MP5098

12V/5V, Low I_Q, Dual-Channel E-Fuse with Current Monitoring and Low On Resistance

DESCRIPTION

The MP5098 is a 12V/5V, low quiescent current (I_Q), low on resistance ($R_{DS(ON)}$), dual-channel e-fuse protection device with current monitoring. It protects output circuitry from input transients, as well as protects input circuitry from output shorts and transients.

At start-up, the inrush current is limited by limiting the output slew rate. The slew rate is controlled via the SS pin capacitor (C_{SS}).

The maximum load current (I_{LOAD_MAX}) at the output is current-limited. The magnitude of the current limit (I_{LIMIIT}) is fixed internally.

Full protection features include output over-voltage protection (OVP), over-current protection (OCP), short-circuit protection (SCP), and thermal shutdown.

The output voltage (V_{OUT}) is limited by output OVP. Each rail's output current (I_{OUT}) can be monitored via a resistor connected between the IMON1 and IMON2 pins.

The MP5098 is available in a space-saving TQFN-10 (2mmx3mm) package.

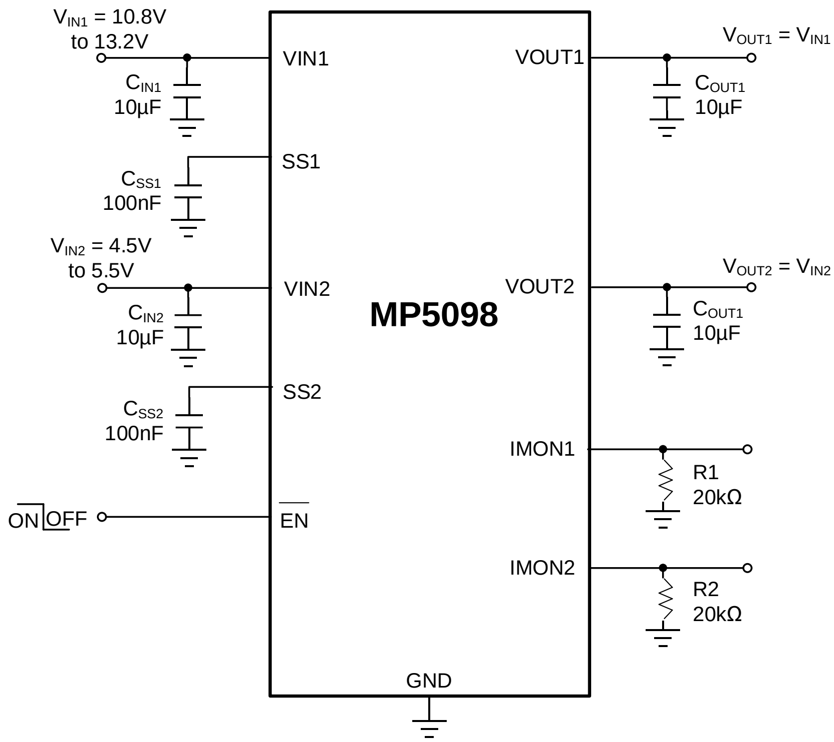
FEATURES

- 12V/5V Integrated Dual E-Fuse
- Dual-Channel Current Limiting
- 24V/100ms Maximum Surge Input Voltage (V_{IN}) Tolerance for 12V Bus and 5V Bus
- 40mΩ Low On Resistance ($R_{DS(ON)}$)
- Low Quiescent Current (I_Q):
  - 210µA I_Q for 12V Bus
  - 190µA I_Q for 15V Bus
- Configurable Soft-Start Time (t_{SS})
- Fixed Trip/Hold Current Limit (I_{LIMIIT}):
  - Fixed 4A Trip I_{LIMIIT} for 12V Bus
  - Fixed 2.5A Hold I_{LIMIIT} for 12V Bus
  - Fixed 3A Trip I_{LIMIIT} for 5V Bus
  - Fixed 1.3A Hold I_{LIMIIT} for 5V Bus
- 15V Over-Voltage Protection (OVP) Threshold for 12V V_{IN} Channel
- 5.7V OVP Threshold for 5V V_{IN} Channel
- Over-Current Protection (OCP) with Hiccup Mode
- Short-Circuit Protection (SCP)
- Thermal Shutdown (Latch-Off Protection)
- Available in a TQFN-10 (2mmx3mm) Package

APPLICATIONS

- Hard-Disk Drives (HDDs)
- Solid-State Drives (SSDs)
- Hot Swap Applications

TYPICAL APPLICATION



ORDERING INFORMATION

Part Number*	Package	Top Marking	MSL Rating
MP5098GDT	TQFN-10 (2mm×3mm)	*See Below*	1

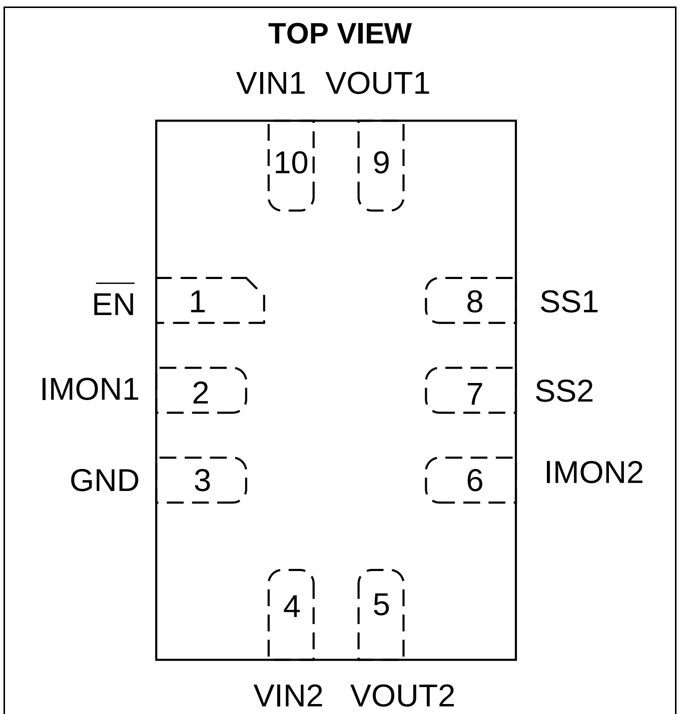
* For Tape & Reel, add suffix -Z (e.g. MP5098GDT-Z).

TOP MARKING

BLB
YWW
LLL

BLB: Product code of MP5098GDT
Y: Year code
WW: Week code
LLL: Lot number

PACKAGE REFERENCE



TQFN-10 (2mmx3mm)

PIN FUNCTIONS

Pin #	Name	Description
1	$\overline{EN}$	**Channel 1 and channel 2 enable.** The $\overline{EN}$ pin is a digital input that turns the regulator on and off. Float $\overline{EN}$ or pull $\overline{EN}$ low to turn the regulator on; pull $\overline{EN}$ high to turn it off.
2	IMON1	**Channel 1 current monitoring.** Connect a resistor between the IMON1 and GND pins to set the current monitor gain.
3	GND	**System ground.**
4	VIN2	**Channel 2 supply voltage.** Channel 2's typical input voltage (V_{IN}) is 5V. Use a ceramic decoupling capacitor to decouple the VIN2 pin. Connect VIN2 using a wide PCB trace.
5	VOUT2	**Channel 2 output terminal.**
6	IMON2	**Channel 2 current monitoring.** Connect a resistor between the IMON2 and GND pins to set the current monitor gain.
7	SS2	**Channel 2 soft start.** Connect a capacitor between the SS2 and GND pins to set channel 2's soft-start time (t_{SS}).
8	SS1	**Channel 1 soft start.** Connect a capacitor between the SS1 and GND pins to set channel 1's t_{SS}.
9	VOUT1	**Channel 1 output terminal.**
10	VIN1	**Channel 1 supply voltage.** Channel 2's typical input voltage (V_{IN}) is 12V. Use a ceramic decoupling capacitor to decouple the VIN1 pin. Connect VIN1 using a wide PCB trace.

ABSOLUTE MAXIMUM RATINGS (1)

V_{IN1}, V_{OUT1} .... -0.3V to +22V
Input positive transient (CH1 = 100ms) 24V
V_{IN2}, V_{OUT2} .... -0.3V to +15V
Input positive transient (CH2 = 100ms) 24V
All other pins .... -0.3V to +5V
Junction temperature .... -40°C to +150°C
Lead temperature .... 260°C
Continuous Power Dissipation (T_A = 25°C) (2)(4)
TQFN-10 (2mmx3mm) 3.1W

ESD Ratings

Human body model (HBM) 2000V
Charged device model (CDM).................1750V

Recommended Operating Conditions (3)

CH1 continuous voltage............. 10.8V to 13.8V
CH2 continuous voltage................. 4.6V to 5.5V
Operating junction temp (T_J) .... -40°C to +125°C

Thermal Resistance

	θ_{JA}	θ_{JC}	
TQFN-10 (2mmx3mm)			
EV5098-D-00A (4)	40	4	°C/W
JESD51-7 (5)	70	5	°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 regulator to go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on the EV5098-D-00A, 2-layer PCB, 54mmx46mm.
5) The value of θ_{JA} given in this table is only valid for comparison with other packages and cannot be used for design purposes. These values were calculated in accordance with JESD51-7, and simulated on a specified JEDEC board. They do not represent the performance obtained in an actual application.

