MPQ5075A

5.5V, 5A, Low-$R_{DS(ON)}$ Load Switch with Configurable Current Limit, AEC-Q100 Qualified

DESCRIPTION

The MPQ5075A is a configurable load switch that provides up to 5A of load protection across a 1.2V to 5.5V input voltage (V_{IN}) range. With low on resistance ($R_{DS(ON)}$) in a tiny package, the MPQ5075A comprises a highly efficient, space-saving solution for automotive infotainment, clusters, and advanced driver assistance system (ADAS) applications.

The MPQ5075A's soft start (SS) function avoids inrush current during circuit start-up. The MPQ5075A also provides a configurable soft-start time (t_{SS}), output discharge functions, over-current protection (OCP), and thermal shutdown.

The maximum load at the output source is current-limited, which is accomplished utilizing a sense MOSFET topology. The current limit magnitude is controlled by an external resistor from the ILIM pin to ground.

An internal charge pump drives the power device gate, allowing a very low-$R_{DS(ON)}$ DMOS power MOSFET of only 10mΩ.

The MPQ5075A is available in a tiny QFN-13 (2.5mmx3mm) package.

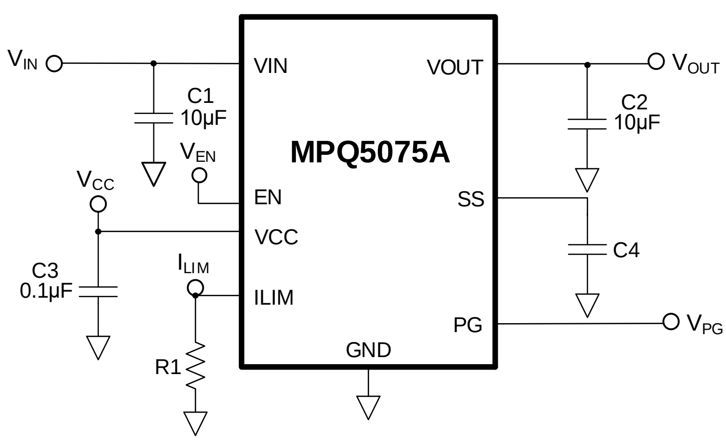
FEATURES

- Guaranteed Industrial/Automotive Temperature Range
- Integrated 10mΩ, On Resistance ($R_{DS(ON)}$) MOSFET
- Adjustable Start-Up Slew Rate
- Wide 1.2V to 5.5V Input Voltage (V_{IN}) Range
- <1µA Shutdown Current
- Configurable 5A Current Limit
- Output Discharge
- Enable (EN) Pin
- <200ns Short-Circuit Protection (SCP)
- Push-Pull Power Good (PG) Indicator
- Thermal Protection
- Available in a Small, Space-Saving QFN-13 (2.5mmx3mm) Package
- Available in AEC-Q100 Grade 1

APPLICATIONS

- Automotive Infotainment
- Automotive Clusters
- Advanced Driver Assistance Systems (ADAS)
- Industrial Systems

TYPICAL APPLICATION



ORDERING INFORMATION

Part Number*	Package	Top Marking	MSL Rating
MPQ5075AGQBE-AEC1	QFN-13 (2.5mmx3mm)	*See Below*	1

* For Tape & Reel, add suffix -Z (e.g. MPQ5075AGQBE-AEC1-Z).

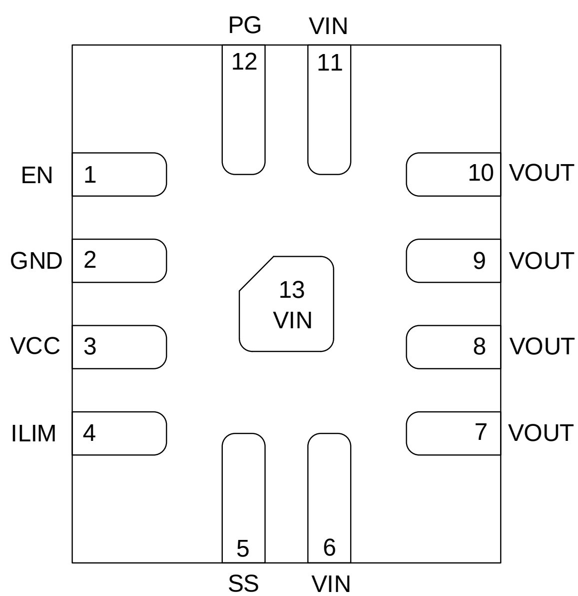
TOP MARKING

BRV
YWW
LLL

BRV: Product code of MPQ5075AGQBE
Y: Year code
WW: Week code
LLL: Lot number

PACKAGE REFERENCE

TOP VIEW



QFN-13 (2.5mmx3mm)

PIN FUNCTIONS

Pin #	Name	Description
1	EN	**Enable input.** Pull the EN pin below the specified threshold to shut down the chip.
2	GND	**Ground.**
3	VCC	**Supply voltage to the control circuitry.**
4	ILIM	**Output current limit configuration.** Place a resistor to ground to set the overload current limit.
5	SS	**Soft start.** An external capacitor connected to the SS pin sets the slew rate for the output voltage (V_{OUT}) soft-start period.
6, 11, 13	VIN	**Input power supply.**
7, 8, 9, 10	VOUT	**Output to the load.**
12	PG	**Power good.** The PG pin is the push-pull output that is triggered by the voltage gap, V_{IN} to V_{OUT} > 200mV, or over-current (OC) limit warning.

ABSOLUTE MAXIMUM RATINGS [1]

Supply voltage (V_{IN}) ....-0.3V to +6.5V
Input voltage (V_{CC}) ....-0.3V to +6.5V
Output voltage (V_{OUT})....................-0.3V to +6.5V
Enable voltage (V_{EN}) ....-0.3V to +6.5V
SS, ILIM ....-0.3V to V_{CC} + 0.3V
Junction temperature ....150°C
Lead temperature ....260°C
Storage temperature .... -65°C to +150°C
Continuous power dissipation [2]
QFN-13 (2.5mmx3mm)................................. 2W

ESD Ratings

Human body model (HBM).........................±2kV
Charged device model (CDM)..................±750V

Recommended Operating Conditions [3]

V_{IN} ....1.2V to 5.5V
V_{CC} ....3V to 5.5V
V_{OUT}..1.2V to 5.5V
Operating junction temp........... -40°C to +125°C

Thermal Resistance [4] *θ_{JA}* *θ_{JC}*

QFN-13 (2.5mmx3mm)……..…..49…...5.3...°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 JESD51-7, a 4-layer PCB.

ELECTRICAL CHARACTERISTICS

V_{IN} = 3.6V, V_{CC} = 3.6V, T_J = -40°C to +125°C, typical values are at T_J = 25°C, unless otherwise noted.

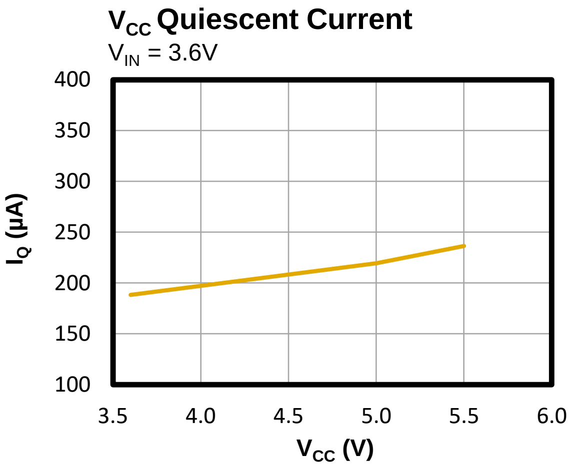
Parameters	Symbol	Condition	Min	Typ	Max	Units
Input and Supply Voltage Range						
Input voltage	V_{IN}		1.2		5.5	V
Supply voltage	V_{CC}		3		5.5	V
Supply Current						
Off-state leakage current	I_{OFF}	V_{IN} = 5V, EN = 0, T_J = 25°C		0.05	1	µA
		V_{IN} = 5V, EN = 0, T_J = -40°C to +125°C			50	
V_{CC} standby current	I_{STBY}	V_{CC} = 5V, EN = 0		0.01	1	µA
		V_{CC} = 5V, enable, no load		220	330	
Power MOSFET						
On resistance	$R_{DS(ON)}$	V_{CC} = 5V		6.5	13	mΩ
		V_{CC} = 3.3V		8.5	16	
Thermal Shutdown and Recovery						
Shutdown temperature (5)	T_{STD}			170		°C
Hysteresis (5)	T_{HYS}			30		°C
Under-Voltage Protection (UVLO)						
V_{CC} UVLO threshold	V_{CC_UVLO}	UVLO rising threshold		2.5	2.8	V
UVLO hysteresis	V_{UVLO_HYS}			200		mV
Soft Start (SS)						
SS pull-up current	I_{SS}			9		µA
Enable (EN)						
EN rising threshold	V_{EN_H}		1.3	1.5	1.7	V
EN hysteresis	V_{EN_HYS}			400		mV
Current Limit						
Current limit	I_{LIMIT}	R_{LIMIT} = 50kΩ, ramping I_{LIMIT} records peak current limit	1.35	1.7	2.04	A
		R_{LIMIT} = 15.4kΩ (5)		5		
Current limit warning		R_{LIMIT} = 50kΩ	1.28	1.6	1.92	
Discharge Resistance						
Discharge resistance	R_{DIS}			200		Ω
Power Good (PG)						
PG rising threshold	V_{PG_R}	Voltage gap between V_{OUT} and V_{IN}		150		mV
PG hysteresis	V_{PG_H}			50		mV
PG delay	V_{PG_D}	Low to high		70		µs
PG high	V_{PG_H}	V_{CC} = 3.3V	3.2			V
PG low	V_{PG_L}	Sink 1mA			0.2	V

