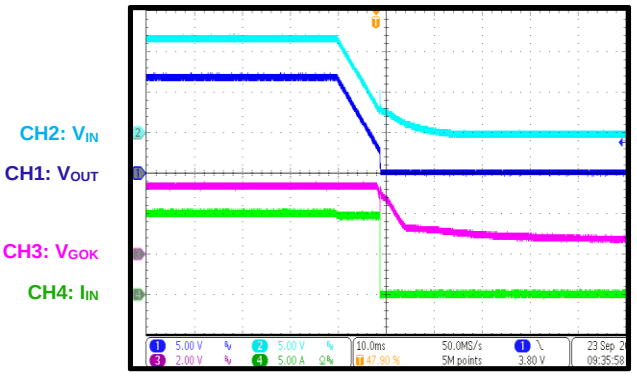
Shutdown through VIN

I_{OUT} = 0A



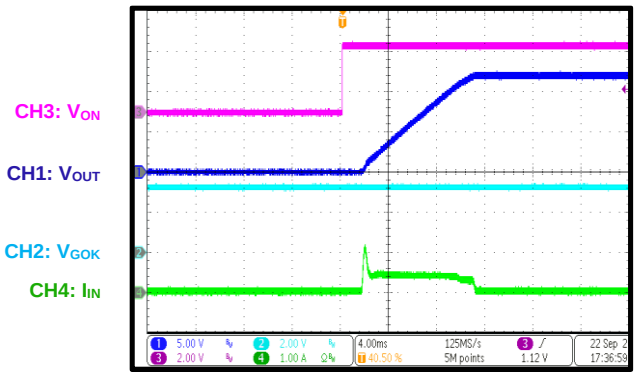
Shutdown through VIN

I_{OUT} = 10A



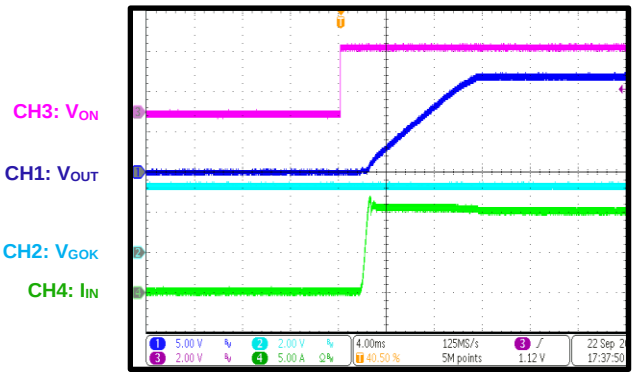
Start-Up through ON

I_{OUT} = 0A



Start-Up through ON

I_{OUT} = 10A



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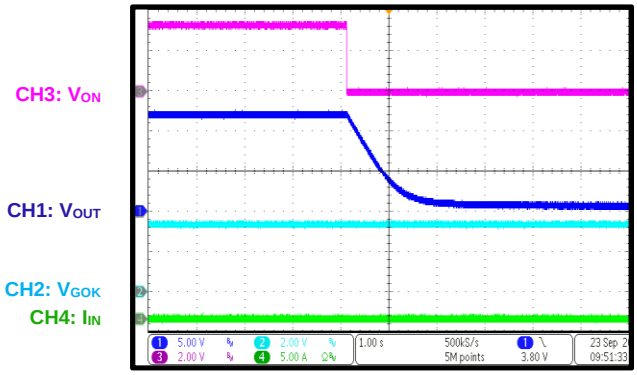
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, C_{OUT} = 330µF, R_{CS} = R_{IMON} = 2kΩ, T_A = 25°C, unless otherwise noted.

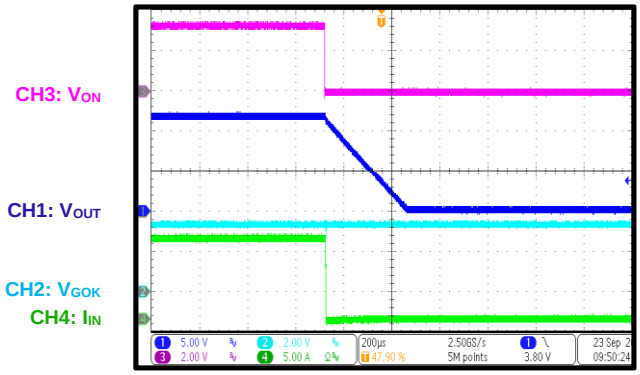
Shutdown through ON

I_{OUT} = 0A



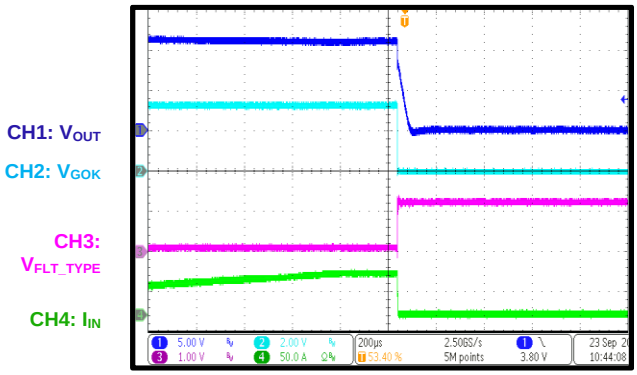
Shutdown through ON

I_{OUT} = 10A



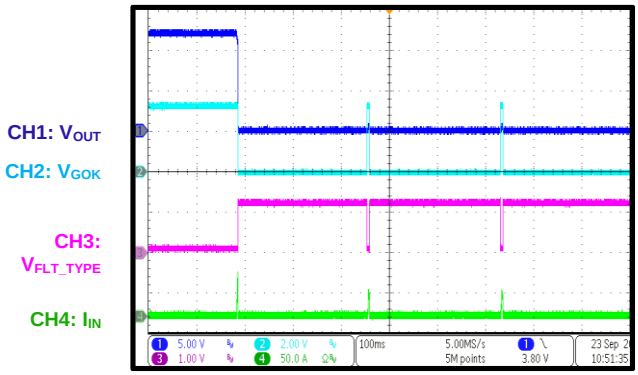
Over-Current Protection

I_{LIMIT} = 50A, latch mode



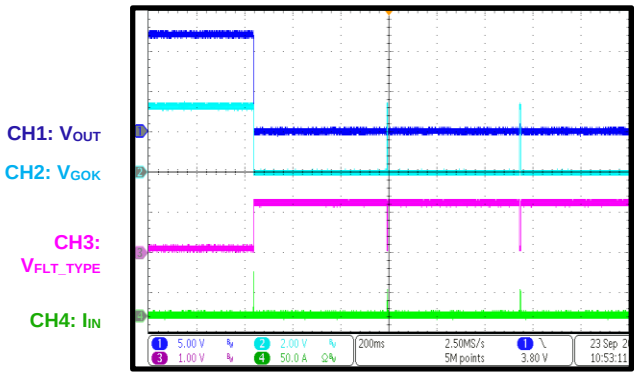
Over-Current Protection

I_{LIMIT} = 50A, hiccup mode, t_{RETRY} = 250ms



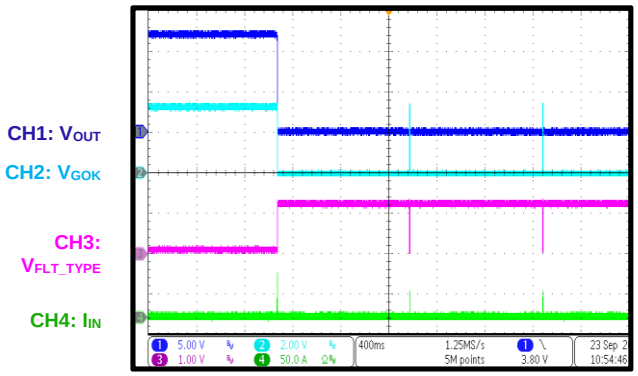
Over-Current Protection

I_{LIMIT} = 50A, hiccup mode, t_{RETRY} = 500ms



Over-Current Protection

I_{LIMIT} = 50A, hiccup mode, t_{RETRY} = 1s



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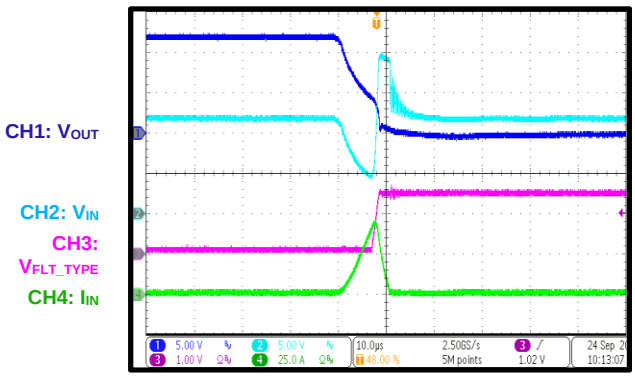
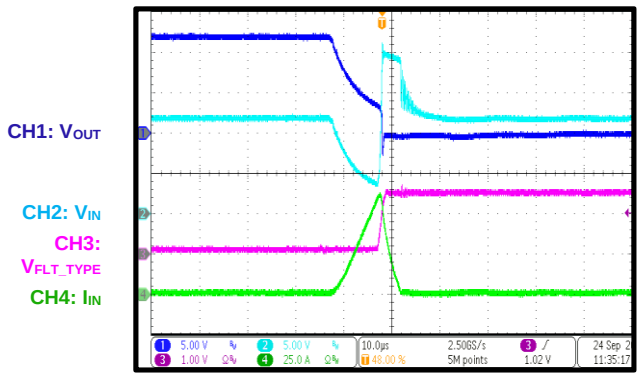
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, C_{OUT} = 330µF, R_{CS} = R_{IMON} = 2kΩ, T_A = 25°C, unless otherwise noted.