ELECTRICAL CHARACTERISTICS

V_{IN1} = 12V, V_{IN2} = 5V, C_{OUT1} = C_{OUT2} = 10µF, T_J = -40°C to +125°C (6), typical values are tested at T_J = 25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Supply Current						
Quiescent current	I_{Q_CH1}	$V_{\overline{EN}}$ is low		210		µA
	I_{Q_CH2}	$V_{\overline{EN}}$ is low		190		µA
Shutdown current	I_{SD_CH1}	$V_{\overline{EN}}$ is high		15		µA
	I_{SD_CH2}	$V_{\overline{EN}}$ is high		10		µA
Power MOSFET						
On resistance	$R_{DS(ON)\_CH1}$	T_J = 25°C		40	50	mΩ
		T_J = 125°C			65	mΩ
	$R_{DS(ON)\_CH2}$	T_J = 25°C		40	50	mΩ
		T_J = 125°C			65	mΩ
Start-up delay	$t_{EN\_DELAY\_CH1}$	From $V_{\overline{EN}}$ is low to I_{OUT1} rises up to 100mA, with 1A load resistor, SS1 is floating		220		µs
	$t_{EN\_DELAY\_CH2}$	From $V_{\overline{EN}}$ is low to I_{OUT2} rises up to 100mA, with 1A load resistor, SS2 is floating		220		µs
Under-Voltage Lockout (UVLO) Protection and Over-Voltage Protection (OVP)						
UVLO rising threshold	$V_{UVLO\_RISING\_CH1}$		9.6	10	10.4	V
	$V_{UVLO\_RISING\_CH2}$		4.25	4.35	4.45	V
UVLO falling threshold	$V_{UVLO\_FALLING\_CH1}$			9.1		V
	$V_{UVLO\_FALLING\_CH2}$			2.65		V
Output OVP threshold	V_{OVP_CH1}		13.8	15	16	V
	V_{OVP_CH2}		5.5	5.7	5.9	V
Output OVP response time (7)	t_{OVP_CH1}	C_{OUT1} = 10µF with 30Ω load resistor, V_{IN1} = 12V to 18V/10µs		2		µs
	t_{OVP_CH2}	C_{OUT2} = 10µF with 10Ω load resistor, V_{IN2} = 5V to 7V/10µs		2		µs
Current Limit (I_{LIMIT})						
I_{LIMIT} during normal operation	I_{LIMIT_CH1}		-10%	4	+10%	A
	I_{LIMIT_CH2}		-10%	3	+10%	A
Constant-current limit during normal operation	$I_{LIMIT\_CC\_CH1}$ (7)			2.5		A
	$I_{LIMIT\_CC\_CH2}$ (7)			1.3		A
I_{LIMIT} response time (7)	t_{CL_CH1}			15		µs
	t_{CL_CH2}			15		µs
Secondary I_{LIMIT} (7)	$I_{LIMIT\_SEC\_CC\_CH1}$			8		A
	$I_{LIMIT\_SEC\_CC\_CH2}$			8		A

ELECTRICAL CHARACTERISTICS *(continued)*

V_{IN1} = 12V, V_{IN2} = 5V, C_{OUT1} = C_{OUT2} = 10µF, T_J = -40°C to +125°C (6), typical values are tested at T_J = 25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Hiccup mode on time	t_{ON_HICCUP}			2		ms
Hiccup mode off time	t_{OFF_HICCUP}			200		ms
Current Monitoring (IMON1/IMON2)						
Current-sense gain	G_{IMON1}			32		µA/A
	G_{IMON2}			34		µA/A
Current-sense offset	I_{OFFSET_CH1}		0.45	2	3.5	µA
	I_{OFFSET_CH2}		0.8	2.3	3.8	µA
Current monitor voltage range (7)	V_{IMON}		0		2.5	V
Enable (EN) Control						
$\overline{EN}$ falling threshold	$V_{EN\_FALLING}$		0.95	1.15	1.35	V
$\overline{EN}$ hysteresis	V_{EN_HYS}			800		mV
$\overline{EN}$ pull down resistance	R_{EN_PD}			0.77		MΩ
Soft Start (SS)						
Soft-start current	I_{SS_CH1}		4	5.5	7	µA
	I_{SS_CH2}		4	5.5	7	µA
Thermal Shutdown						
Thermal shutdown (7)	T_{SD}			155		°C

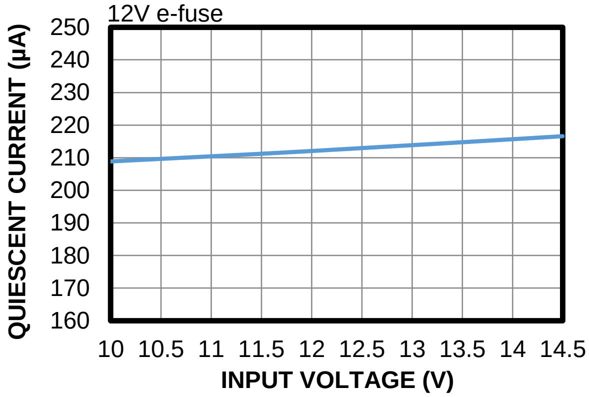
Notes:

6) Guaranteed by over-temperature correlation. Not tested in production.
7) Guaranteed by engineering sample characterization.

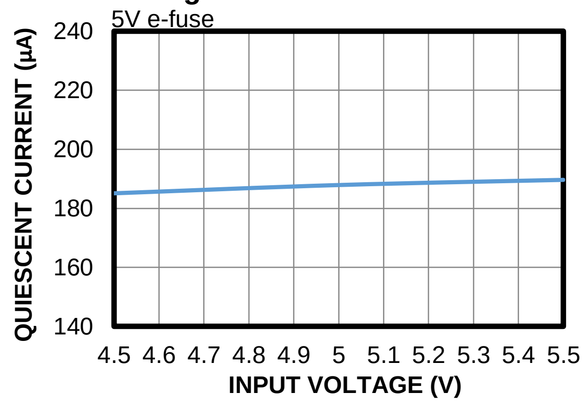
TYPICAL CHARACTERISTICS

V_{IN1} = 12V, V_{IN2} = 5V, T_A = 25°C, unless otherwise noted.