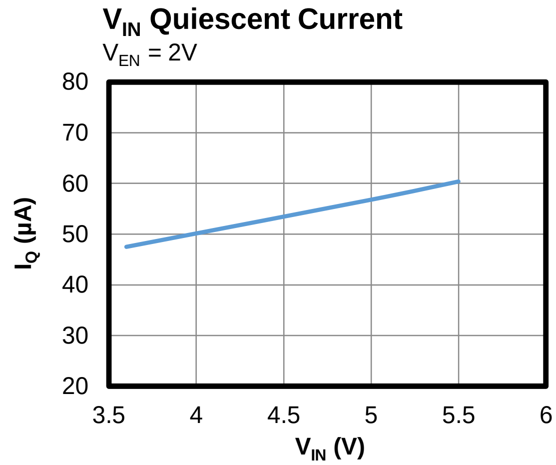
Note:

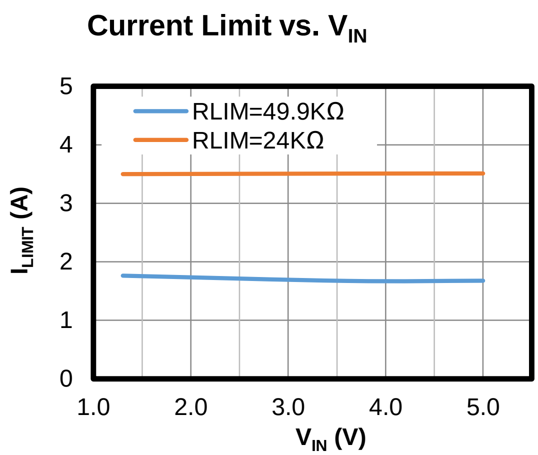
5) Guaranteed by characterization. Not tested in production.

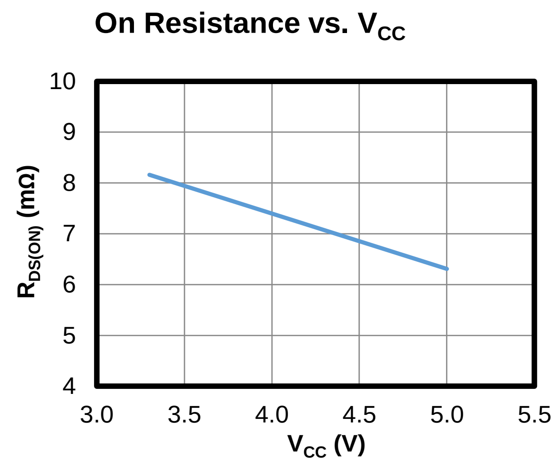
TYPICAL PERFORMANCE CHARACTERISTICS

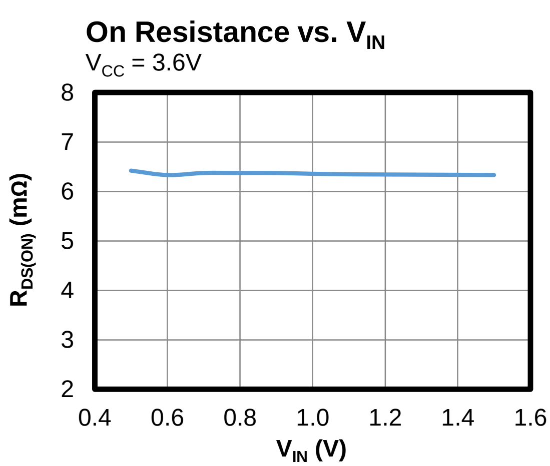
V_{IN} = 3.6V, V_{EN} = 3.6V, R_{ILIM} = 15.4kΩ, T_A = 25°C, unless otherwise noted.

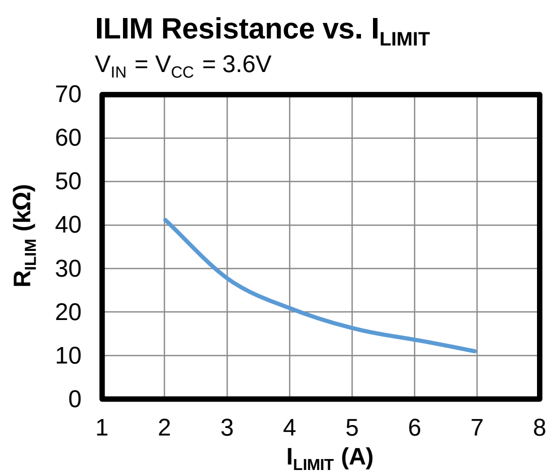










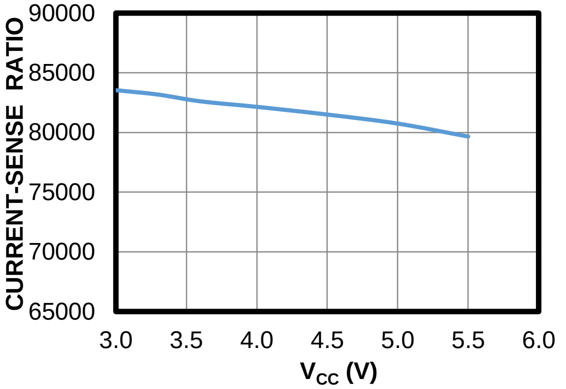


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 3.6V, V_{EN} = 3.6V, R_{ILIM} = 15.4kΩ, T_A = 25°C, unless otherwise noted.