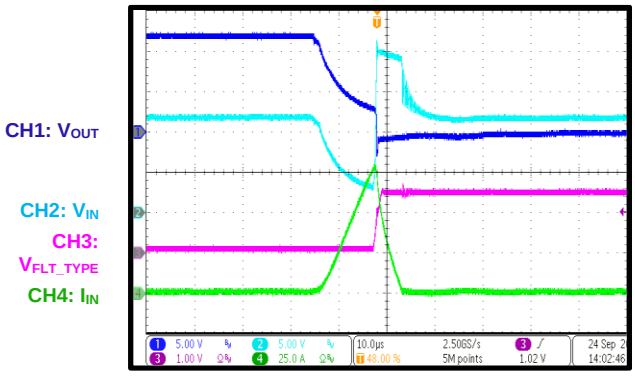
Short-Circuit Protection
I_{LIMIT} = 40A, latch mode



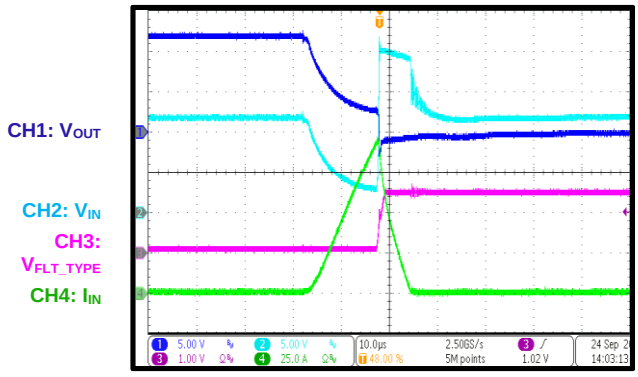
Short-Circuit Protection
I_{LIMIT} = 60A, latch mode



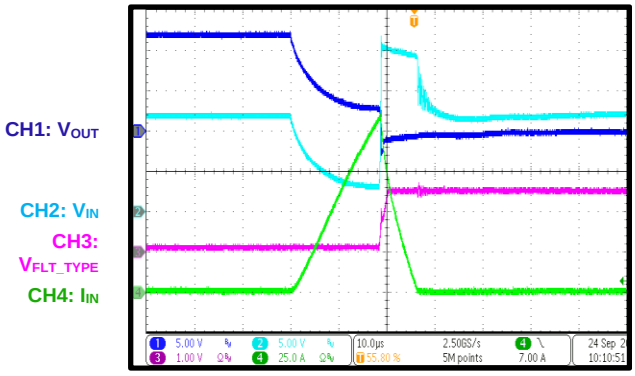
Short-Circuit Protection
I_{LIMIT} = 80A, latch mode



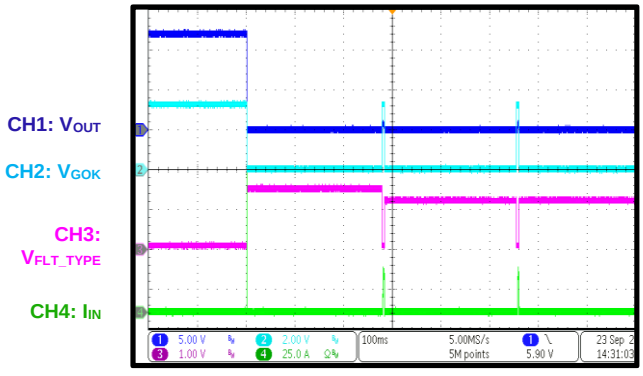
Short-Circuit Protection
I_{LIMIT} = 100A, latch mode



Short-Circuit Protection
I_{LIMIT} = 120A, latch mode



Short-Circuit Protection
I_{LIMIT} = 100A, hiccup mode, t_{RETRY} = 250ms



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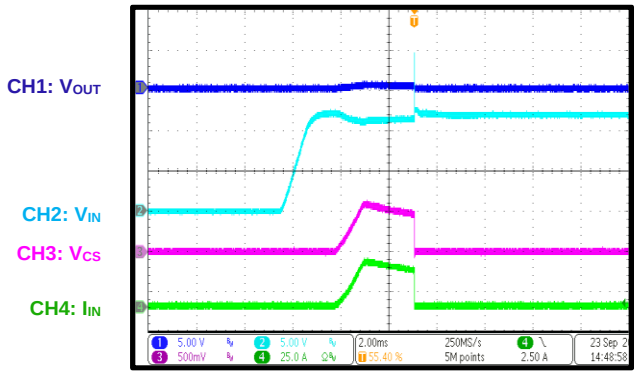
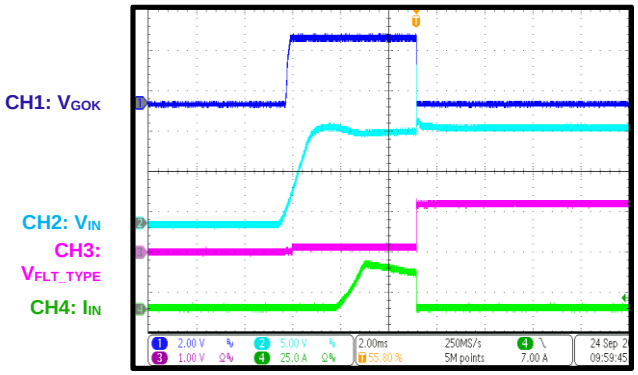
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, C_{OUT} = 330µF, R_{CS} = R_{IMON} = 2kΩ, T_A = 25°C, unless otherwise noted.