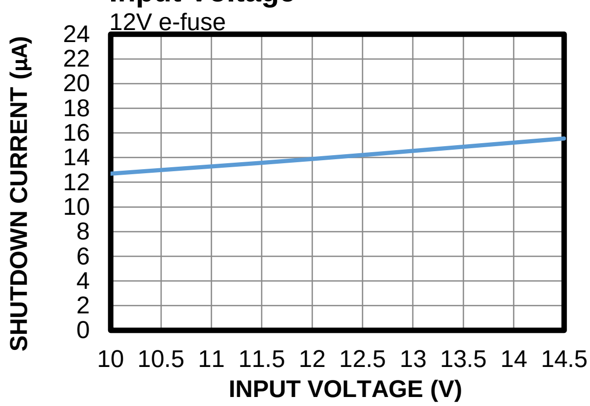
Quiescent Current vs. Input Voltage



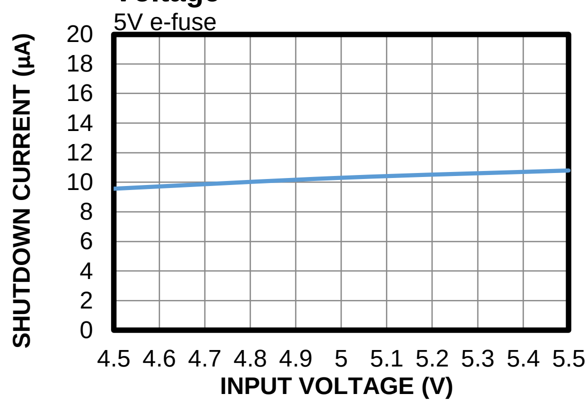
Quiescent Current vs. Input Voltage



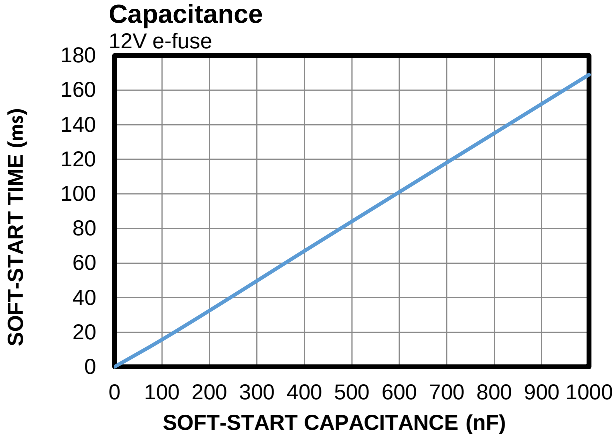
Shutdown Current vs. Input Voltage



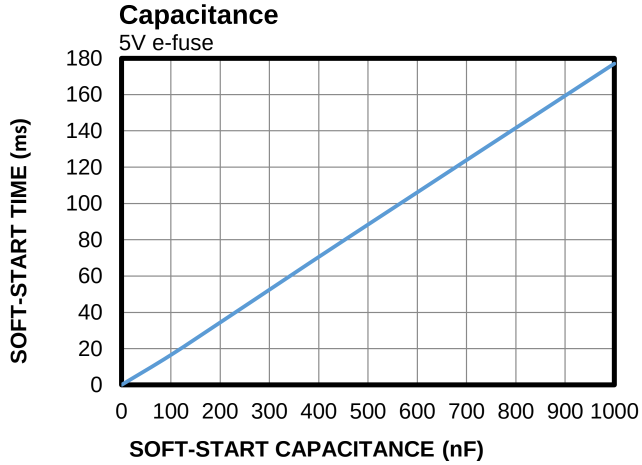
Shutdown Current vs. Input Voltage



Soft-Start Time vs. Soft-Start Capacitance

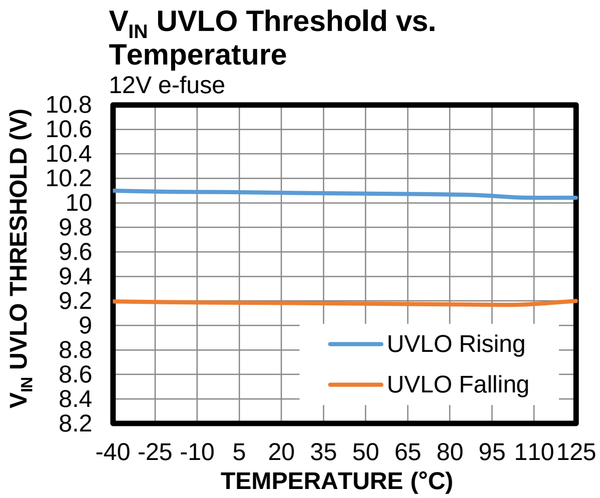


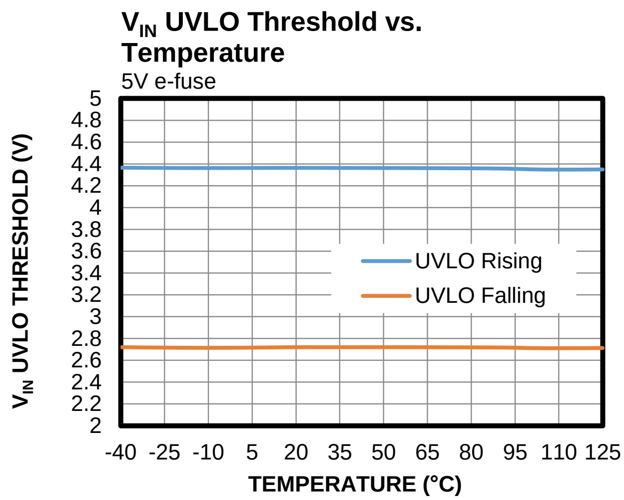
Soft-Start Time vs. Soft-Start Capacitance

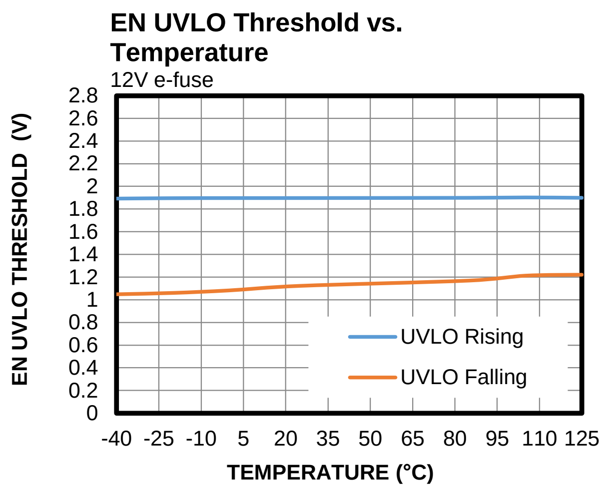


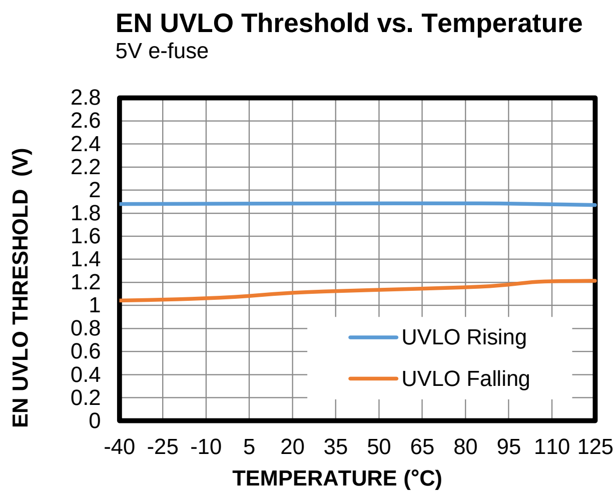
TYPICAL CHARACTERISTICS *(continued)*

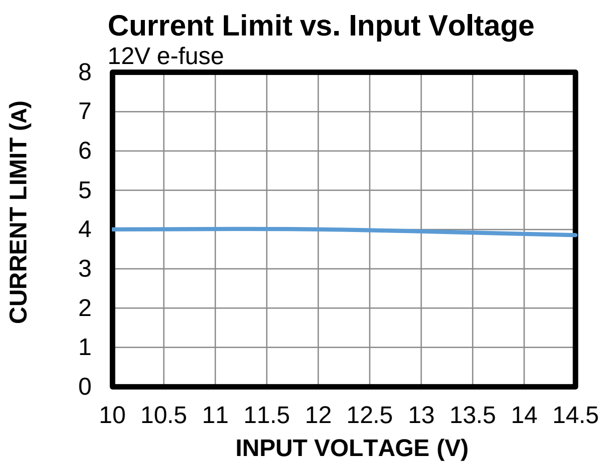
V_{IN1} = 12V, V_{IN2} = 5V, T_A = 25°C, unless otherwise noted.

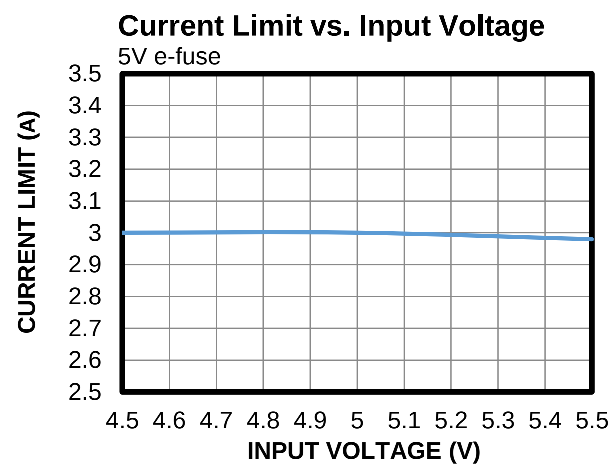






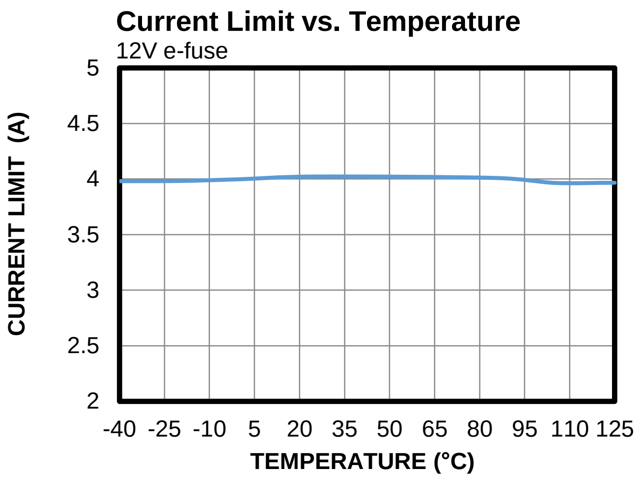


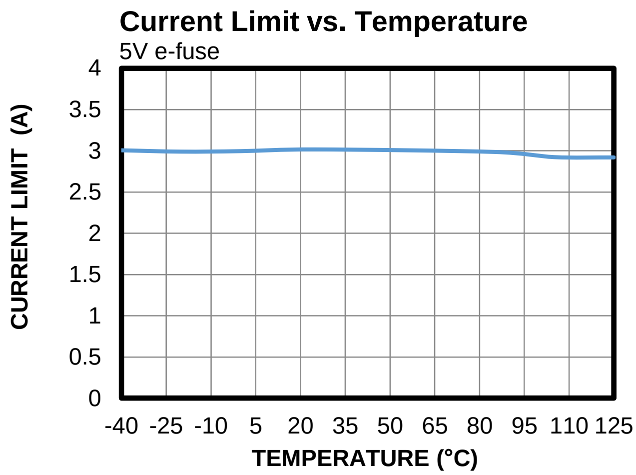


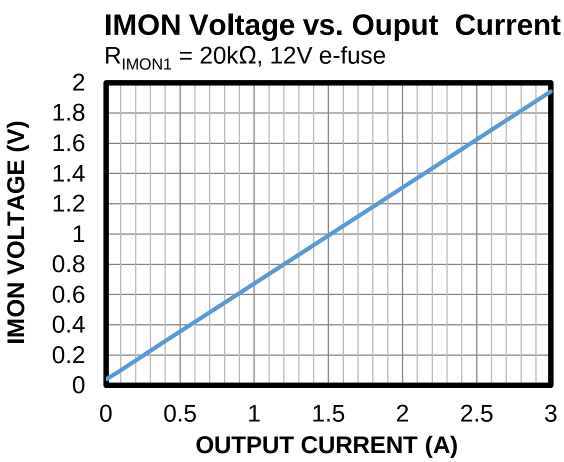


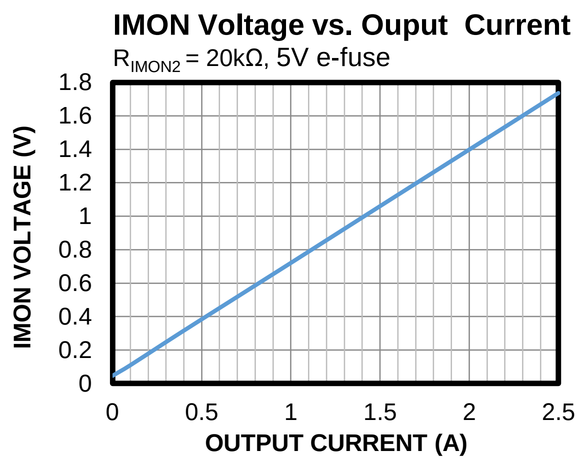
TYPICAL CHARACTERISTICS *(continued)*

V_{IN1} = 12V, V_{IN2} = 5V, T_A = 25°C, unless otherwise noted.