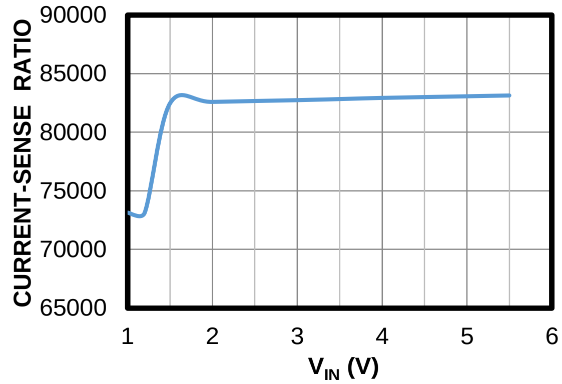
Current-Sense Ratio vs. V_{CC}

V_{IN} = 3.6V, R_{ILIM} = 24.3kΩ



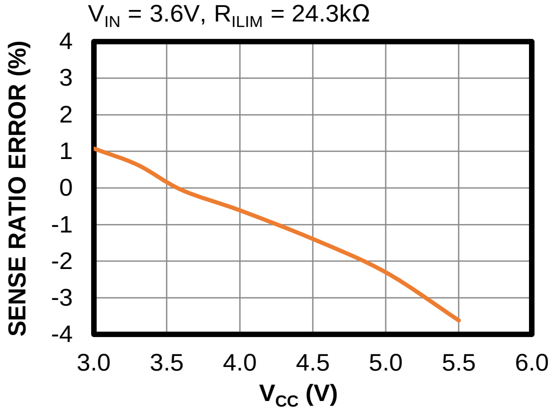
Current-Sense Ratio vs. V_{IN}

V_{IN} = 3.6V, R_{ILIM} = 24.3kΩ



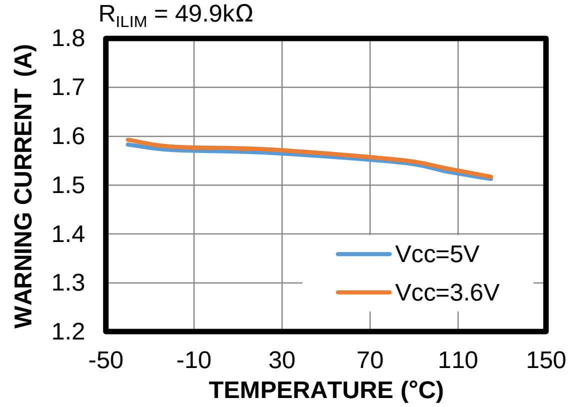
Sense Ratio Error vs. V_{CC}

V_{IN} = 3.6V, R_{ILIM} = 24.3kΩ



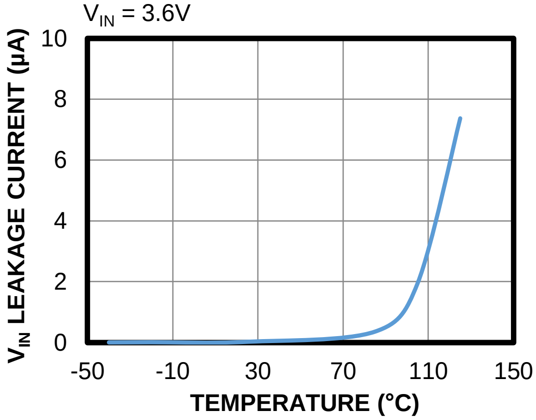
Warning Current vs. Temperature

R_{ILIM} = 49.9kΩ



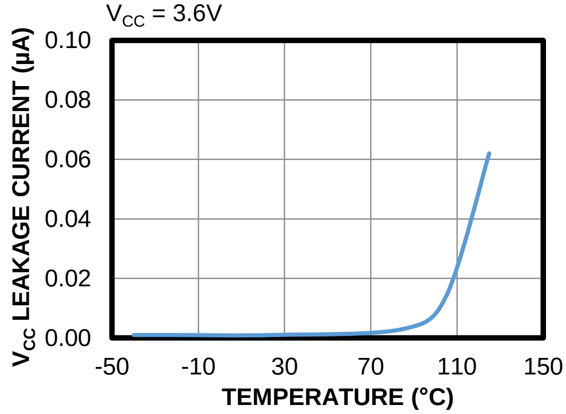
V_{IN} Leakage Current vs. Temperature

V_{IN} = 3.6V



V_{CC} Leakage Current vs. Temperature

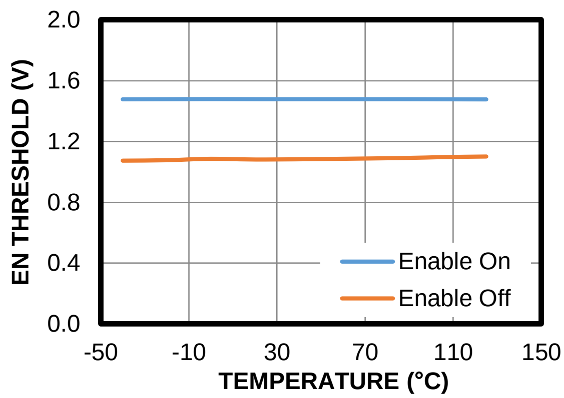
V_{CC} = 3.6V



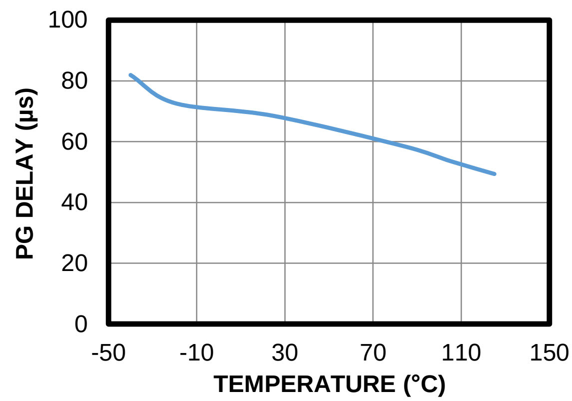
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 3.6V, V_{EN} = 3.6V, R_{ILIM} = 15.4kΩ, T_A = 25°C, unless otherwise noted.

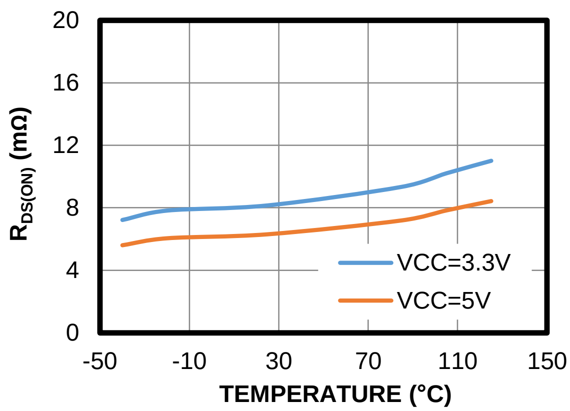
EN Threshold vs. Temperature



PG Delay vs. Temperature

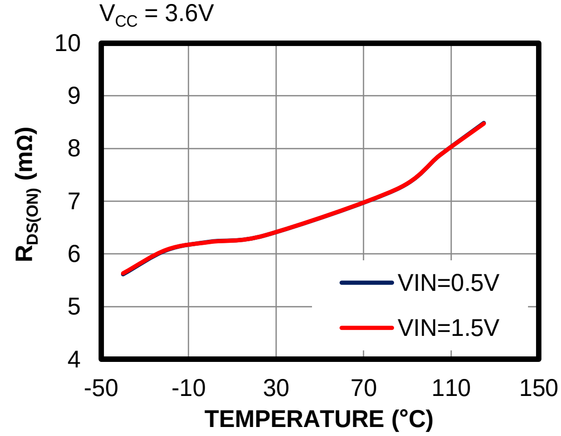


On Resistance vs. Temperature

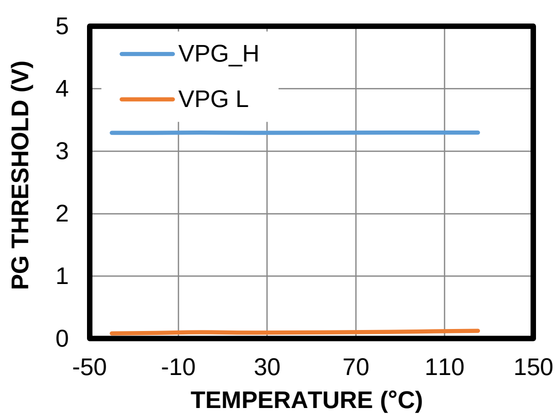


On Resistance vs. Temperature

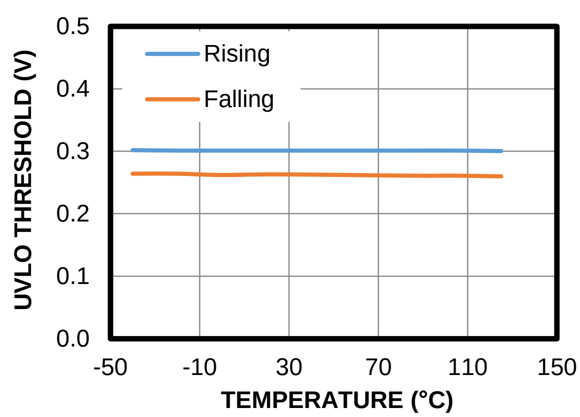
V_{CC} = 3.6V



PG Threshold vs. Temperature



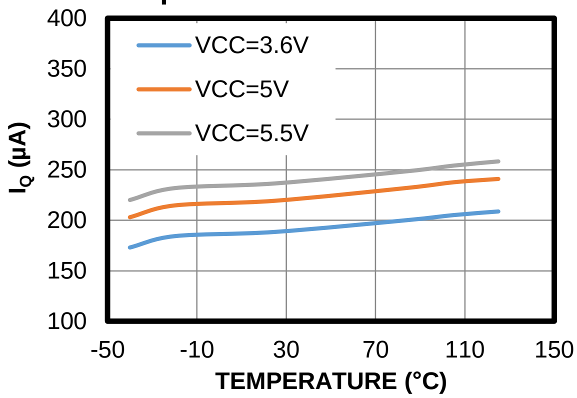
UVLO Threshold vs. Temperature



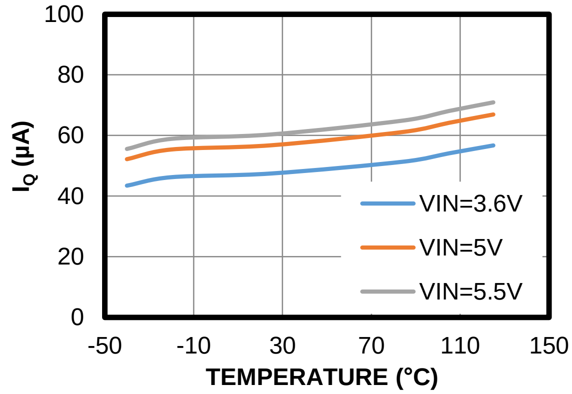
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 3.6V, V_{EN} = 3.6V, R_{ILIM} = 15.4kΩ, T_A = 25°C, unless otherwise noted.