Short-Circuit Start-Up

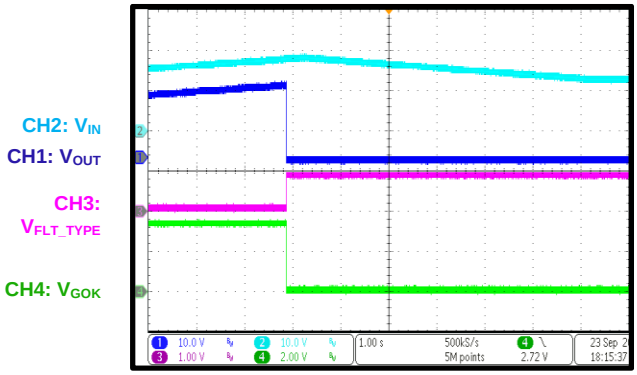


Short-Circuit Start-Up



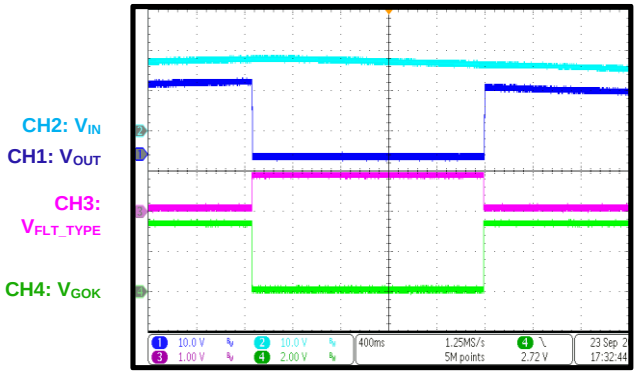
V_{IN} OVP in Latch Mode

Latch mode, 18.5V applied to VIN, then V_{IN} is reduced



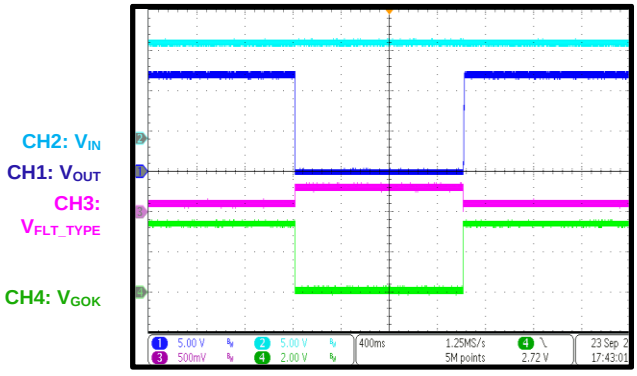
VIN OVP in Hiccup Mode

Hiccup mode, 18.5V applied to VIN, then V_{IN} is reduced



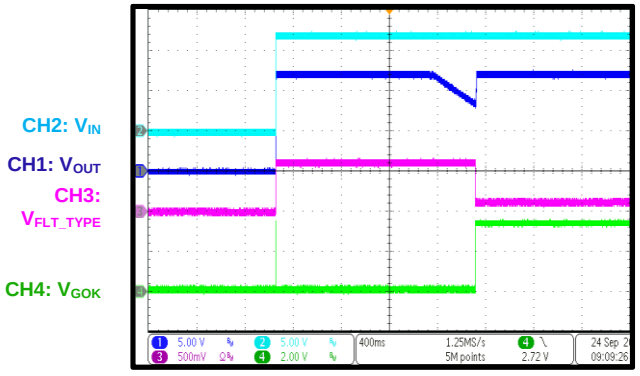
GOK Fault

GOK is pulled to GND, then GOK is pulled high



DS Short

Start-up with DS short, then DS short is removed



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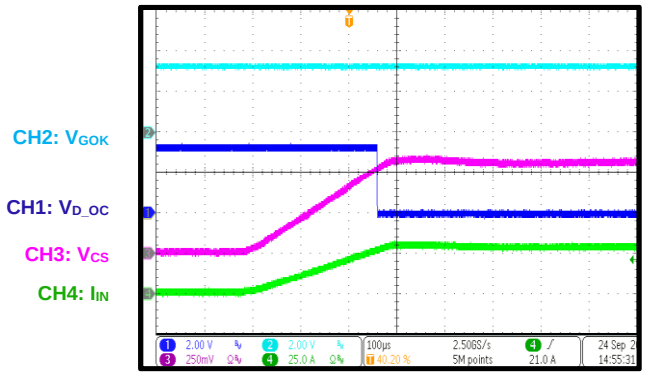
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, C_{OUT} = 330µF, R_{CS} = R_{IMON} = 2kΩ, T_A = 25°C, unless otherwise noted.

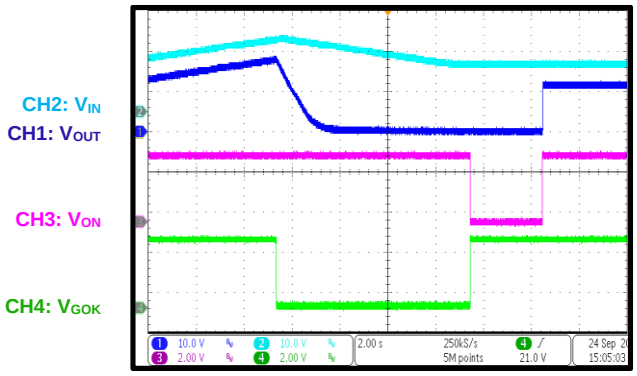
D_OC Status

Normal operation, V_{OCREF} = 0.6V, increase load, D_OC is pulled low once V_{CS} = 0.51V



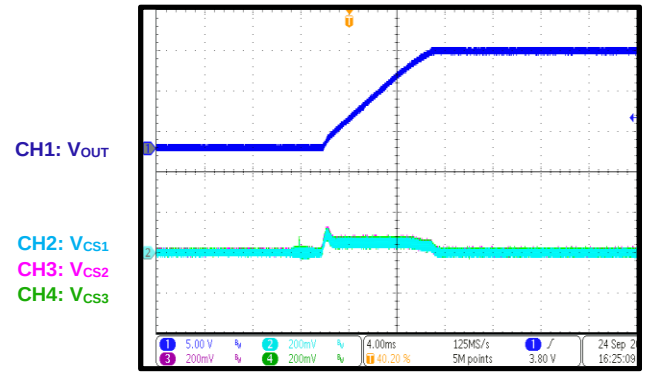
ON Signal to Clear Fault Status

Latch mode, apply V_{IN} to trigger OVP, then reduce V_{IN} to 12V, then cycle the power on ON



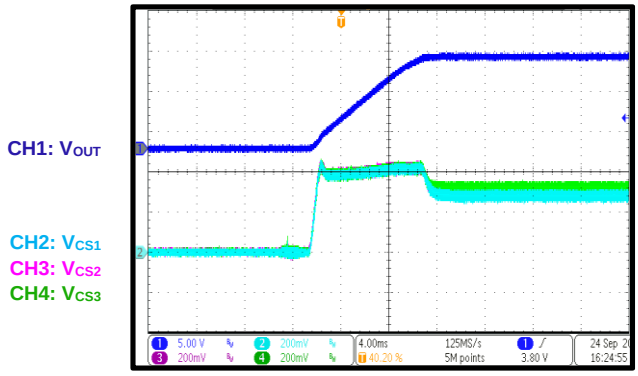
Current Balance during Start-Up

MP5991 3-phase parallel operation, R_{IMON} = R_{CS} (per MP5991), I_{OUT} = 0A



Current Balance during Start-Up

MP5991 3-phase parallel operation, R_{IMON} = R_{CS} (per MP5991), I_{OUT} = 45A



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FUNCTIONAL BLOCK DIAGRAM

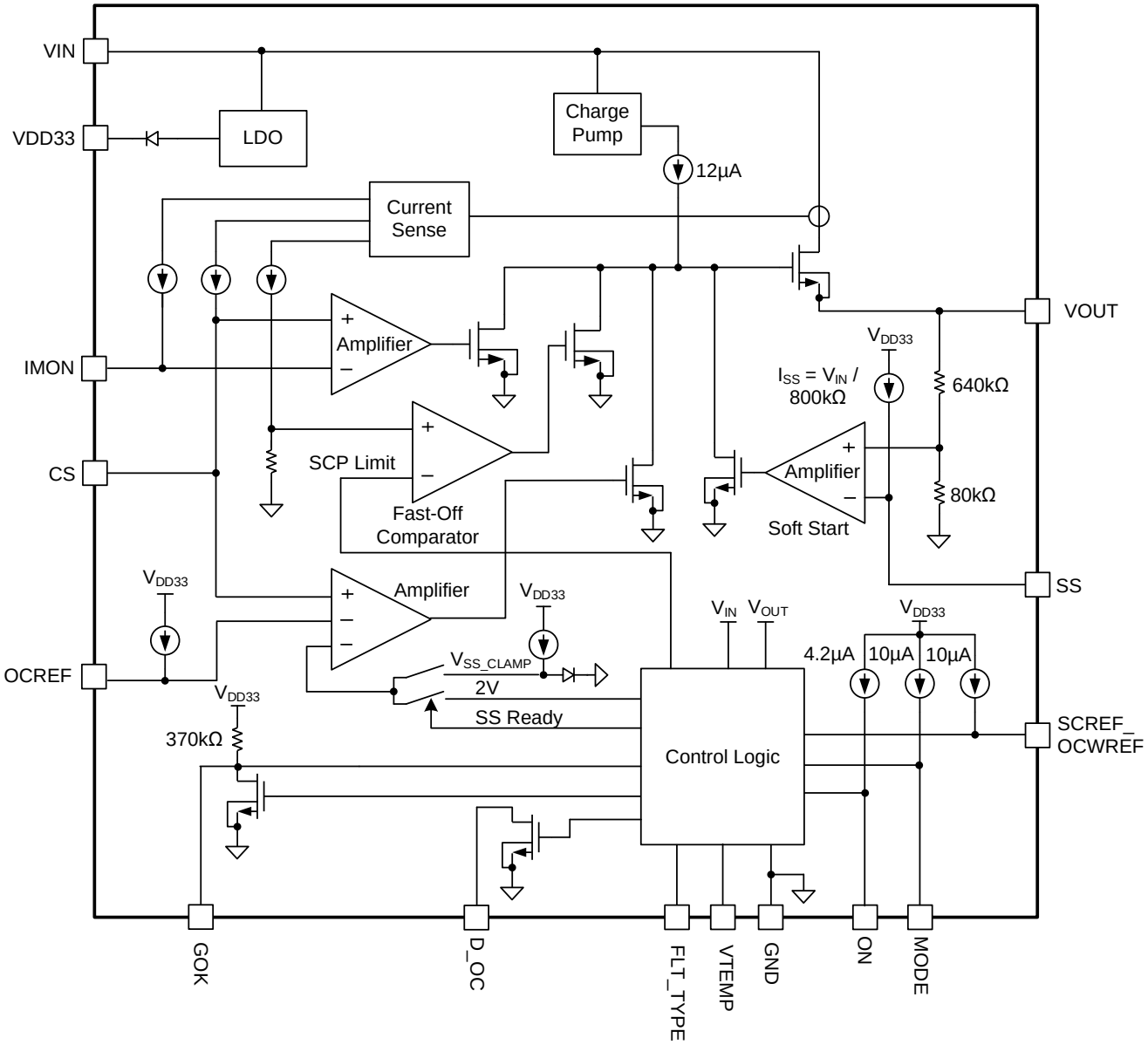

Figure 5: Functional Block Diagram

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OPERATION

The MP5991 is a monolithic Intelli-Fuse device with an integrated, 1mΩ $R_{DS(ON)}$ power MOSFET that is ideally suited for multi-fuse hot-swap applications. The MP5991 can operate alone or can be controlled via a hot-swap controller for multi-fuse operation. It can drive up to 50A of continuous output current (I_{OUT}) per device at room temperature, and up to 60A of continuous I_{OUT} with air flow.