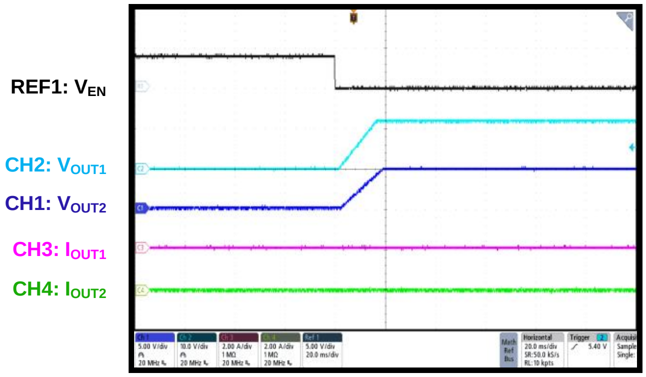


TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN1} = 12V, V_{IN2} = 5V, T_A = 25°C, unless otherwise noted.

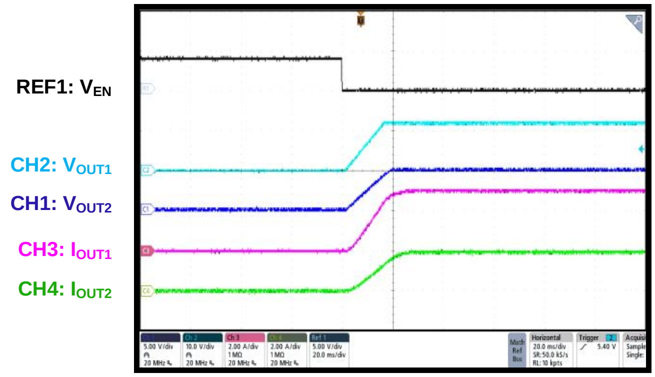
CH1/CH2 Start-Up through EN

I_{OUT1} = I_{OUT2} = 0A



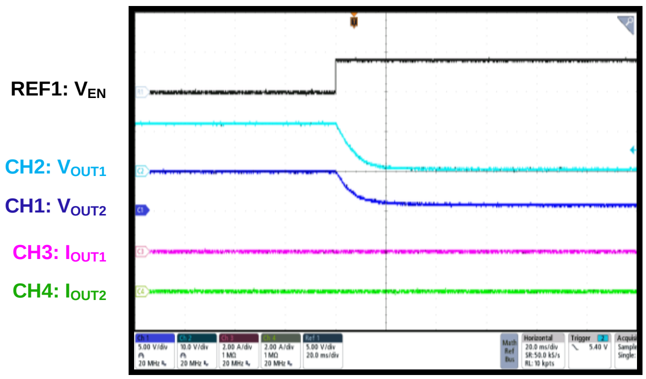
CH1/CH2 Start-Up through EN

I_{OUT1} = 3A, I_{OUT2} = 2A



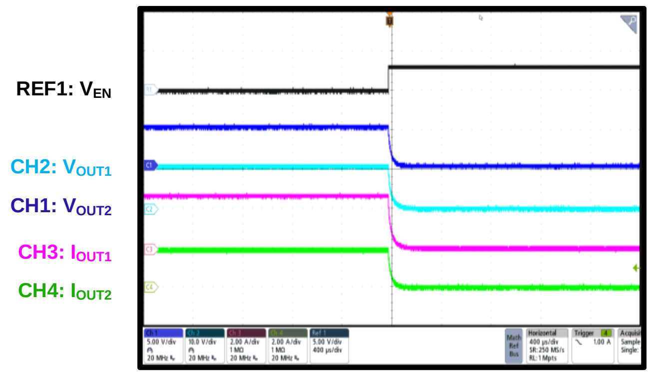
CH1/CH2 Shutdown through EN

I_{OUT1} = I_{OUT2} = 0A



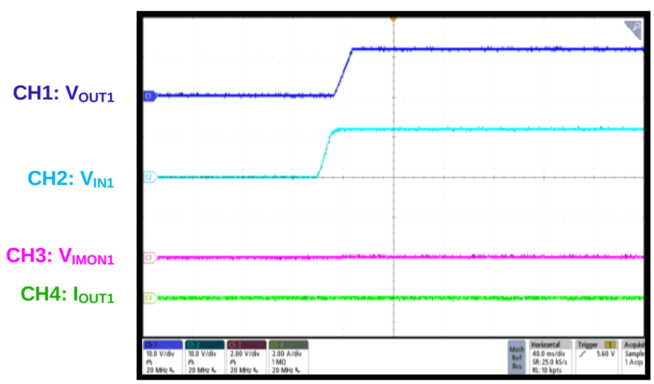
CH1/CH2 Shutdown through EN

I_{OUT1} = 3A, I_{OUT2} = 2A



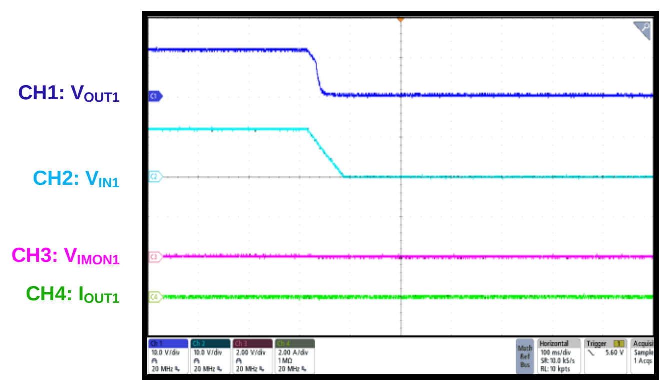
Start-Up through VIN1

12V e-fuse, no load



Shutdown through VIN1

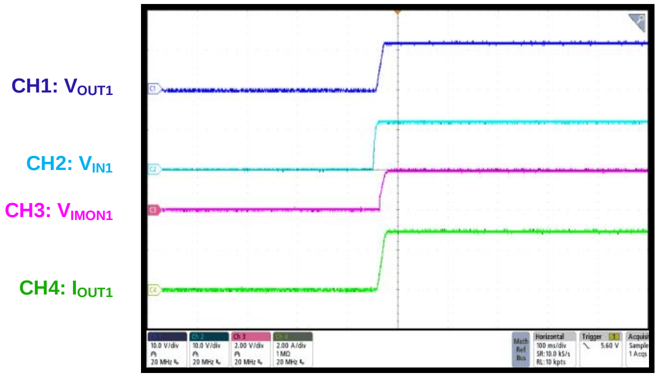
12V e-fuse, no load



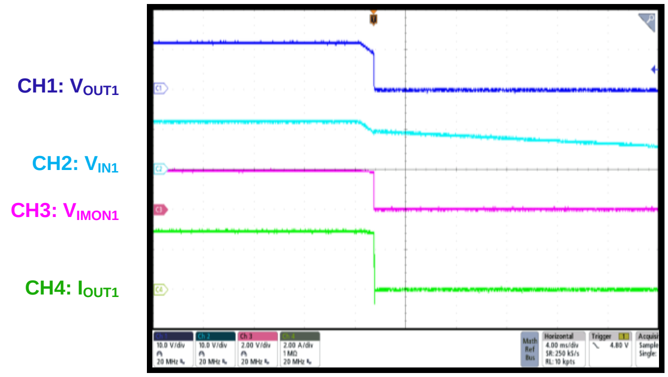
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN1} = 12V, V_{IN2} = 5V, T_A = 25°C, unless otherwise noted.