V_{CC} Quiescent Current vs. Temperature



V_{IN} Quiescent Current vs. Temperature

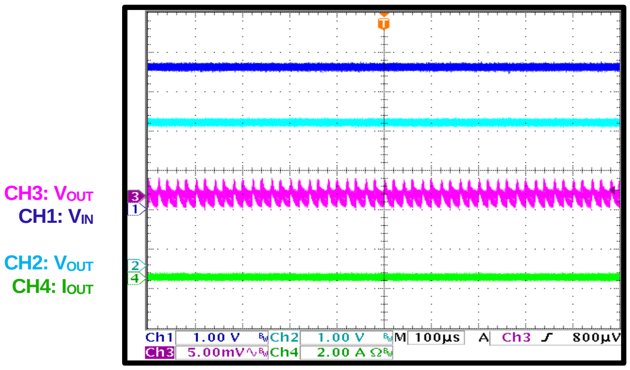


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 3.6V, V_{EN} = 3.6V, R_{ILIM} = 15.4kΩ, T_A = 25°C, unless otherwise noted.

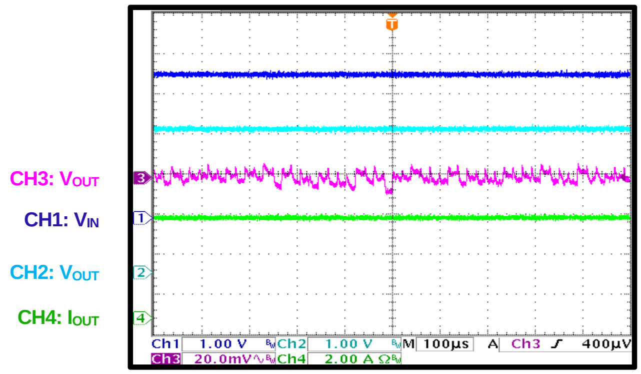
Steady State

V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 0A



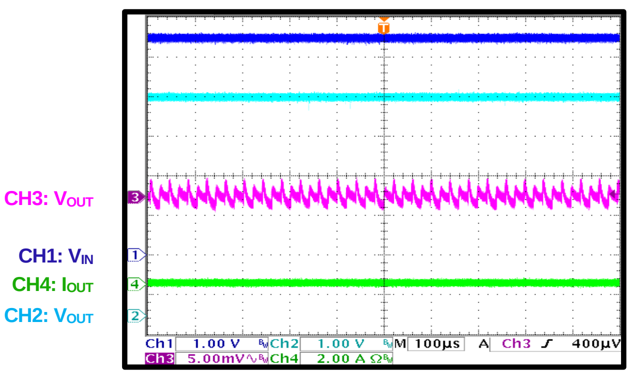
Steady State

V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 5A



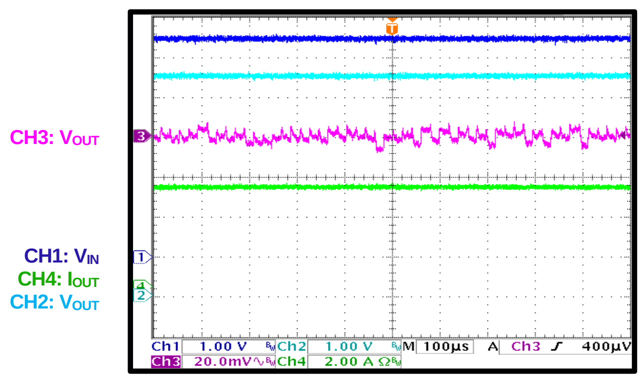
Steady State

V_{IN} = 5.5V, V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 0A



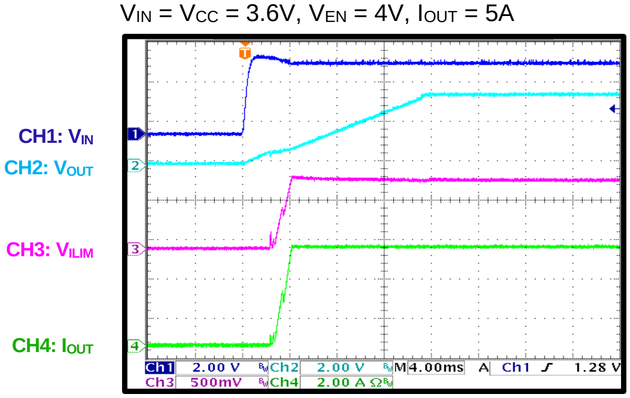
Steady State

V_{IN} = 5.5V, V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 5A



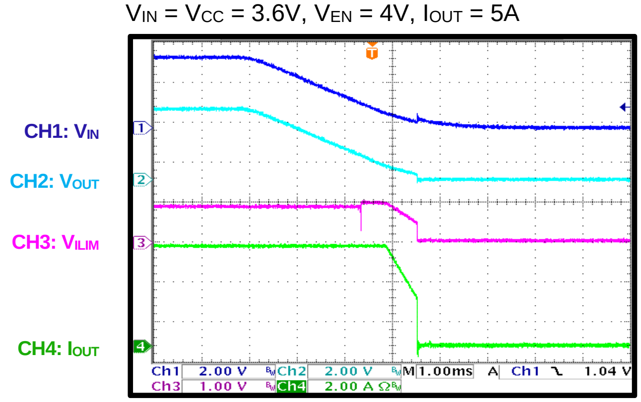
Start-Up

V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 5A



Shutdown

V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 5A



TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 3.6V, V_{EN} = 3.6V, R_{ILIM} = 15.4kΩ, T_A = 25°C, unless otherwise noted.

Start-Up

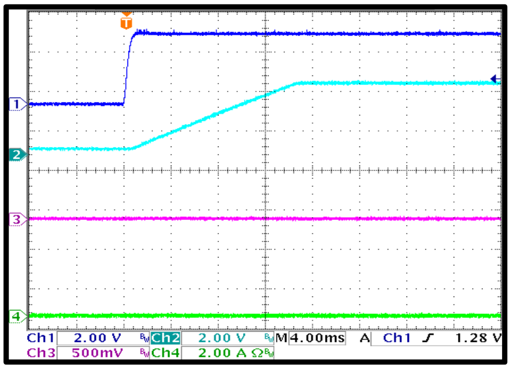
V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 0A

CH1: V_{IN}

CH2: V_{OUT}

CH3: V_{ILIM}

CH4: I_{OUT}



Shutdown

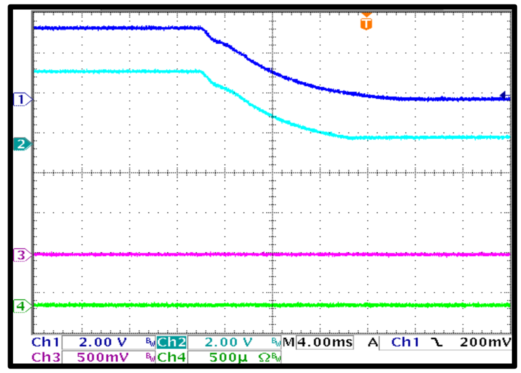
V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 0A

CH1: V_{IN}

CH2: V_{OUT}

CH3: V_{ILIM}

CH4: I_{OUT}



Start-Up through VCC

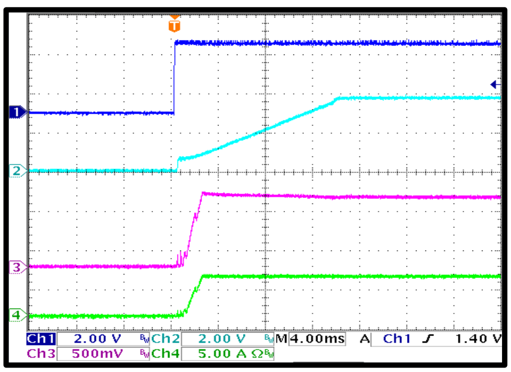
V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 5A

CH1: V_{CC}

CH2: V_{OUT}

CH3: V_{ILIM}

CH4: I_{OUT}



Shutdown through VCC

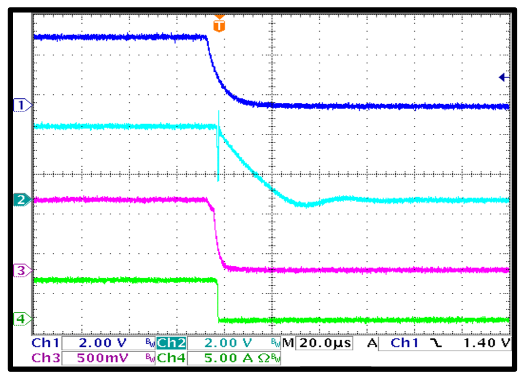
V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 5A

CH1: V_{CC}

CH2: V_{OUT}

CH3: V_{ILIM}

CH4: I_{OUT}



Start-Up with PG

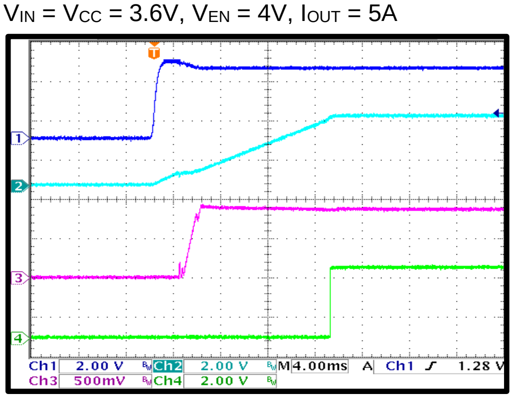
V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 5A