The device limits the backplane voltage drop by limiting the inrush current to the load while a circuit card is inserted into a live backplane power source. It also provides an integrated current mirror to monitor I_{OUT} and the integrated on-die temperature sense. This eliminates the need for an external current-sense power resistor, power MOSFET, and temperature-sense device.

The MP5991 monitors the current and temperature to feedback information to the processor or controller. It limits the internal MOSFET current (I_{FET}) by controlling the gate voltage (V_{GATE}) via the current limit (I_{LIMIT}) reference input and soft-start ramp.

MOSFET On/Off Control (ON)

The ON pin turns the power MOSFET on and off. Pull ON above 1.4V to turn the MOSFET on; pull ON below 1.2V to turn it off. There is a fixed t_{ON_DELAY} (1.3ms) that starts once ON exceeds 1.4V. The MOSFET remains off until t_{ON_DELAY} is finished. If a fault does not occur, the ON pin can turn the MOSFET on after 1.3ms. Figure 6 shows the MOSFET on/off control for when GOK is pulled up to VDD33.

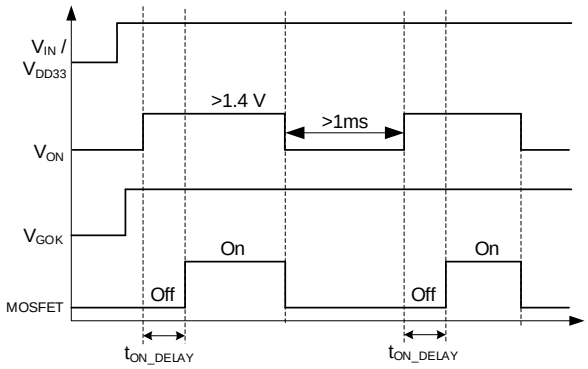

Figure 6: MOSFET On/Off Control

If a fault occurs, the GOK is pulled low and the device shuts down. The fault status is cleared and GOK is pulled high once ON is pulled low, regardless of whether the fault is removed. If the fault is removed while ON is low, pull ON above 1.4V after a blanking time (t_{ON_BLANK}) (1ms) can start up the device, regardless of which mode it is in (either latch-off mode or hiccup mode). Figure 7 shows the MOSFET on/off control if a fault occurs.

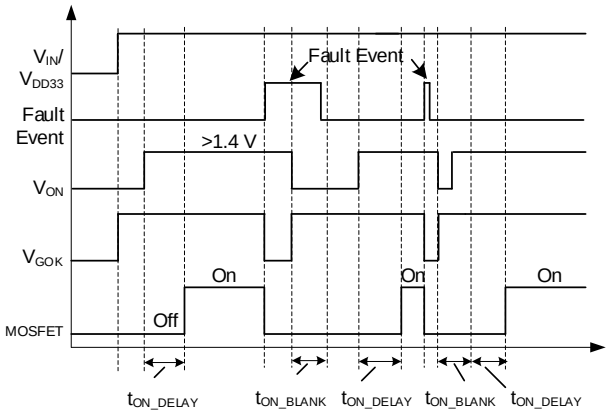

Figure 7: MOSFET On/Off Control if a Fault Occurs

In standalone mode, the C_{ON} can be used for automatic start-up via the internal pull-up current source (4.2μA). If the MP5991 is paired with an Intelli-Fuse master or controller, then ON is controlled via the master or controller.

Soft Start (SS)

A soft-start capacitor (C_{SS}) determines the soft-start time (t_{SS}). If ON is pulled high and t_{ON_DELAY} finishes, a constant-current source proportional to V_{IN} charges C_{SS}. V_{OUT} rises at a similar slew rate to V_{SS}.

C_{SS} can be calculated with Equation (1):

$$C_{SS}(nF) = \frac{9 \times t_{SS}(ms)}{R_{SS}} \quad (1)$$

Where R_{SS} is 0.8MΩ.

For example, a 100nF capacitor sets t_{SS} to 8.9ms. If the load capacitance is extremely large, the current required to maintain the preset t_{SS} should exceed the current limit (I_{LIMIT}).

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Then the rise time is controlled by the load capacitor and I_{LIMIT}. Float the SS pin to generate a fast ramp-up voltage. A current source (12μA) pulls up the MOSFET gate. The gate charge current controls the V_{OUT} rise time, and t_{SS} is about 1.5ms, which is the minimum V_{OUT} t_{SS}.

If multiple MP5991s are operating in parallel, then their SS pins should be connected. This controls the soft-start slew rate for all of the devices in parallel during soft start.

Start-Up Sequence

For hot-swap applications where V_{IN} rises immediately, V_{GATE} should be pulled low during V_{IN} plug-in with high dv/dt. The MP5991 has two operation modes: standalone mode and slave mode.

Standalone Mode

In standalone mode, connect an external capacitor (C_{ON}) between the ON and GND pins for automatic start-up. Figure 8 shows a typical application circuit of the MP5991 in standalone mode.

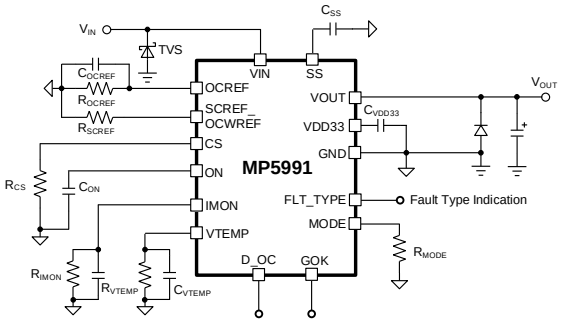

Figure 8: MP5991 Typical Application Circuit in Standalone Mode

The internal current source (4.2μA) charges C_{ON} once the VDD33 voltage (V_{DD33}) exceeds its UVLO rising threshold. ON can also be pulled up to VDD33 externally. The OCREF current (I_{OCREF}) (10μA) determines the over-current (OC) limit (I_{LIMIT_OC}) level via the OCREF resistor (R_{OCREF}). The SCREF current (I_{SCREF}) (10μA) determines I_{LIMIT_SC} level via the SCREF resistor (R_{SCREF}).

Once V_{ON} exceeds 1.4V and t_{ON_DELAY} finishes, the MOSFET is charged by the internal 12μA charge pump. The MOSFET turns on once the gate-to-source (GS) voltage (V_{GS}) exceeds its threshold (V_{GS_TH}), and V_{OUT} rises. If the external current-limit reference voltage (V_{OCREF}) exceeds the internal V_{SS_CLAMP}, then the actual current-limit reference is clamped internally at V_{SS_CLAMP} (see Figure 9). If the external V_{OCREF} is below V_{OCREF_CLAMP}, then the current-limit reference is determined by V_{OCREF}.

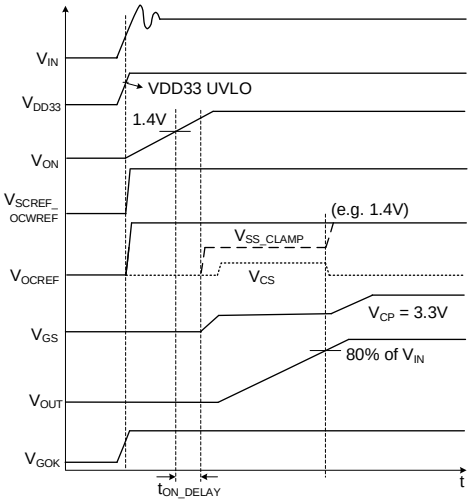

Figure 9: Start-Up in Standalone Mode

Slave Mode

If the MP5991 is controlled by a hot-swap master or controller (e.g. design with the MP5990), then the part should be configured to operate in slave mode. In slave mode, V_{OCREF}, V_{SCREF}, and the OCWREF voltage (V_{OCWREF}) are configured via the controller.