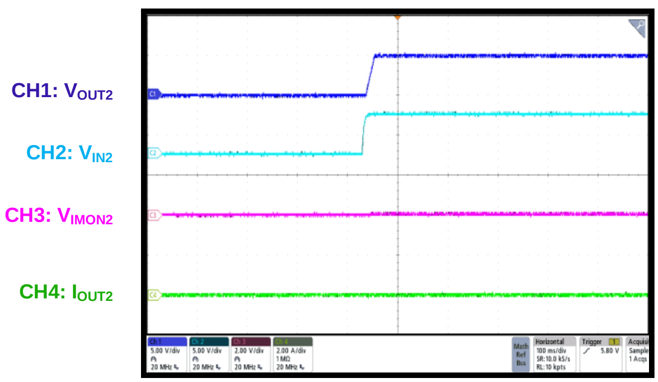
Start-Up through VIN1
12V e-fuse, 3A load



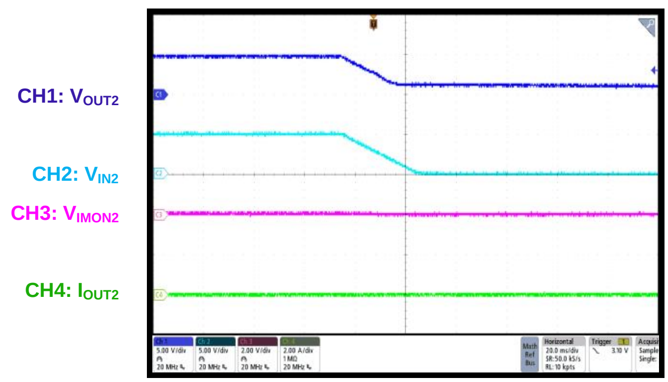
Shutdown through VIN1
12V e-fuse, 3A load



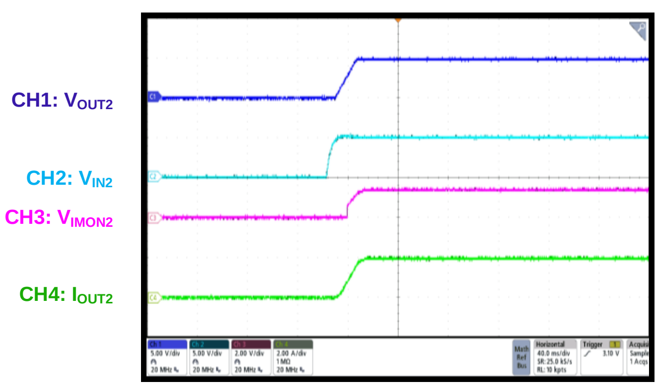
Start-Up through VIN2
5V e-fuse, no load



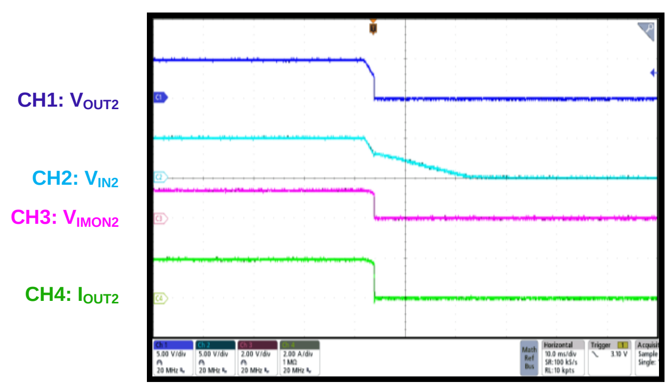
Shutdown through VIN2
5V e-fuse, no load



Start-Up through VIN2
5V e-fuse, 2A load



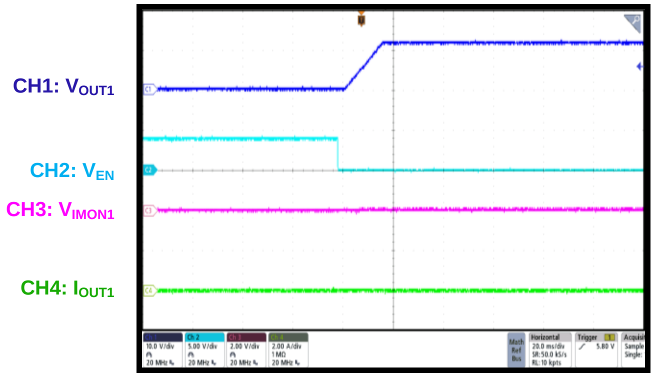
Shutdown through VIN2
5V e-fuse, 2A load



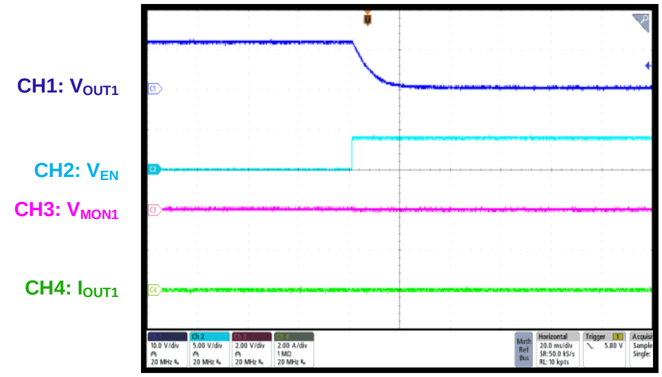
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN1} = 12V, V_{IN2} = 5V, T_A = 25°C, unless otherwise noted.

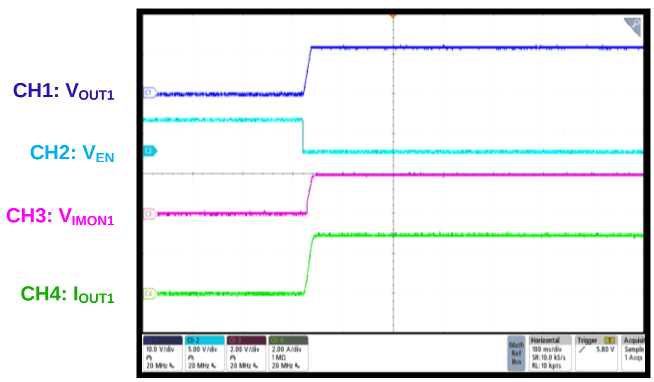
Start-Up through EN
12V e-fuse, no load



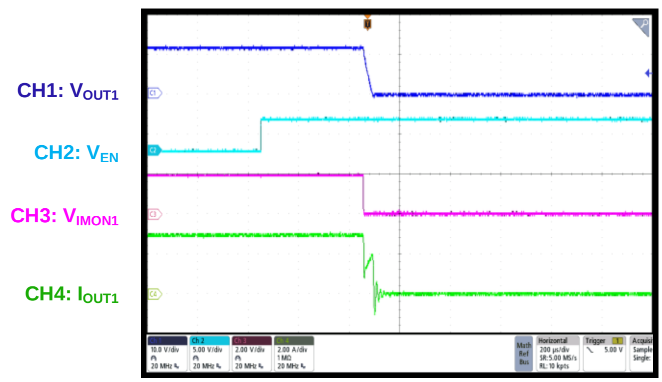
Shutdown through EN
12V e-fuse, no load



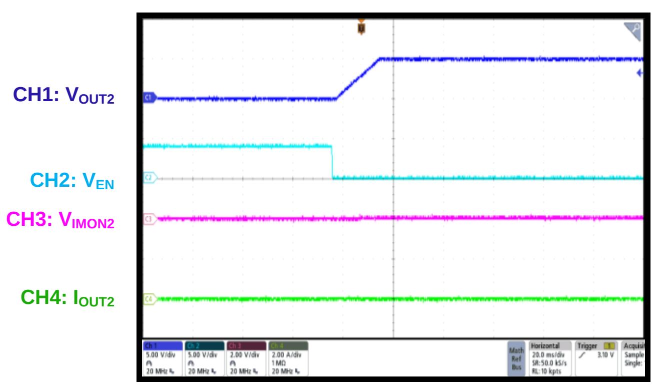
Start-Up through EN
12V e-fuse, 3A load



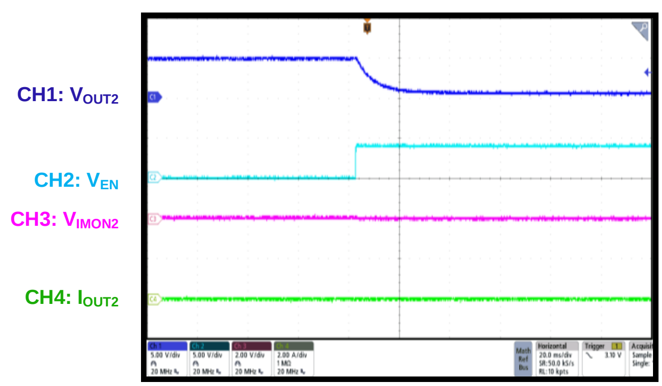
Shutdown through EN
12V e-fuse, 3A load



Start-Up through EN
5V e-fuse, no load



Shutdown through EN
5V e-fuse, no load

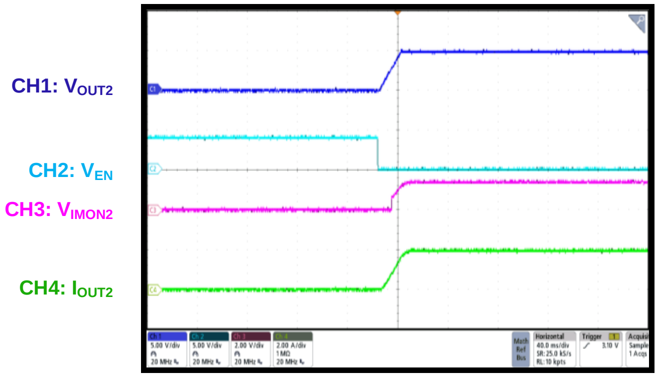


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN1} = 12V, V_{IN2} = 5V, T_A = 25°C, unless otherwise noted.