CH1: V_{IN}

CH2: V_{OUT}

CH3: V_{ILIM}

CH4: V_{PG}



Shutdown with PG

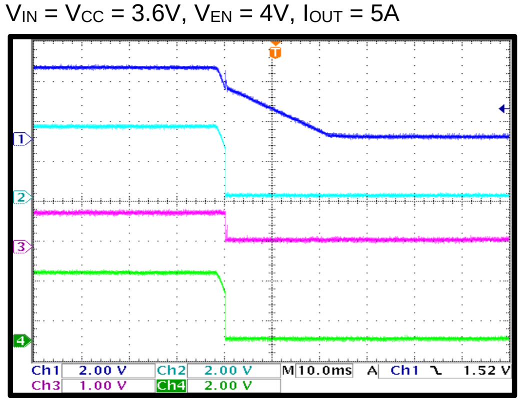
V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 5A

CH1: V_{IN}

CH2: V_{OUT}

CH3: V_{ILIM}

CH4: V_{PG}

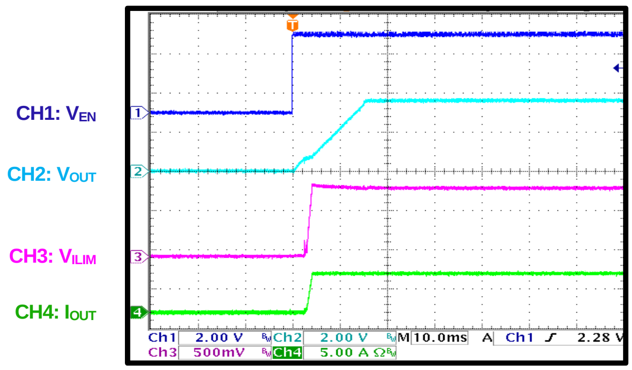


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 3.6V, V_{EN} = 3.6V, R_{ILIM} = 15.4kΩ, T_A = 25°C, unless otherwise noted.

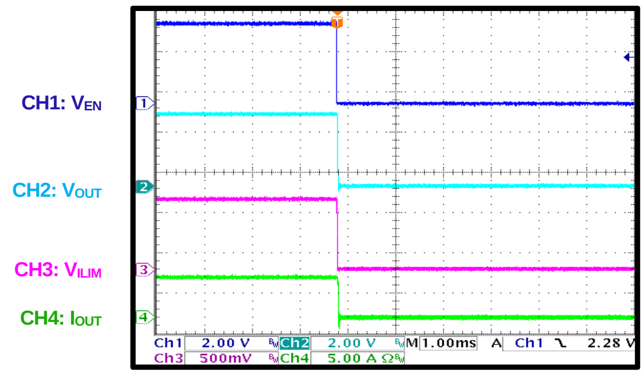
Start-Up through EN

V_{IN} = V_{CC} = 3.6V, I_{OUT} = 5A



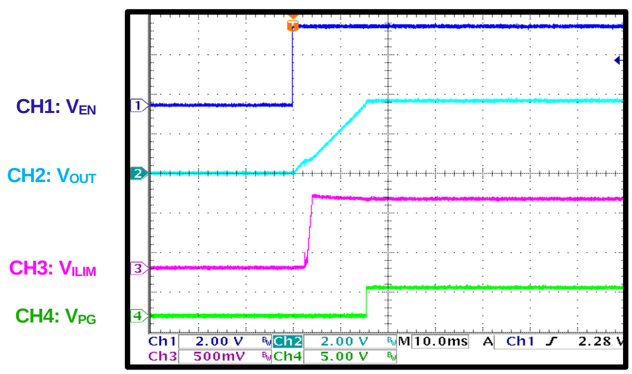
Shutdown through EN

V_{IN} = V_{CC} = 3.6V, I_{OUT} = 5A



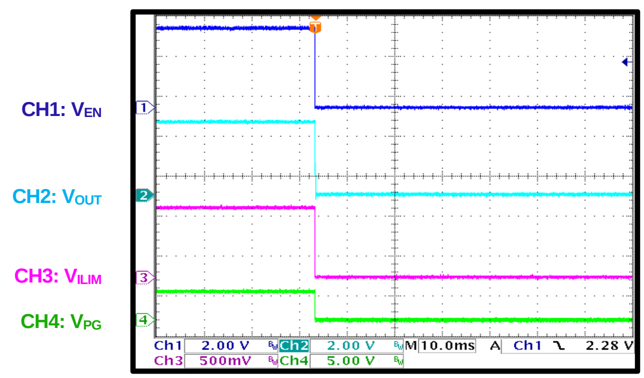
Start-Up through EN with PG

V_{IN} = V_{CC} = 3.6V, I_{OUT} = 5A



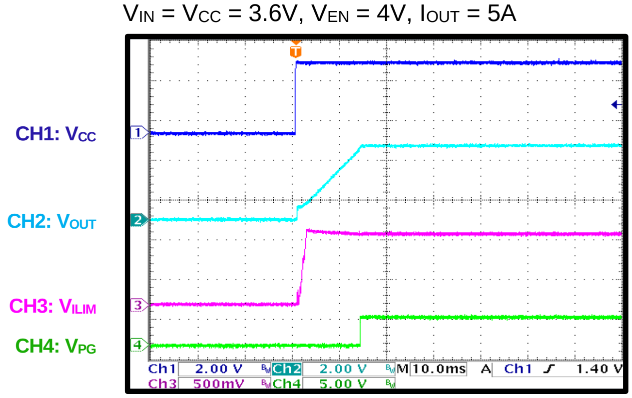
Shutdown through EN with PG

V_{IN} = V_{CC} = 3.6V, I_{OUT} = 5A



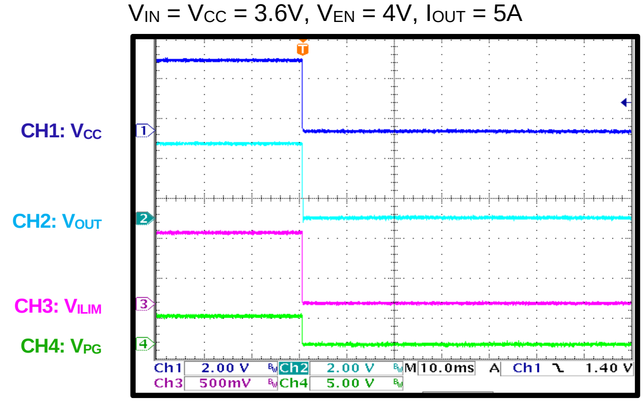
Start-Up through VCC with PG

V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 5A



Shutdown through VCC with PG

V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 5A

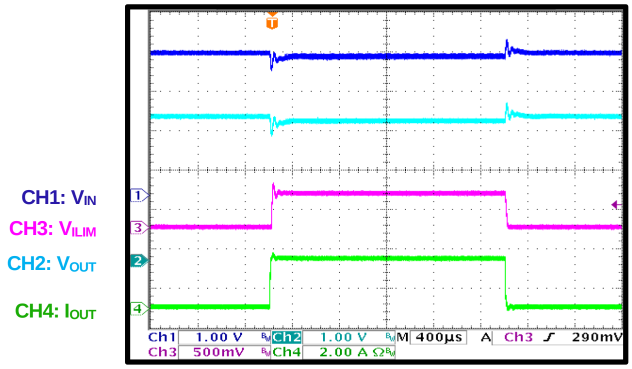


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 3.6V, V_{EN} = 3.6V, R_{ILIM} = 15.4kΩ, T_A = 25°C, unless otherwise noted.