The MOSFET remains off until V_{ON} is pulled high. If V_{ON} goes high and t_{ON_DELAY} finishes, then the MOSFET is charged by the internal 12μA charge pump. V_{OUT} rises once V_{GS} exceeds V_{GS_TH} (see Figure 10).

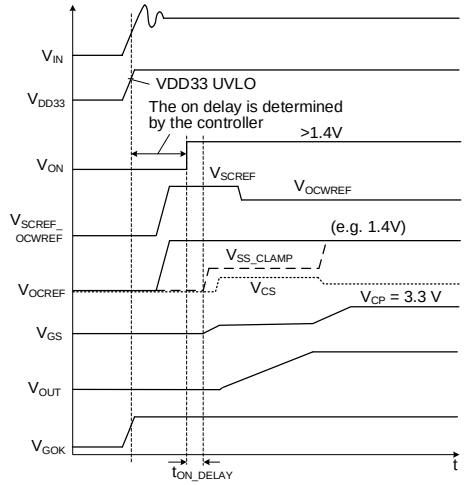

Figure 10: Start-Up while the MP5991 is Controlled via a Hot-Swap Controller

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If I_{LOAD} is high, then the maximum CS voltage (V_{CS}) is clamped at V_{SS_CLAMP} during soft start.

If the ON signal from the hot-swap controller remains high, then the MP5991 can also be turned on or off via the VIN pin.

Current-Sense Output (CS)

The CS pin provides a current proportional to the current flowing through the device (I_{OUT}). V_{CS} is used for OC limiting, OC warning indication, and parallel operation with start-up current balancing. The current-sense gain is 10μA/A while the MOSFET is on fully. The current-sense resistor (R_{CS}) is used to generate V_{CS}. I_{CS} can be calculated with Equation (2):

$$I_{CS} = I_{OUT} \times 10\mu A/A \quad (2)$$

Then V_{CS} can be calculated with Equation (3):

$$V_{CS} = I_{CS} \times R_{CS} \quad (3)$$

Once V_{CS} exceeds the OCREF I_{LIMIT} threshold, the internal circuitry regulates V_{GATE} to maintain a constant I_{FET}.

Current Monitor Output (IMON)

The MP5991 provides a high-accuracy power MOSFET current monitor output (IMON). The gain of the current monitor (g_{IMON}) is 10μA/A. Connect a resistor (R_{IMON}) between the IMON and GND pins. The IMON voltage (V_{IMON}) range (0V to 1.8V) is required to keep the IMON current (I_{IMON}) linearly proportional to I_{FET}. I_{IMON} can be calculated with Equation (4):

$$I_{IMON} = I_{OUT} \times 10\mu A/A \quad (4)$$

Then V_{IMON} can be calculated with Equation (5):

$$V_{IMON} = I_{IMON} \times R_{IMON} \quad (5)$$

The current monitor output can be used by the master or controller to accurately monitor the I_{OUT}. Place a 2.2nF to 100nF capacitor between the IMON and GND pins to reduce noise and maintain a smooth indicator voltage.

Current Balancing for Parallel Operation

Multiple MP5991 devices can be used in parallel for higher-current applications. The current balance loop balances the start-up current for each active channel. Connect the IMON pins of all devices for current balancing.

The sensed current from each active IMON pin is summed together, and then divided by the number of active channels. The resulting average I_{LOAD} provides a measure of the total I_{LOAD}. The MP5991's current balance is achieved by comparing the sensed CS current (I_{CS}) in each device to the average current, which creates an appropriate V_{GATE} adjustment for each Intelli-Fuse during start-up. The equivalent average R_{IMON} (R_{IMON_AVG}) can be calculated with Equation (6):

$$R_{IMON_AVG} = R_{CS} / N \quad (6)$$

Where N is the number of active MP5991s.

Start-up current balancing is essential for improved thermal performance during parallel operation. Good current sharing reduces power loss by dissipating it across the devices and across a larger area.

Over-Current Limit Reference (OCREF)

The MP5991's I_{LIMIT} is set by V_{OCREF} and the external R_{CS}. V_{CS} is compared to V_{OCREF} via an amplifier to regulate V_{GATE}. This prevents the Intelli-Fuse current from exceeding I_{LIMIT} set by the reference. V_{OCREF} is set by the OCREF pin via a resistor (R_{OCREF}). V_{OCREF} can be calculated with Equation (7):

$$V_{OCREF} = I_{OCREF} \times R_{OCREF} \quad (7)$$

Where I_{OCREF} is 10μA.

To protect the MP5991 from overheating during start-up, the OCREF pin has internal clamp voltage (V_{OCREF_CLAMP}) that is determined by V_{IN} and V_{OUT} (see Figure 11).

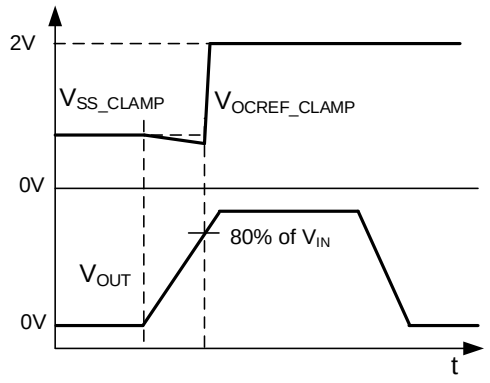

Figure 11: OCREF Clamp Voltage

If V_{OUT} is below 80% of V_{IN}, then V_{OCREF_CLAMP} is equal to V_{SS_CLAMP} (about 635mV with a negative temperature coefficient). If V_{OUT} exceeds 80% of V_{IN}, then V_{OCREF_CLAMP} is 2V.

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If V_{OCREF} is below V_{OCREF_CLAMP}, then the current-limit reference voltage is determined by V_{OCREF}. If V_{OCREF} exceeds V_{OCREF_CLAMP}, then the current-limit reference voltage is determined by V_{OCREF_CLAMP}.

The desired I_{LIMIT} is a function of R_{CS}, the current-sense gain (g_{CS}) and V_{OCREF}. I_{LIMIT} can be calculated with Equation (8):

$$I_{LIMIT} = \frac{V_{OCREF}}{g_{CS} \times R_{CS}} \quad (8)$$

I_{LIMIT} can exceed the maximum load current (I_{LOAD_MAX}) during normal operation to allow for tolerances in the current-sense value.

Over-Current Protection (OCP) during Start-Up

Once V_{CS} exceeds V_{OCREF} during soft start, V_{GATE} is regulated to maintain a constant I_{FET}. If V_{OUT} is below (1/8 x V_{IN}), and I_{FET} is regulated by V_{SS_CLAMP} for 2.1ms, then the MOSFET latches off, and GOK is pulled low (see Figure 12).

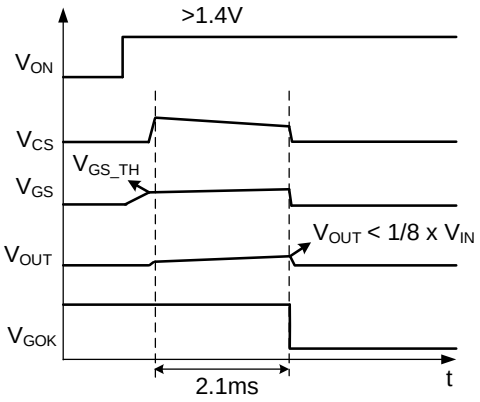

Figure 12: Failed Start-Up with Output Hard Short

OCP during Normal Operation

If V_{OUT} exceeds 80% of V_{IN}, then V_{OCREF_CLAMP} is pulled to 2V, and V_{GATE} is close to the internal charge pump voltage (V_{CP}). Once soft start is complete, the MP5991 begins normal operation.

Once V_{CS} (configured via an external resistor) exceeds V_{OCREF}, the internal circuitry regulates V_{GATE} to maintain a constant current on the MOSFET. To limit I_{OUT}, the MOSFET's V_{GS} is regulated between 3.3V and 1V. The response time is about 14µs. I_{OUT} may have a small overshoot during this response time.

If I_{OUT} exceeds I_{LIMIT}, then the internal fault timer (220µs) starts. If I_{OUT} drops below I_{LIMIT} within the fault timer period, then the device resumes normal operation. If I_{OUT} exceeds I_{LIMIT} for 220µs, then the MOSFET latches off, and GOK is pulled low.

If an OC fault occurs, then the GOK and SS pins are pulled low, and FLT_TYPE outputs 1.2V to indicate an OC fault.

In latch-off mode, cycle the power on VIN, VDD33, or ON to reset FLT_TYPE to 0.1V. This initiates a soft start, and then MOSFET turns on.

In hiccup mode, the device attempts to initiate a new soft start automatically, and GOK is pulled high after a retry delay time (t_{RETRY}). FLT_TYPE continues to indicate an OC fault during t_{RETRY}. FLT_TYPE is reset to 0.1V after t_{RETRY}.