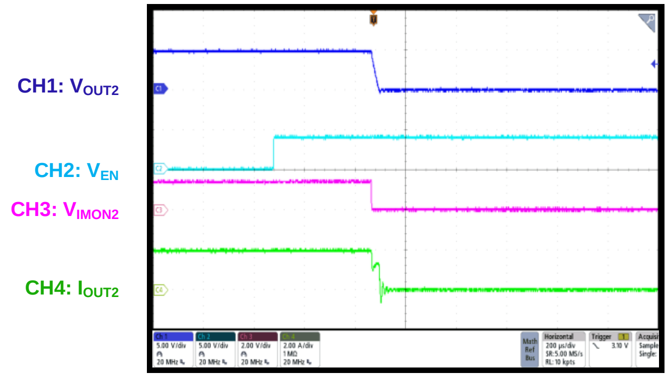
Start-Up through EN

5V e-fuse, 2A load



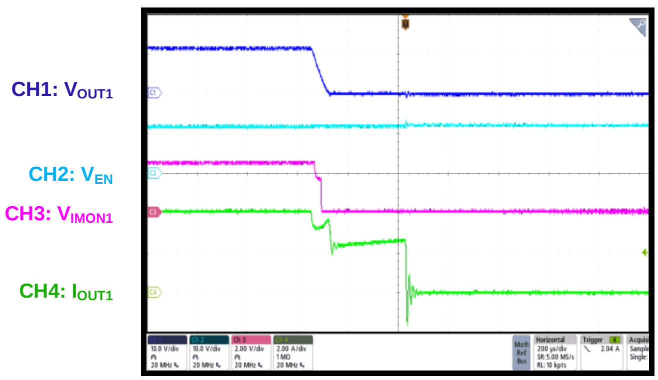
Shutdown through EN

5V e-fuse, 2A load



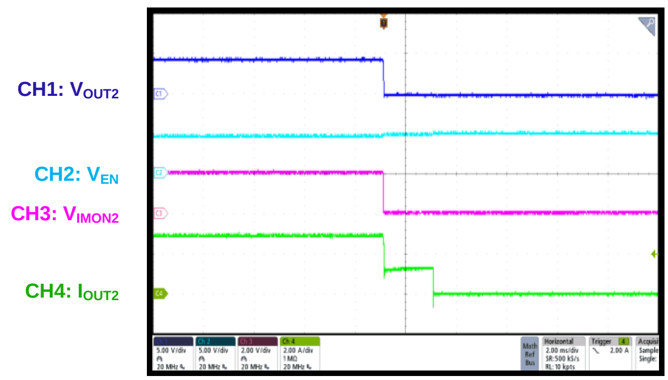
Current Limit

12V e-fuse, I_{OUT} increases slowly



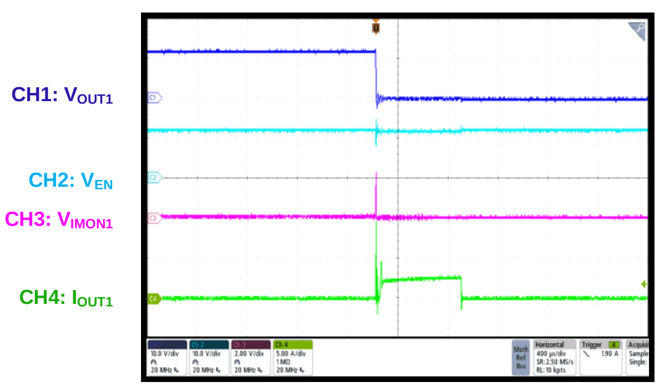
Current Limit

5V e-fuse, I_{OUT} increases slowly



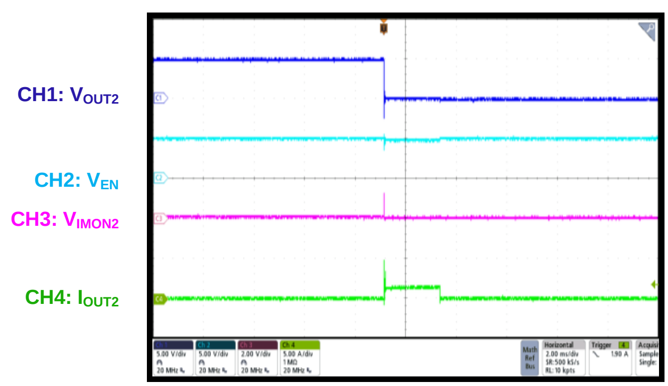
SCP Entry

12V e-fuse



SCP Entry

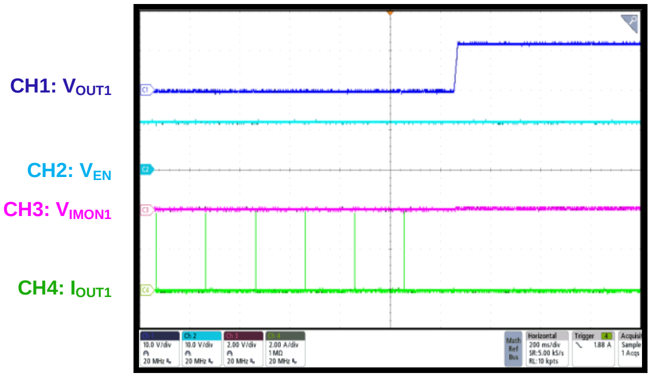
5V e-fuse



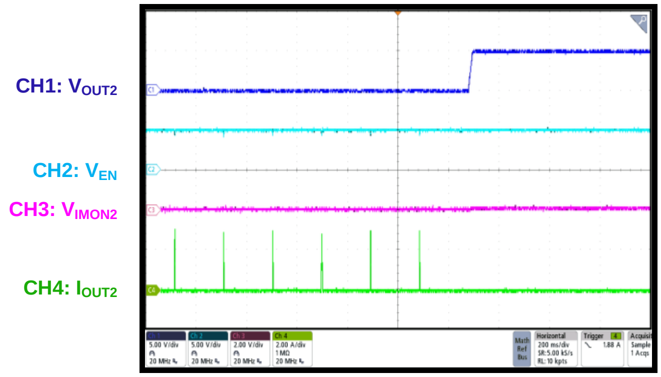
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN1} = 12V, V_{IN2} = 5V, T_A = 25°C, unless otherwise noted.