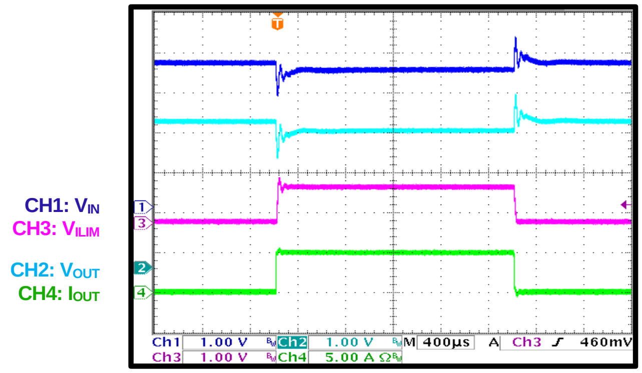
Load Transient

V_{IN} = V_{CC} = 3.6V, I_{OUT} = 0A to 2.5A



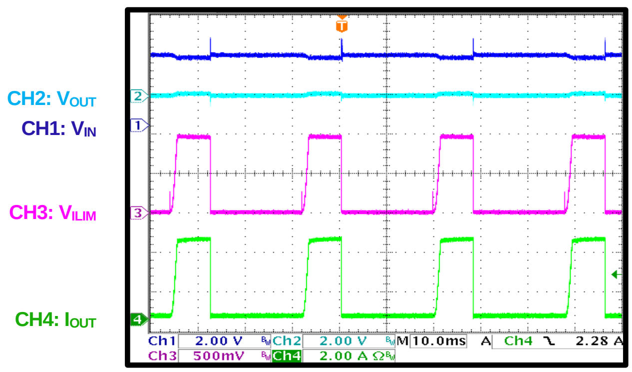
Load Transient

V_{IN} = V_{CC} = 3.6V, I_{OUT} = 0A to 5A



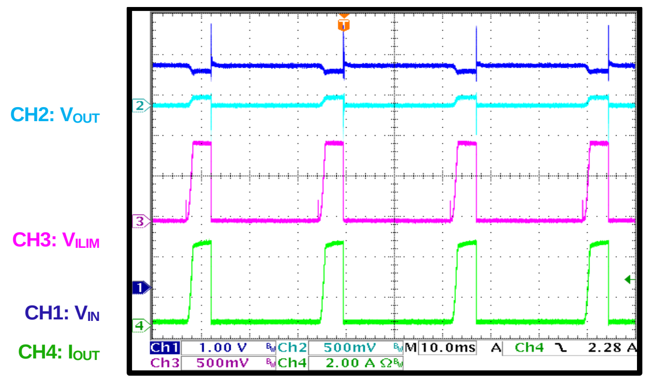
SCP

V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V



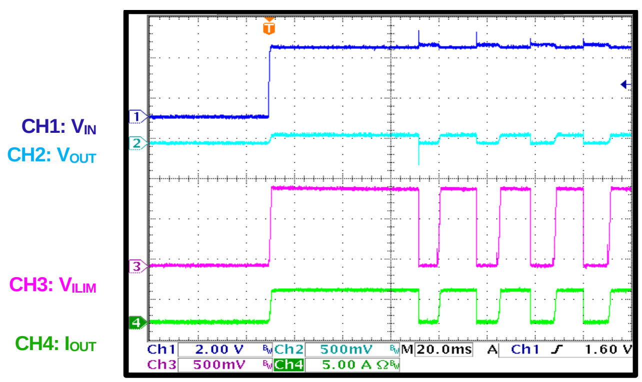
SCP

V_{IN} = 5.5V, V_{CC} = 3.6V, V_{EN} = 4V



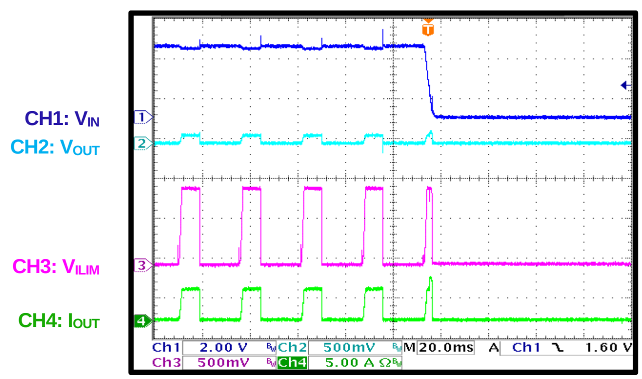
SCP Start-Up

V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V



SCP Shutdown

V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V

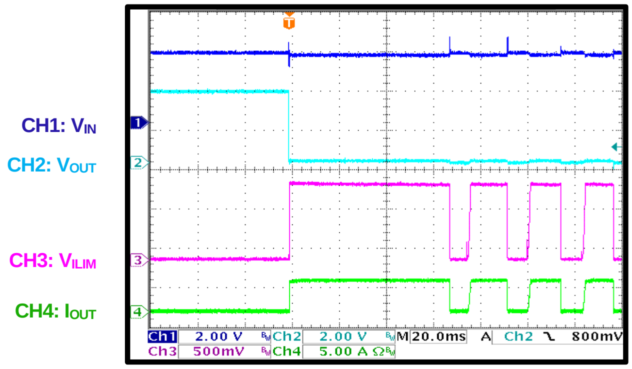


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 3.6V, V_{EN} = 3.6V, R_{ILIM} = 15.4kΩ, T_A = 25°C, unless otherwise noted.