Short-Circuit Current Limit (SCREF)

If I_{LOAD} increases rapidly due to a short circuit, the current may exceed I_{LIMIT} significantly before the hot-swap control loop can respond. Once the Intelli-Fuse current reaches the short-circuit current limit (I_{LIMIT_SC}), a fast turn-off circuit in the Intelli-Fuse is enabled to turn the MOSFET off. The total short-circuit response time is about 200ns. If I_{FET} exceeds I_{LIMIT_SC}, GOK is pulled low.

To determine I_{LIMIT_SC}, the MP5991 samples the SCREF voltage (V_{SCREF}) once the ON voltage (V_{ON}) exceeds its rising threshold during the t_{ON_DELAY} (see Figure 13).

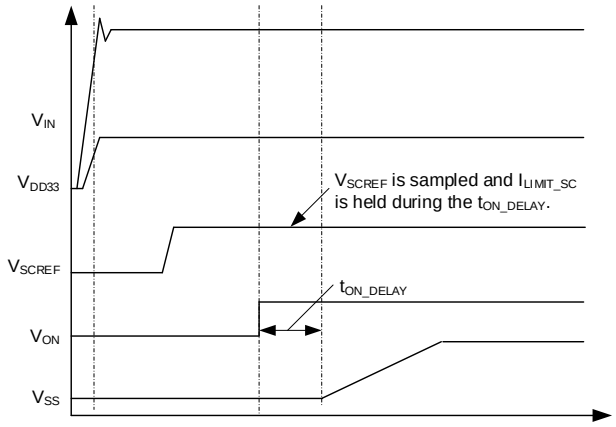

Figure 13: SCREF Voltage Sampling to Determine the Short-Circuit Current Limit

I_{LIMIT_SC} is held once t_{ON_DELAY} is finished. Changing V_{SCREF} after t_{ON_DELAY} does not affect

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I_{LIMIT_SC}. Cycle the power on VIN, VDD33, or ON to enter another t_{ON_DELAY} and set a new I_{LIMIT_SC}.

The MP5991 provides five types of short-circuit current levels that can be selected via the SCREF pin. Table 1 shows the selectable short-circuit current limits for different SCREF voltages in standalone mode (the recommended R_{SCREF} value is also shown for when V_{SCREF} is generated by R_{SCREF}).

Table: 1 Short-Circuit Current Limit Selection for Different V_{SCREF} in Standalone Mode

V_{SCREF} (V)	R_{SCREF}	I_{LIMIT_SC} (A)
<0.16	Pulled to GND	40
0.24 to 0.36	30kΩ	60
0.48 to 0.72	60kΩ	80
0.96 to 1.44	120kΩ	120
>1.68	200kΩ	100

In latch-off mode, cycle the power on VIN, VDD33, or ON to reset FLT_TYPE to 0.1V. This initiates a soft start, and then MOSET turns on.

In hiccup mode, the device attempts to retry automatically, and GOK is pulled high after t_{RETRY}. FLT_TYPE continues to indicate an SC fault during t_{RETRY}. FLT_TYPE is reset to 0.1V after t_{RETRY}.

Temperature-Sense Output (VTEMP)

The VTEMP pin reports the junction temperature (T_J) while there is no thermal gradient on the IC. If V_{DD33} exceeds its UVLO rising threshold, then VTEMP is a voltage output proportional to T_J. The VTEMP voltage (V_{TEMP}) is 8.7mV/°C, and has a 152.5mV offset. V_{TEMP} can be calculated with Equation (9):

$$V_{TEMP} = T_J \times 8.7mV + 152.5mV \quad (9)$$

For example, if T_J is 100°C, then V_{TEMP} is 1.022V. If V_{TEMP} is 0V, then T_J is -18°C. The total temperature-sense range is -18°C to +150°C. If T_J drops below -18°C, then V_{TEMP} is 0V.

During multi-fuse operation, the VTEMP pins of each Intelli-Fuse can be connected to the controller's temperature monitor pin. Connect a ≤1nF capacitor and a ≥10kΩ resistor in parallel on VTEMP. Figure 14 shows the temperature sense function during multi-fuse parallel operation.

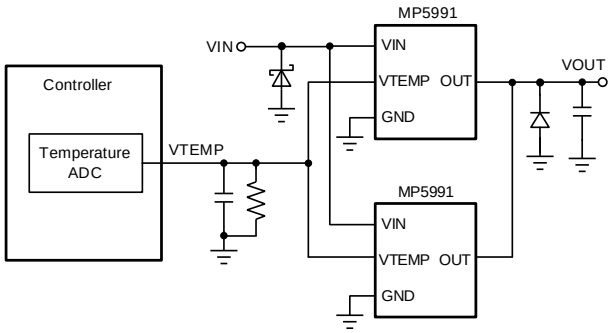

Figure 14: Temperature Sense during Multi-Fuse Parallel Operation

Mode Selection (MODE)

The MP5991 provides both latch-off mode and hiccup mode for the following protections: input over-voltage protection (OVP), output over-current protection (OCP), short-circuit protection (SCP), over-temperature protection (OTP), and MOSFET GS short protection. The MODE pin selects either latch-off mode or hiccup mode with t_{RETRY}. MODE also determines whether the MP5991 operates in slave mode.

In slave mode, the part operates with the following conditions:

- The internal I_{OCREF} (10μA) and I_{SCREF} (10μA) are disabled, so V_{OCREF} and V_{SCREF} are controlled by controller.
- The internal V_{OCREF_CLAMP} remains active, and the soft-start clamp voltage (V_{SS_CLAMP}) controls the soft-start current-limit threshold
- The internal ON current (I_{ON}) 4.2μA is disabled.
- If V_{CS} exceeds V_{OCWREF}, then D_OC is pulled low. D_OC is not pulled low if V_{CS} exceeds 85% of V_{OCREF}.
- Hiccup mode or latch-off mode and t_{RETRY} are selected via the controller.

If the device exceeds either the V_{DD33} or V_{IN} UVLO rising threshold, then the MODE pin is detected. Once a mode is selected, it is held until the power on VDD33 or VIN is cycled again.

Table 2 on page 26 shows the mode selection and t_{RETRY} for common resistor values.

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Table 2: Mode Selection

R_{MODE}	Protection Mode	Retry Delay Time
Pulled to GND	Hiccup mode	500ms
30kΩ	Hiccup mode	250ms
60kΩ	Hiccup mode	1s
120kΩ	Slave mode	
Pulled to VDD33 or floating	Latch-off mode	

GOK Reporting

The GOK pin is an open-drain with an internal weak pull-up, active-low signal that reports Intelli-Fuse faults. If a fault occurs, GOK is pulled low. Pull GOK up to the VDD33 via a 10kΩ to 100kΩ resistor. During start-up, the GOK voltage (V_{GOK}) rises according to V_{DD33}.

The MP5991 also provides a comparator on the GOK pin to control the MOSFET. If V_{GOK} drops below 1.16V, the system see this as a fault, and the MOSFET turns off.

D_OC Reporting

The D_OC pin is an open-drain, active-low output that reports OC warnings while V_{OUT} exceeds 90% of V_{IN}. If V_{CS} exceeds 85% of V_{OCREF} in standalone mode, then D_OC is pulled low. If V_{CS} drops below 85% of V_{OCREF}, then D_OC is pulled high. In slave mode, this threshold is determined by V_{OCWREF}, not 85% of the V_{OCREF}. Pull D_OC up to VDD33 via a 10kΩ to 100kΩ resistor.

Fault Type Indication (FLT_TYPE)

The MP5991 reports the fault type via a voltage on the FLT_TYPE pin. Table 3 shows the FLT_TYPE voltage (V_{FLT_TYPE}) for each fault condition.

Table 3: Fault Type Indication

Fault Types	FLT_TYPE Voltage
Short circuit	1.5V
OC fault during normal operation or during SS	1.2V
OT fault or V_{IN} OV fault	0.9V
GS/DS short	0.6V
GOK fault	0.3V
Other statuses	0.1V

Do not short FLT_TYPE to ground. V_{FLT_TYPE} indicates the associated value only while the fault is present and the MOSFET is off. For example, if an OC fault occurs, the FLT_TYPE outputs 1.2V after the fault timer (220µs) ends and the MOSFET turns off.

A higher V_{FLT_TYPE} indicates a more serious fault has occurred in the system. If multiple faults occur at the same time, then FLT_TYPE outputs the voltage for the most serious fault. For example, if an OC fault and an OT fault occur simultaneously, then FLT_TYPE outputs 1.2V to indicate the OC fault (the more serious fault).

In multi-fuse operation, the FLT_TYPE pins of each Intelli-Fuse can be connected together to indicate the highest-priority fault in the entire system.