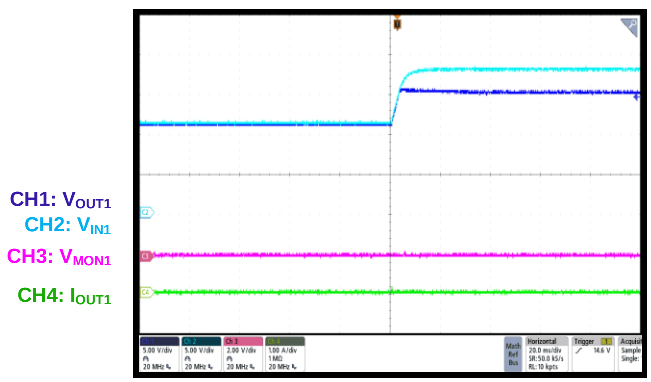
SCP Recovery
12V e-fuse



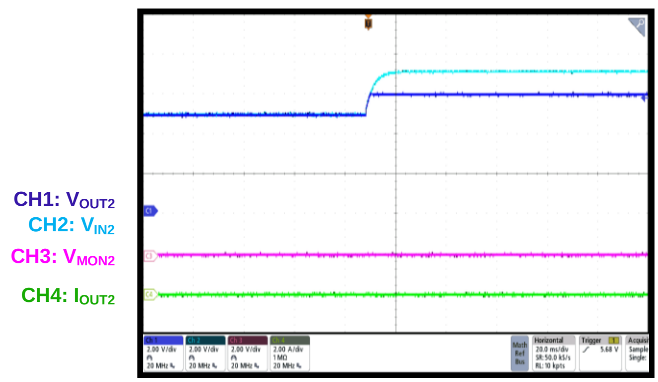
SCP Recovery
5V e-fuse



Output OVP
12V e-fuse, V_{IN1} = 12V to 18V



Output OVP
5V e-fuse, V_{IN2} = 5V to 7V



FUNCTIONAL BLOCK DIAGRAM

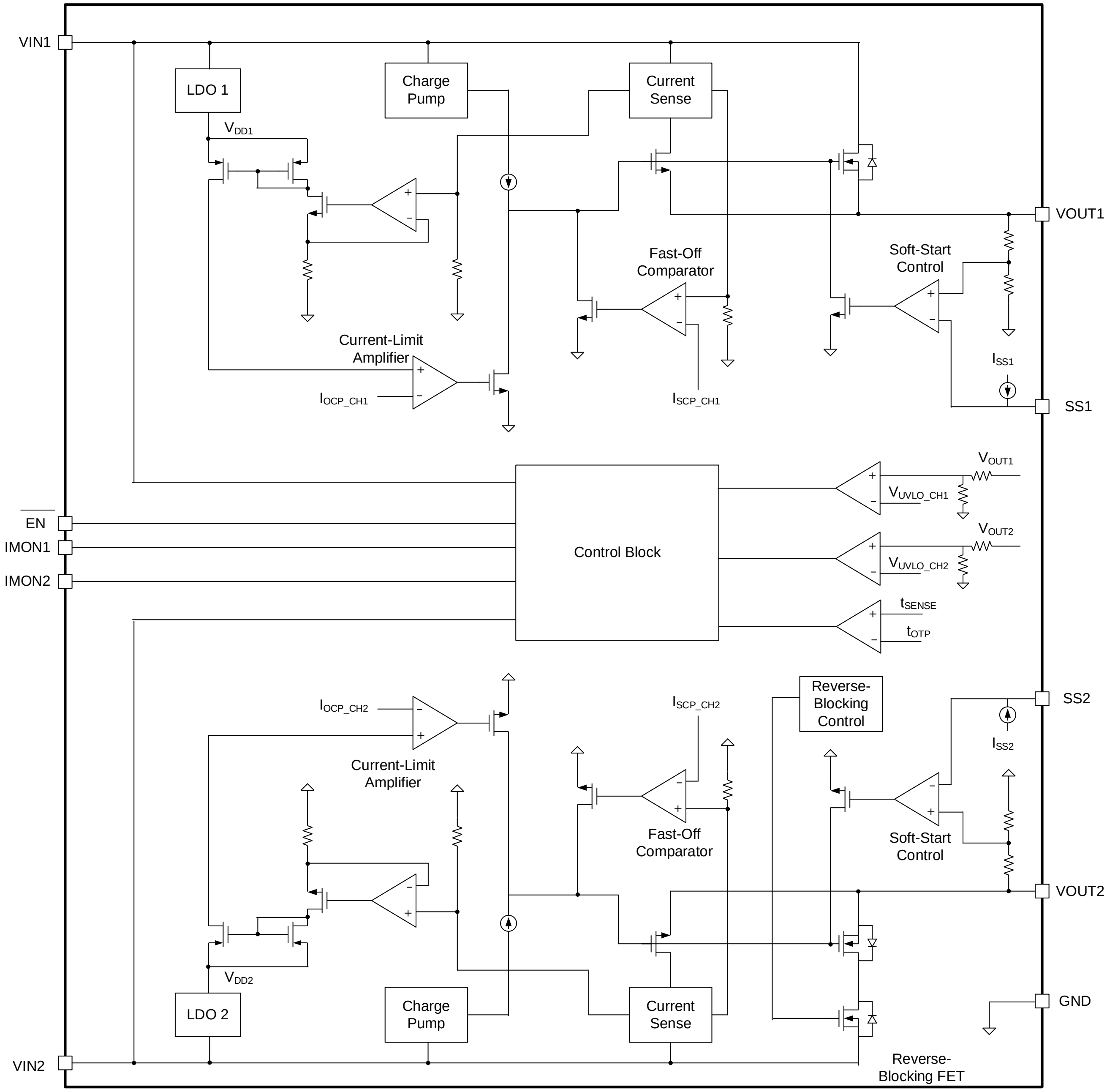


Figure 1: Functional Block Diagram

OPERATION

The MP5098 is a 12V/5V, dual-channel e-fuse with current limiting. It is designed to limit the inrush current to the load while a circuit card is inserted into a live backplane power source. This limits the backplane's voltage drop and the dV/dt to the load. The MP5098 offers an integrated solution that can monitor the input voltage (V_{IN}), output voltage (V_{OUT}), output current (I_{OUT}), and die temperature. This eliminates the need for an external current-sense resistor, power MOSFET, and thermal-sensing device.

Under-Voltage Lockout (UVLO) Protection

Channel 1 can be used in the 12V system, and channel 2 can be used in the 5V system. High energy transients can occur during normal operation or hot swap. These transients are determined by the wire's parasitic inductance and resistance, as well as the VCC capacitor (C_{VCC}). If a power-clamped TVS diode is not used, then the e-fuse should be able to withstand the transient voltage. The MP5098 integrates a high-voltage MOSFET and a high-voltage circuit at VCC to guarantee safe operation.

If V_{IN} drops below the under-voltage lockout (UVLO) threshold, then the output is disabled. Once V_{IN} exceeds the UVLO threshold, the output is enabled.

Soft Start (SS)

Connect a capacitor to the SS pin to set the soft-start time (t_{SS}). t_{SS} is a function of the soft-start capacitor (C_{SS}). A constant-current source charges C_{SS}, and the SS voltage (V_{SS}) ramps up. V_{OUT} ramps up at a similar slew rate to V_{SS}.

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

$$t_{DV/DT}(ms) = \frac{1V \times C_{SS}(nF)}{I_{SS}} \quad (1)$$

Where $t_{DV/DT}$ is t_{SS} between 0% and 100% of V_{OUT}, and I_{SS} is the soft-start current.

Output Over-Voltage Protection (OVP)

The MP5098 provides output over-voltage protection (OVP) to protect the downstream load from surge voltages at the input. An accurate, fast comparator monitors V_{OUT}. If V_{OUT} exceeds the OVP threshold, then the gate voltage (V_{GATE}) of the internal MOSFETs is pulled down. V_{GATE} is regulated at a certain value to keep V_{OUT} clamped at the OVP threshold. Fast loop response speed (typically 2µs) reduces the over-voltage (OV) overshoot.

Over-Current Protection (OCP)

If an over-current (OC) fault occurs (e.g. the load exceeds the current limit [I_{LIMIT_CHx}] or a short occurs), then over-current protection (OCP) is triggered and the part enters constant-current mode. If the OC condition remains after 150µs, then the part enters hiccup mode and shuts down. After a 200ms off time (t_{OFF}), the part starts up again. The MP5098 repeats this operation until the OC condition has been removed.

Channel 1's current limit (I_{LIMIT_CH1}) is set at 4A internally, and its constant-current limit ($I_{LIMIT\_CC\_CH1}$) is set at 2.5A. Channel 2's current limit (I_{LIMIT_CH2}) is set at 3A internally, and its constant-current limit ($I_{LIMIT\_CC\_CH2}$) is set at 1.3A.

Current Monitoring

The MP5098 provides current monitoring for both channel 1 and channel 2. The IMONx pin generates a current proportional to channel 1 and channel 2's load current (I_{LOAD_CHx}). Connect a resistor to IMONx to generate the current monitor voltage (V_{IMONx}). The effective V_{IMONx} range is between 0V and 2.5V to guarantee that the sensing results are linear. V_{IMONx} can be calculated with Equation (2):

$$V_{IMONx}(mV) = G_{IMONx} \times IOUT(A) \times R_{IMONx}(k\Omega) + I_{OSSFET\_CHx} \times R_{IMONx}(k\Omega) \quad (2)$$

Where G_{IMON_CHx} is the current-sense gain, R_{IMON_CHx} is the current-sense resistor, and I_{OFFSET_CHx} is the current-sense offset.

Short Circuit Protection (SCP)

If the I_{LOAD_CHx} increases rapidly due to a short circuit, the current may exceed I_{LIMIT_CHx} before the control loop can respond. If the current reaches the secondary I_{LIMIIT} level (8A), then short-circuit protection (SCP) is triggered and the fast turn-off circuit turn offs the MOSFET (see Figure 1 on page 15). This limits the peak current through the MOSFET to maintain V_{IN}. The total short-circuit response time is less than

1µs. Once the e-fuse turns off, the part starts up after a delay (200ms). If the short still remains, then V_{GATE} is regulated to maintain the current at its I_{LIMIIT} level, and the part enters hiccup mode after a 200ms off time (t_{OFF}). The MP5098 repeats this operation until the short circuit has been removed.

Enable

$\overline{EN}$ is a digital control pin that enables and disabled the current-limit MOSFET. Pull $\overline{EN}$ low or float $\overline{EN}$ to turn the current-limit MOSFET on; pull $\overline{EN}$ high to turn it off. An internal 770kΩ resistor connected between $\overline{EN}$ and GND allows $\overline{EN}$ to float to start up the device.

Thermal Shutdown

Thermal shutdown monitors the silicon die temperature to prevent the chip from operating at exceedingly high temperatures. If the temperature exceeds 155°C, then the part shuts down.

APPLICATION INFORMATION

Setting the Soft-Start Time (t_{SS})

The soft-start time (t_{SS}) is a function of the soft-start capacitor (C_{SS}). t_{SS} can be calculated with Equation (3):

$$t_{DV/DT}(ms) = \frac{1V \times C_{SS}(nF)}{I_{SS}} \quad (3)$$

Where $t_{DV/DT}$ is t_{SS} between 0% and 100% of V_{OUT}.

Design Example

Table 1 shows a design example following the application guidelines for the specifications.

Table 1: Design Example

V_{IN1}	12V
V_{OUT1}	12V
V_{IN2}	5V
V_{OUT2}	5V

Figure 3 on page 19 shows the detailed application schematic. The typical performance and waveforms are shown in the Typical Characteristics section on page 7 and the Typical Performance Characteristics section on page 10. For more device applications, refer to the related evaluation board datasheet.

PCB Layout Guidelines

Efficient PCB layout is critical for stable operation. For best results, refer to Figure 2 and follow the guidelines below:

1. Place the high-current paths (VIN and VOUT) close to the device using short, direct, and wide traces.
2. Place the input capacitors as close to the VIN and GND pins as possible.
3. To improve thermal performance, connect the VIN pad to the large VIN plane, and the VOUT pad to the large VOUT plane.
4. Place C_{SS} as close to SS pin as possible.