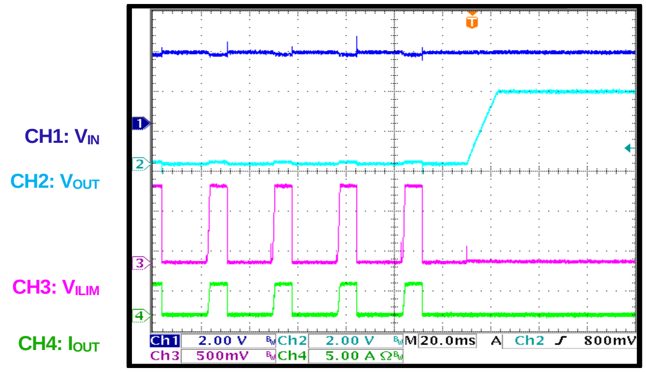
SCP

V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V



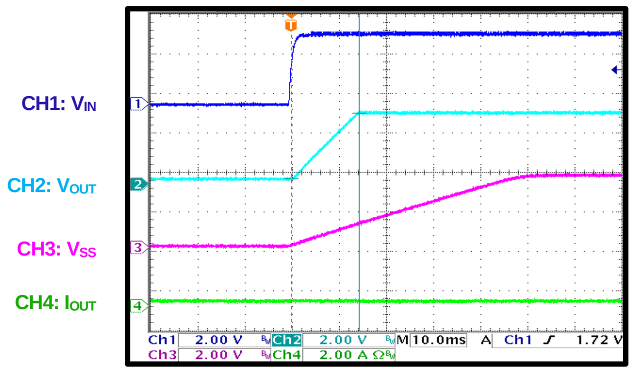
SCP Recovery

V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V



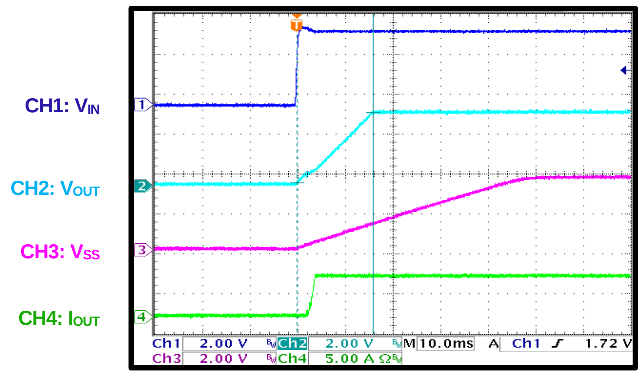
Soft Start

V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 0A



Soft Start

V_{IN} = V_{CC} = 3.6V, V_{EN} = 4V, I_{OUT} = 5A



FUNCTIONAL BLOCK DIAGRAM

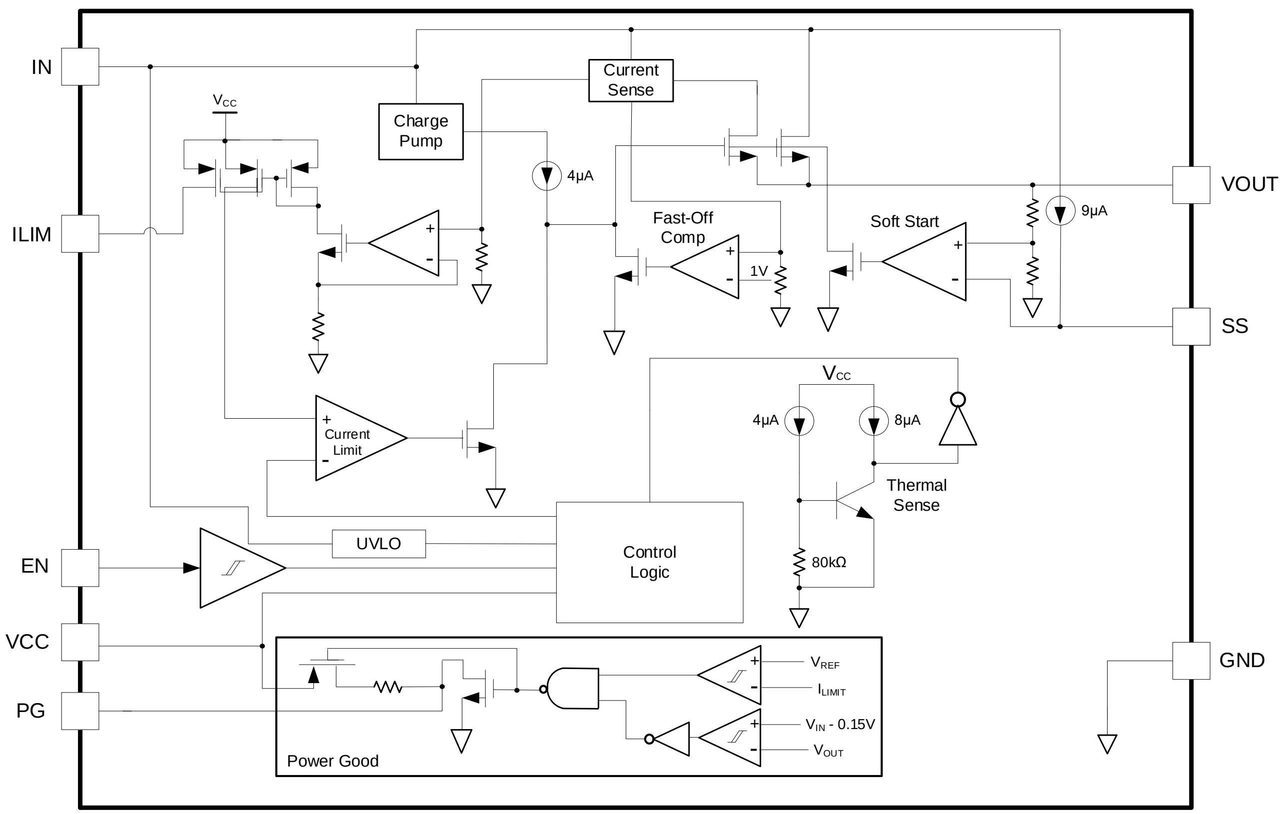


Figure 1: Functional Block Diagram

OPERATION

The MPQ5075A is a configurable load switch designed to limit the inrush current to the load, which limits the backplane's voltage drop and the slew rate of the voltage to the load. The MPQ5075A provides an integrated solution to monitor the input voltage (V_{IN}), output voltage (V_{OUT}), and output current (I_{OUT}), eliminating the need for an external current power MOSFET and current switch device.

Enable (EN)

Once V_{IN} exceeds the under-voltage lockout (UVLO) threshold (typically 0.5V) and the EN pin is pulled above 1.5V, the MPQ5075A is enabled. Pull EN down to ground to disable the MPQ5075A.

Current Limit

The MPQ5075A provides a constant current limit configured by an external resistor. Once the device reaches its current limit (I_{LIMIT}) threshold, the IC regulates the gate voltage to hold a constant current in the power MOSFET. The typical response time is about 20µs, during which a small overshoot in I_{OUT} may occur. The preset I_{LIMIT} can be calculated with Equation (1):

$$I_{LIMIT} = (0.974 / R_{ILIM}) \times S \quad (1)$$

Where 0.974 is the reference value, S is the MPQ5075A's current-sense ratio, and the typical value is 85000 when V_{IN} = 3.6V.

S shifts incrementally when V_{CC} and V_{IN} change. See the Typical Performance Characteristics section on page 5 for more information.

If the I_{LIMIT} block starts regulating I_{OUT}, the power loss in the power MOSFET causes the IC's temperature to rise. If the junction temperature (T_J) rises high enough, the MPQ5075A goes into thermal shutdown. When thermal shutdown occurs, the output is disabled until the over-temperature (OT) fault is removed. The OT threshold is 170°C, and the hysteresis is 30°C.

Power Good (PG)

The power good (PG) pin is the push-pull of a MOSFET that can be pulled high to V_{CC}. The MOSFET turns on when V_{IN} is applied to pull PG to GND. Once the voltage gap between V_{IN} and V_{OUT} is below 150mV, PG is pulled high after a 70µs delay. If the voltage gap exceeds 200mV or the over-current (OC) limit warning is triggered, then PG is pulled low without a time delay. PG has a typical 200Ω pull-down resistance and a 250kΩ pull-up resistance. If PG is pulled to GND via the internal pull-down resistor, the maximum sink current should be <10mA.

Short-Circuit Protection (SCP)

If a short circuit causes the load current to rapidly increase, the current may significantly exceed its limit threshold before the control loop is able to respond. If the current reaches the internal secondary I_{LIMIT} (typically 5A), a fast turn-off circuit shuts down the power MOSFET, limiting the peak current through the switch and V_{IN} drop. The total short circuit response time is about 200ns. If the fast turn-off works, the power MOSFET remains off for 80µs. After the 80µs, the power MOSFET turns back on. If the short circuit remains, the MPQ5075A reduces and holds I_{LIMIT} to 2/3 of the preset value until the part is hot enough to trigger thermal shutdown. Once the short circuit condition is removed, I_{LIMIT} automatically recovers to the preset value.

Output Discharge

The MPQ5075A provides output discharge to discharge V_{OUT} via an internal pull-down resistor when the IC's EN pin is disabled or V_{CC} shuts down and the load is very light.

Soft Start (SS)

The capacitor connected to the SS pin determines the soft-start time (t_{SS}). An internal, 9µA constant-current source charges the SS capacitor (C_{SS}) and ramps up the voltage on the SS pin (V_{SS}). V_{OUT} rises at three times the slew rate of V_{SS}. t_{SS} can be calculated with Equation (2):

$$t_{SS}(ms) = \frac{1}{3} \times \frac{V_{OUT}(V) \times C_{SS}(nF)}{I_{SS}(\mu A)} \quad (2)$$

Where I_{SS} is the internal, 9µA constant current.

It is recommended that the minimum C_{SS} should exceed 4.7nF. If the SS pin is floating or C_{SS} is too small, then the V_{OUT} rise time is only limited by the power MOSFET charge time.

APPLICATION INFORMATION

Selecting the ILIM Resistor

I_{LIMIT} is set by the ILIM resistor (R_{ILIM}) and can be calculated with Equation (1) on page 15.

The I_{LIMIT} threshold is recommended to be 10% to 20% greater than the maximum load current. For example, if a system's full load is 5A, set I_{LIMIT} to 5.5A.

Selecting the Soft-Start Capacitor (C_{SS})

An internal, 9μA constant-current source charges C_{SS} and ramps up V_{SS}. V_{OUT} rises at three times the slew rate of V_{SS}.

If the inrush of I_{OUT} reaches I_{LIMIT} during start-up (e.g. if there is a large output capacitor or large load), the MPQ5075A limits I_{OUT} and t_{SS} increases simultaneously.

Figure 2 shows SS under different loads.

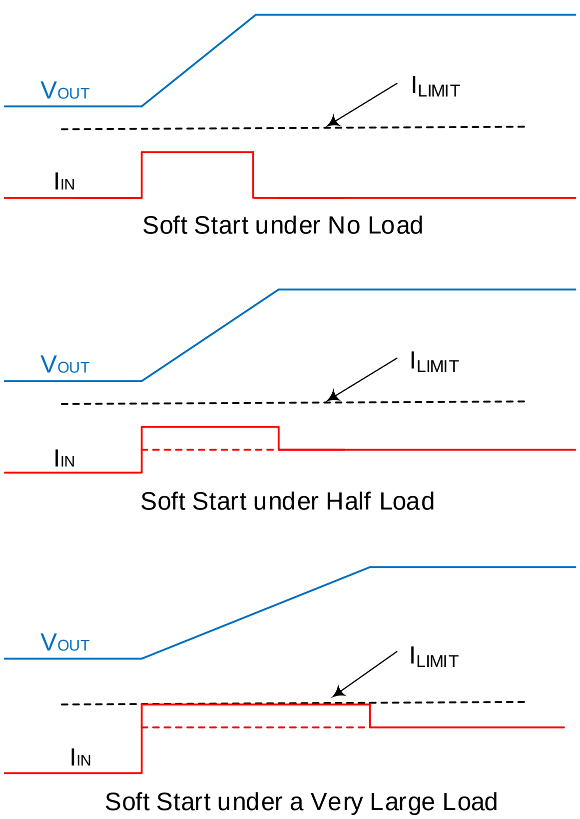


Figure 2: SS under Different Loads

Figure 3 shows SS with different output capacitances.

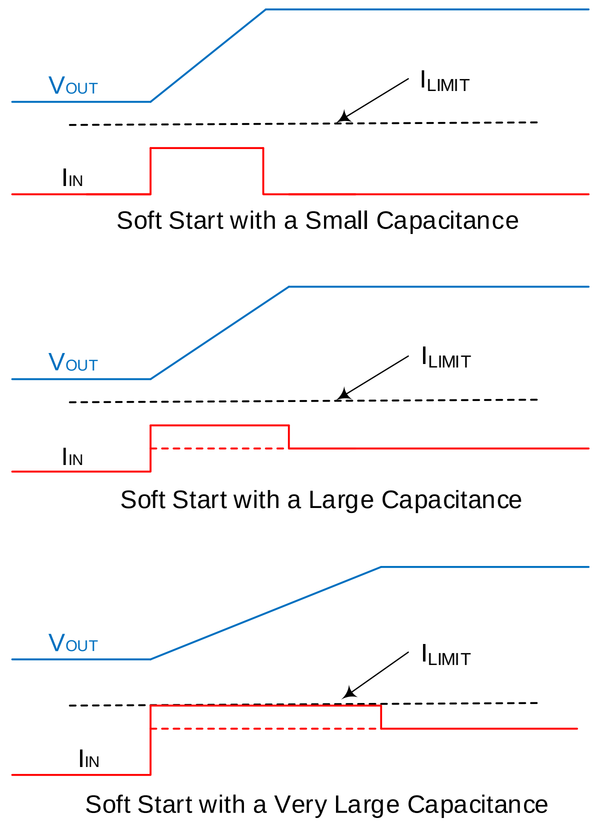


Figure 3: SS with Different Output Capacitances

Design Example

Table 1 lists key parameters for selecting components.