Other Fault Protections

Over-Temperature Protection (OTP)/Thermal Shutdown

The MP5991 senses the MOSFET's junction temperature (T_J) internally. If T_J exceeds the thermal shutdown threshold (about 145°C), then the device shuts down. The GOK and SS pins are pulled low, and FLT_TYPE outputs 0.9V (if there are no other higher-priority faults have occurred).

In latch-off mode, cycle the power on VIN, VDD33, or ON to reset FLT_TYPE to 0.1V. This initiates a soft start, and then MOSFET turns on.

Once T_J drops below 100°C in hiccup mode, the device attempts to retry automatically, and GOK is pulled high after t_{RETRY}. FLT_TYPE continues to indicate an OT fault during t_{RETRY}. FLT_TYPE is reset to 0.1V after t_{RETRY}.

V_{IN} Over-Voltage Protection (OVP)

The MP5991 monitors V_{IN} to determine whether an over-voltage (OV) fault has occurred. If V_{IN} exceeds 18.5V, then the MOSFET turns off, and the GOK and SS pins are pulled low. If no other higher-priority faults have occurred, then FLT_TYPE outputs 0.9V to indicate an OV fault.

In latch-off mode, cycle the power on VIN, VDD33, or ON to reset FLT_TYPE to 0.1V. This initiates a soft start, and then MOSFET turns on.

Once V_{IN} drops below 17.5V in hiccup mode,

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the device attempts to retry automatically, and GOK is pulled high after t_{RETRY}. FLT_TYPE continues to indicate an OV fault during t_{RETRY}. FLT_TYPE is reset to 0.1V after t_{RETRY}.

Damaged Intelli-Fuse MOSFET Detection

The MP5991 can detect a shorted pass MOSFET during start-up. Once V_{DD33} exceeds its UVLO rising threshold and V_{ON} exceeds its rising threshold (1.4V), the device treat output voltages that exceed 90% of V_{IN} during the t_{ON_DELAY} as a short. This is called a drain-to-source (DS) short. GOK is pulled low once the device detects that V_{OUT} has exceeded 90% of V_{IN} during start-up, and FLT_TYPE outputs 0.6V to indicate a DS short. The DS short is non-latch fault, regardless of the operation mode. GOK is pulled high once the DS short is removed and the device detects that V_{OUT} is below 70% of V_{IN}. Then FLT_TYPE is reset to 0.1V. The MP5991 initiates a soft start and resumes normal operation.

Power MOSFET is Not Fully On

If the following conditions are met once the part starts up and V_{OUT} starts to ramp up, it means the power MOSFET is not fully on:

- V_{SS} exceeds V_{DD33} - 0.7V
- V_{GS} is below V_{CP} - 0.7V
- No OC faults have occurred
- No SC faults have occurred

The MP5991 stops regulating and the MOSFET turns off after 250ms. The GOK and SS pins are pulled low, and FLT_TYPE outputs 0.6V to indicate a GS short has occurred (see Figure 15).

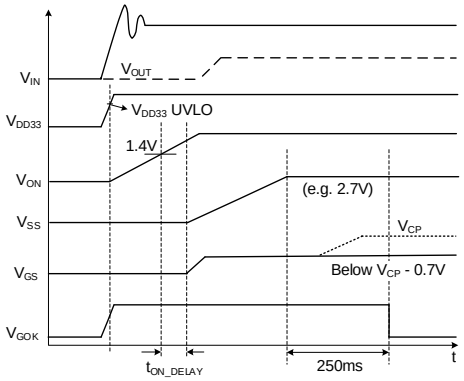

Figure 15: Power MOSFET is Not Fully On in Latch-Off Mode

In latch-off mode, cycle the power on VIN, VDD33, or ON to reset FLT_TYPE to 0.1V. This initiates a soft start, and then MOSFET turns on.

In hiccup mode, the device attempts to retry automatically, and GOK is pulled high after t_{RETRY} ends. FLT_TYPE continues to indicate a GS short fault during t_{RETRY}. FLT_TYPE is reset to 0.1V after t_{RETRY}.

GOK Fault

The MP5991 provides a comparator on the GOK pin to control the MOSFET. If V_{GOK} drops below 1.16V, then the system sees this as a fault, and the MOSFET turns off after a delay time (10µs). FLT_TYPE outputs 0.3V to indicate a GOK fault.

The GOK fault is non-latch fault. Once V_{GOK} exceeds 2.06V, the device initiates a soft start and resumes normal operation. FLT_TYPE resets to 0.1V.

For standalone operation, GOK has an internal pull-up resistor (370kΩ) to avoid falsely triggering a GOK fault when there is not an external pull-up resistor.

Under-Voltage Lockout (UVLO) Protection

The MP5991 has two under-voltage lockout (UVLO) protections: V_{DD33} UVLO with a 2.7V rising threshold, and V_{IN} UVLO with a 3.2V rising threshold. The device starts up once both V_{DD33} and V_{IN} exceed their respective rising thresholds. The MP5991 shuts down if either V_{DD33} or V_{IN} drops below its UVLO (2.3V and 2.7V, respectively). V_{DD33} UVLO and V_{IN} UVLO are non-latch protections.

Input and Output Transient Protection

Parasitic inductance in the input circuitry can cause the hot-swap system to experience positive transients on the input during a hot plug or during rapid shutdown with a high current. To reduce input transients, a transient voltage suppressor (TVS) diode may be required on the input to limit transient voltages below the absolute maximum ratings.

Inductance in the output circuitry can cause the output to experience negative transients during rapid turn-off with a high current. If a transient causes the output to drop further, then the MOSFET may not turn off properly.

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An output voltage clamp diode is required on the output to limit negative transients. Select a Schottky diode with a low forward voltage.

Parallel Operation

The MP5991 can work in parallel operation to support higher currents (maximum 20-phase operation). The following connections and conditions are required to support multi-phase parallel operation (see Figure 2 on page 3 for more details):

- Connect the VIN pins to the same input bus
- Connect the VOUT pins to the same output bus
- Tie the ON pins together for start-up sequence control
- Tie the SS pins together for soft-start sequence control
- Tie the GOK pins together for system fault control
- Design the current-sense resistor (R_{CS}) to have the same resistance in each phase
- Tie the IMON pins together, and design the total system's IMON resistance to equal R_{CS} / N (where N is the number of phases) for soft-start current-balance control
- Tie the OCREF pins together
- Select the same mode for all phases
- Tie the VTEMP pins together to report the highest T_J of all the phases
- Tie the FLT_TYPE pins together to indicate the highest-priority fault

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APPLICATION INFORMATION

Selecting the Current-Limit Resistor (R_{CS})

The MP5991's over current limit (I_{LIMIT}) should exceed the normal I_{LOAD_MAX}. This allows for tolerances in the current-sense value. I_{LIMIT} can be calculated with Equation (10):

$$I_{LIMIT} = \frac{V_{OCREF}}{R_{CS}} \times 10^5 (A) \quad (10)$$

Where VOCREF is the OCREF voltage while the MOSFET operates in linear mode.

If R_{CS} is 3kΩ and V_{OCREF} is 1.2V, then I_{LIMIT} is 40A. If V_{OCREF} is 0.3V, then I_{LIMIT} is 10A.

Current-Limit Reference Voltage (OCREF)

The OCREF pin sets the current-limit reference via the hot-swap controller in slave mode or via a resistor connected to ground in standalone mode. I_{OCREF} (10μA) sets V_{OCREF} in standalone mode. Place a 1nF to 10nF capacitor between the OCREF and GND pins to reduce noise and maintain a smooth indicator voltage.

During normal operation, V_{OCREF} can be set between 0.3V and 1.8V to configure I_{LIMIT} either low or high while R_{CS} is fixed.

Current Monitor Setting (IMON)

The MP5991 provides a power MOSFET current-monitoring function. Connect a resistor (R_{IMON}) between the IMON and GND pins to set the I_{OUT} gain.

In a single-fuse application, R_{IMON} should be ≥R_{CS}. If the device is used in a multi-fuse parallel application, the start-up current balance per device can be achieved by connecting the IMON pins together.

The equivalent average IMON resistance (R_{IMON_AVG}) can be calculated with Equation (6).

Figure 16 shows the IMON and CS connections of multiple MP5991s in a multi-fuse parallel application.