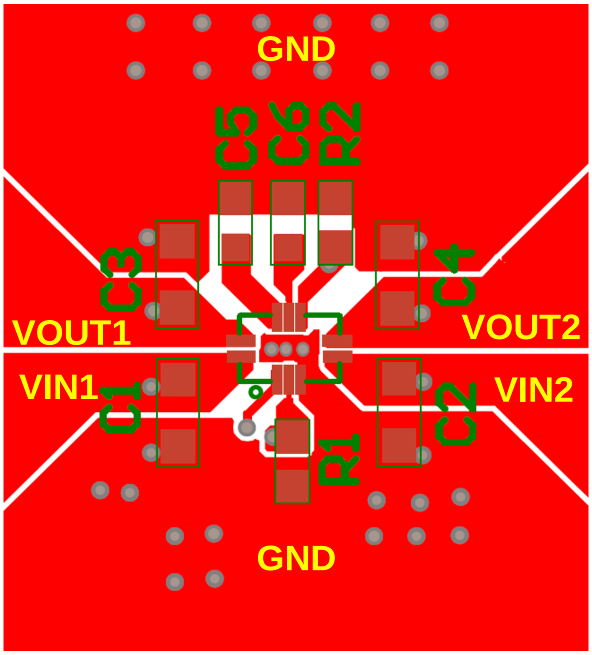


Figure 2: Recommended PCB Layout

TYPICAL APPLICATION CIRCUIT

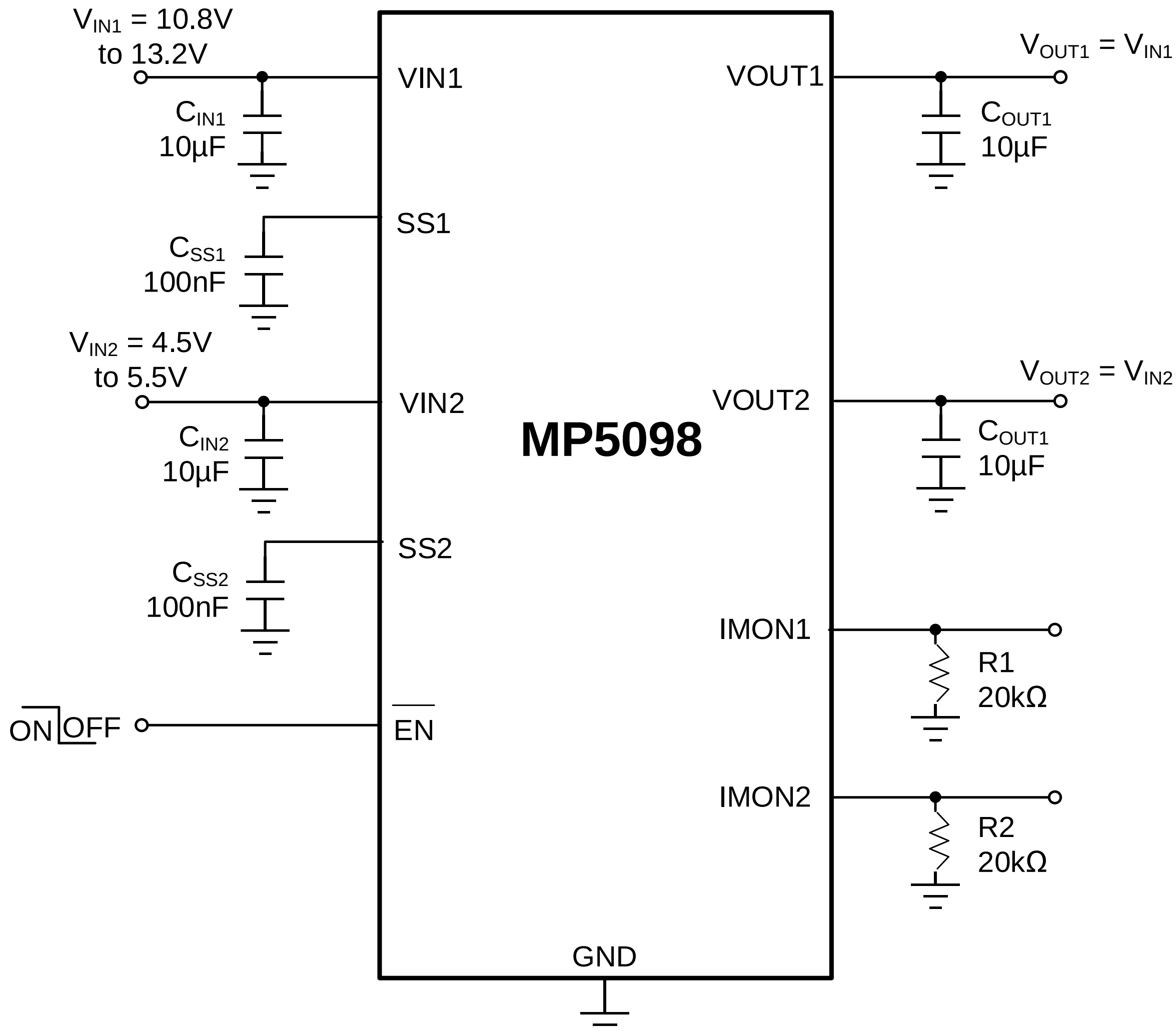
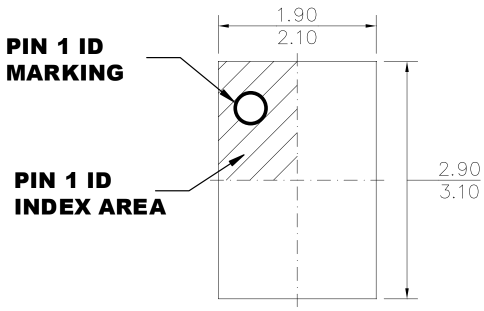


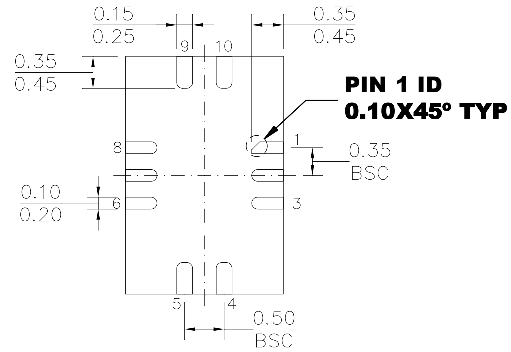
Figure 3: Typical Application Circuit

PACKAGE INFORMATION

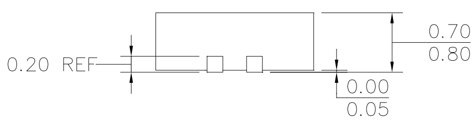
TQFN-10 (2mmx3mm)



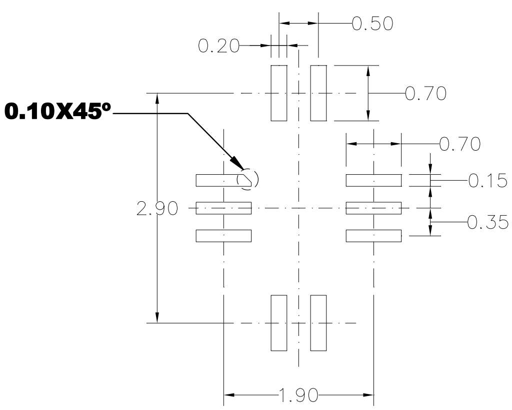
TOP VIEW



BOTTOM VIEW



SIDE VIEW

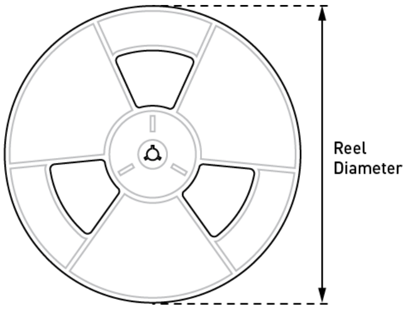


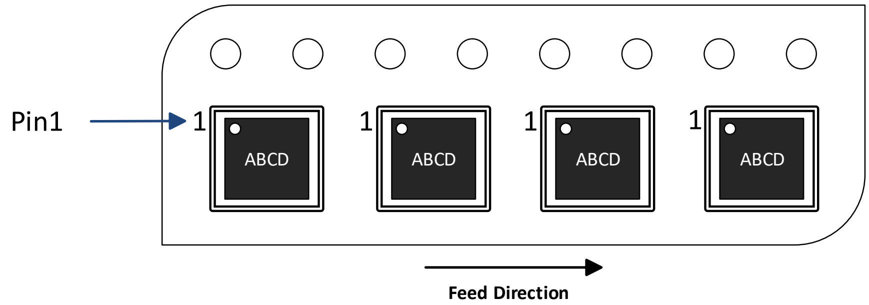
RECOMMENDED LAND PATTERN

NOTE:

1) ALL DIMENSIONS ARE IN MILLIMETERS.
2) LEAD COPLANARITIES SHALL BE 0.08 MILLIMETERS MAX.
3) JEDEC REFERENCE IS MO-220.
4) DRAWING IS NOT TO SCALE.

CARRIER INFORMATION





Part Number	Package Description	Quantity/ Reel	Quantity/ Tube	Quantity/ Tray	Reel Diameter	Carrier Tape Width	Carrier Tape Pitch
MP5098GDT-Z	TQFN-10 (2mmx3mm)	5000	N/A	N/A	13in	12mm	8mm

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	11/02/2021	Initial Release	-