Table 1: Components Selection

V_{IN} (V)	Max Load Range (A)	R_{ILIM} (kΩ)	C_{SS} (nF)	t_{SS} (ms)
5	3	26.1	22	4
5	5	15.4	47	9

See Figure 5 on page 18 for the Typical Application Circuit.

PCB Layout Guidelines

Efficient PCB layout is critical to achieve stable operation. For the best results, refer to Figure 4 and follow the guidelines below:

1. Place R_{ILIM} close to the ILIM pin.
2. Place the input capacitor close to the VCC pin.
3. Place enough vias around the IC to improve thermal performance.

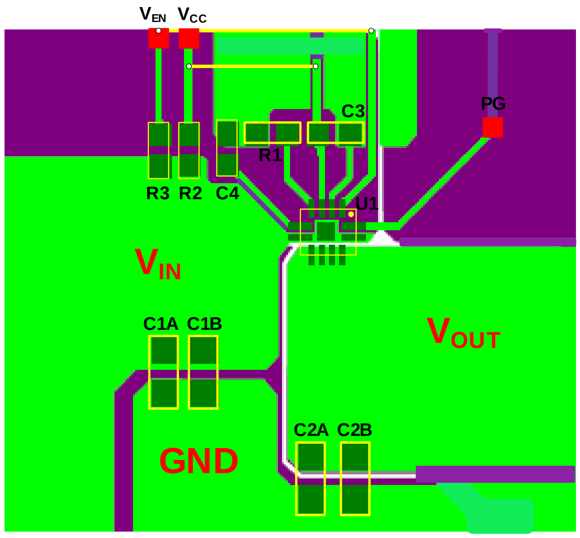


Figure 4: Recommended PCB Layout

TYPICAL APPLICATION CIRCUIT

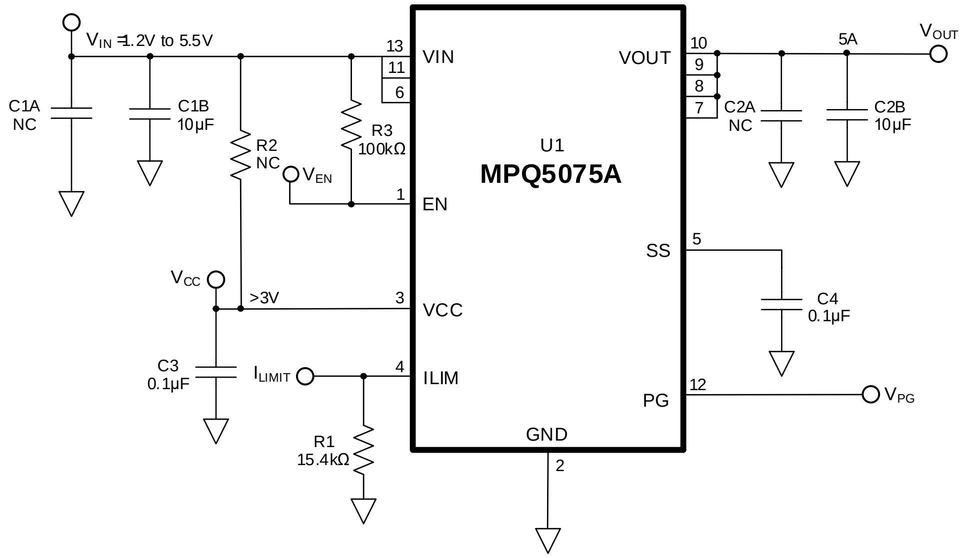
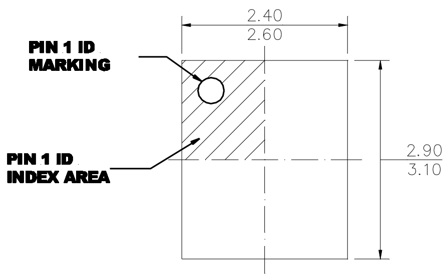


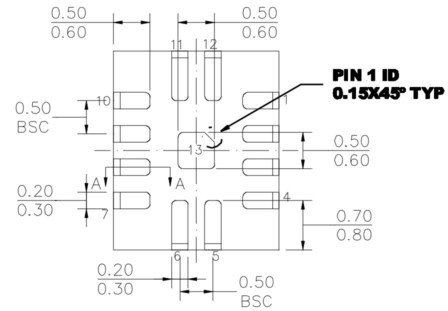
Figure 5: Typical Application Circuit

PACKAGE INFORMATION

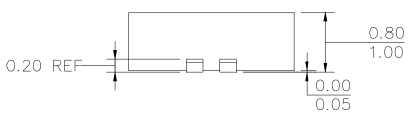
QFN-13 (2.5mmx3mm)



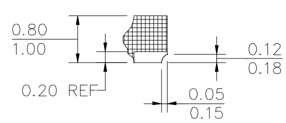
TOP VIEW



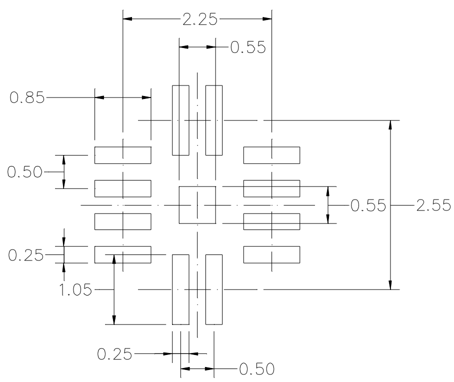
BOTTOM VIEW



SIDE VIEW



SECTION A-A

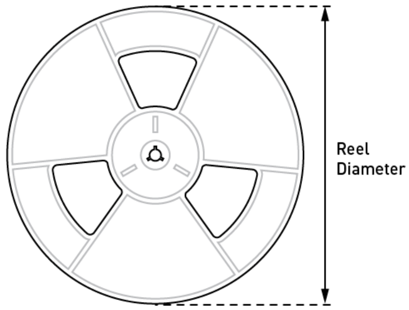


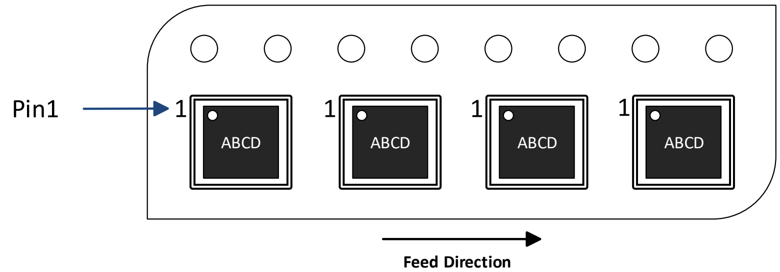
RECOMMENDED LAND PATTERN

NOTE:

1) THE LEAD SIDE IS WETTABLE.
2) ALL DIMENSIONS ARE IN MILLIMETERS.
3) LEAD COPLANARITY SHALL BE 0.08 MILLIMETERS MAX.
4) JEDEC REFERENCE IS MO-220.
5) 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
MPQ5075AGQBE-AEC1-Z	QFN-13 (2.5mmx3mm)	5000	N/A	N/A	13in	12mm	8mm

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	10/31/2022	Initial Release	-
1.1	4/2/2024	• Updated the Features section: ○ Removed "s" from "MOSFETs" from bullet point 2 • Updated the Typical Application section's C1 and C2 = 10µF	1
		• Updated Absolute Maximum Ratings section: ○ Added "Enable Voltage (V_{EN})…-0.3V to +6.5V" • Removed "EN" from the next line	3
		• Added the Typ value in the off-state leakage current section • Updated the Typ value in the V_{CC} standby current section • Updated the Min value in the shutdown temperature section • Updated the Typ value in the V_{CC} UVLO threshold section • Updated the Typ value in the shutdown temperature section • Updated the current limit section: ○ Updated the Min, Typ, and Max values of current limit and current limit warning (R_{LIMIT} = 50kΩ) ○ Added a new Condition (R_{LIMIT} = 15.4kΩ) to Current limit and its Typ value	4
		• Updated top left graph title to V_{CC} Quiescent Current • Updated top right graph title to VIN Quiescent Current; updated condition from "VEN = 0V" to "VEN = 2V"	5
		• Updated top left graph title by adding "V_{CC}" • Updated top right graph title by adding "V_{IN}"	8
		• Removed "or float EN" in the Enable (EN) section • Updated the shutdown temperature in the Current Limit section • Updated "83000" to "85000" in the Current Limit section	15
		• Updated Figure 5: ○ Updated capacitors C1A/C2A = NC ○ Updated C1B/C2B = 10µF	18