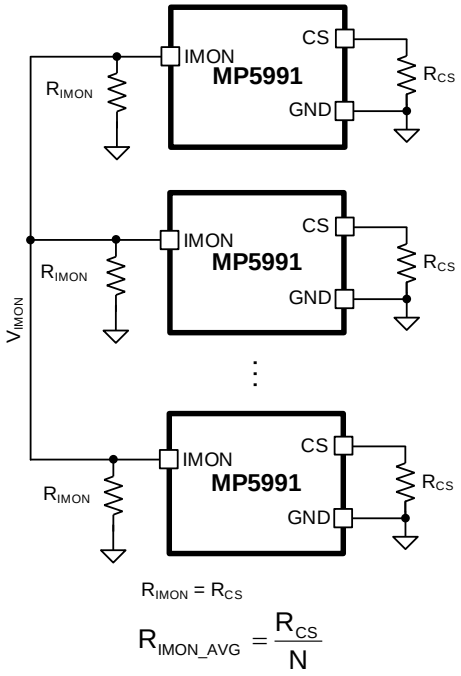

Figure 16: IMON and CS Connections in Multi-Fuse Parallel Application

Maximum Output Current

The MP5991 can drive up to 50A of continuous I_{OUT} per device at room temperature, and up to 60A I_{OUT} with air flow. Figure 17 shows the case temperature rise at different air flow conditions.

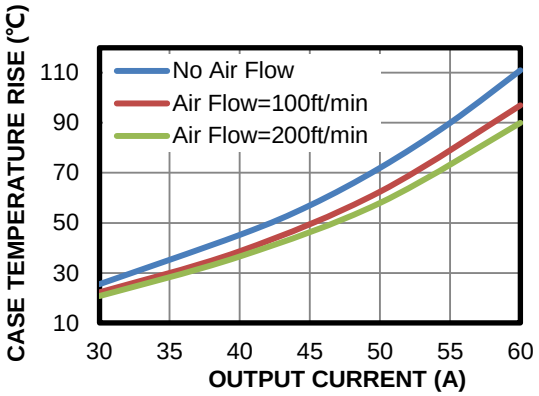

Figure 17: Case Temperature Rise

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PCB Layout Guidelines

Efficient PCB layout is critical for stable operation. A 4-layer layout is strongly recommended for improved thermal performance. For the best results, refer to Figure 18 and follow the guidelines below:

1. Place the IC close to the VIN to minimize trace inductance.
2. Place a small input capacitor (e.g. 100nF) close to VIN and GND to minimize transients on the input. (7)
3. Place a 1µF capacitor as close to VDD33 as possible.
4. Route the high-current path and the return path between the input and the load close to each other in parallel to minimize loop inductance.
5. Place an analog signal ground (AGND) plane locally in the IC.
6. Connect the AGND plane to PGND planes at a single point.
7. If the MP5991 is controlled via a hot-swap controller, connect all of the IC's AGNDs to the controller's reference ground.
8. Place multiple vias on the board to improve better thermal performance.
   a. Place ≥9 vias on the bottom of the VIN pad.
   b. Place ≥12 vias close to the VIN pads at the edge of the IC.
   c. Place ≥9 vias close to VOUT pads.

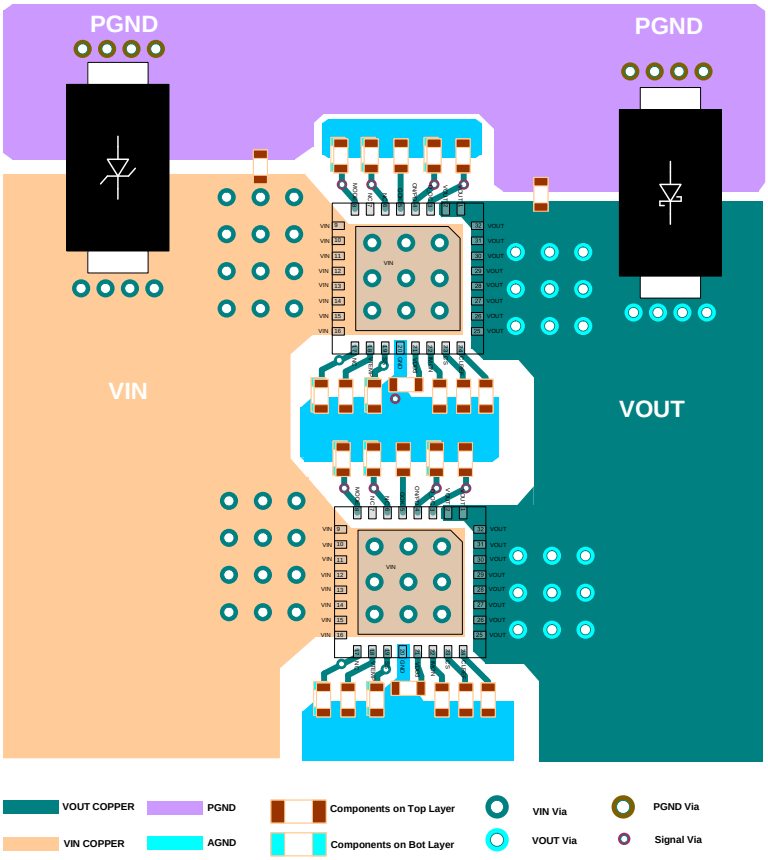

Figure 18: Recommended PCB Layout

VIN TVS Diode PN: SMDJ13A

VOUT Diode PN (Standalone Operation): MBRA340T3G

VOUT Diode PN (Parallel Operation): MBRS540T3G

Note:

7) Transient voltages can occur on the input if the MOSFET is turned off by a large I_{LOAD}.

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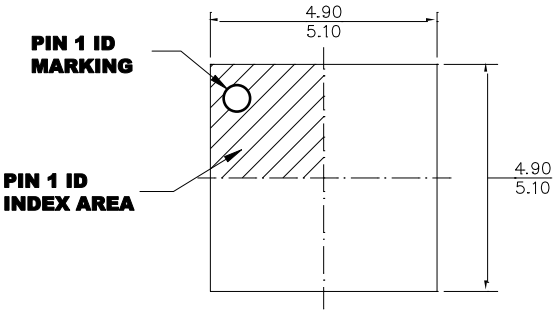
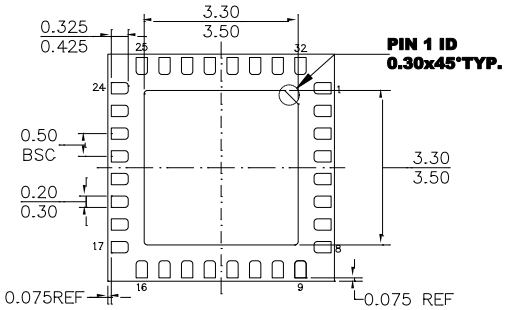
PACKAGE INFORMATION

LGA-32 (5mmx5mm)

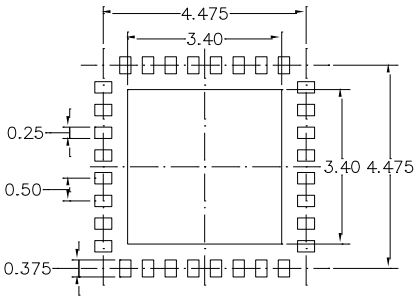


TOP VIEW



BOTTOM VIEW

SIDE VIEW



RECOMMENDED LAND PATTERN

NOTE:

1) ALL DIMENSIONS ARE IN MILLIMETERS.
2) LEAD COPLANARITY SHALL BE 0.10 MILLIMETERS MAX.
3) JEDEC REFERENCE IS MO-303.
4) DRAWING IS NOT TO SCALE.

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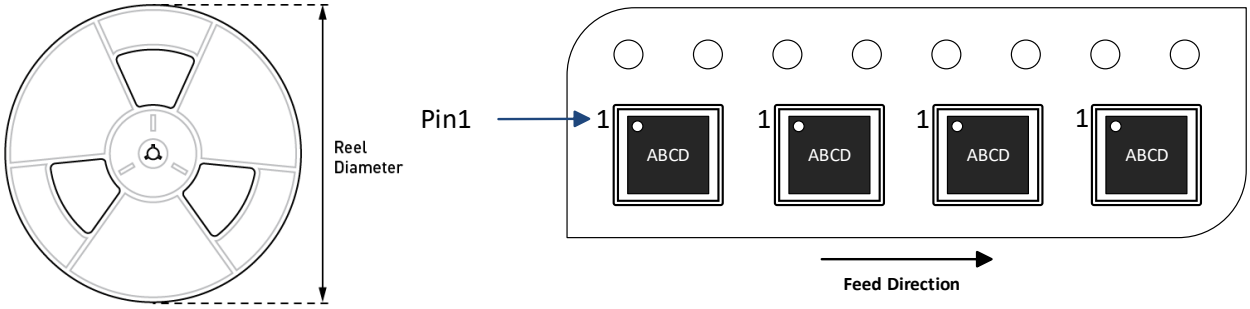
CARRIER INFORMATION



Part Number	Package Description	Quantity/ Reel	Quantity/ Tube	Quantity/ Tray	Reel Diameter	Carrier Tape Width	Carrier Tape Pitch
MP5991GLU-Z	LGA-32 (5mmx5mm)	5000	N/A	N/A	13in	12mm	8mm

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REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	4/27/2022	Initial Release	-

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