MIC2039

High-Accuracy, High-Side, Adjustable Current Limit Power Switch

General Description

The MIC2039 is a high-side MOSFET power distribution switch providing increased system reliability by using 5% current-limit accuracy.

The MIC2039 has an operating input voltage range from 2.5V to 5.5V, is internally current limited, and has thermal shutdown to protect the device and system. The MIC2039 is offered with either active-high or active-low logic level enable input controls. It has an open drain fault status output flag with a built-in 32ms delay that asserts low during overcurrent or thermal-shutdown conditions.

The MIC2039 switches feature an adjustable output current limit that is resistor programmable from 0.2A to 2.5A. The MIC2039 switch also offers a unique, Kickstart feature that allows momentary high-current surges up to the secondary current limit (I_{LIMIT_2nd}) during startup or while operating in steady state. This is useful for charging loads with high inrush currents, such as capacitors. After an overcurrent condition is established, these switches enter into a constant current-limit mode unless the die temperature exceeds the thermal-shutdown specification.

The MIC2039 is available in 6-pin SOT-23 and 6-pin 2mm × 2mm thin DFN packages. The MIC2039 has an operating junction temperature range of –40°C to +125°C.

Datasheets and support documentation are available on Micrel's web site at: www.micrel.com.

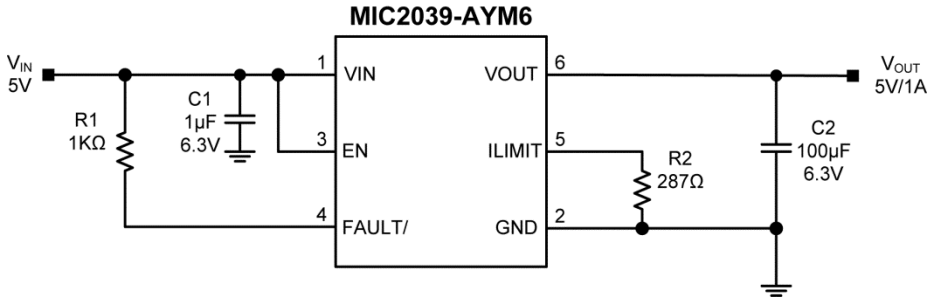
Features

- ±5% current limit accuracy
- Input supply range from 2.5V to 5.5V
- Low quiescent current: 100µA typical (switch ON)
- 75mΩ typical $R_{DS(ON)}$ at 5.0V
- 0.2A to 2.5A adjustable output current
- Kickstart – momentary secondary current-limit threshold (120ms period)
- Soft-start functionality
- Undervoltage lockout (UVLO)
- Fast 10µs short-circuit response time (non-Kickstart options)
- Fault status output flag
- Logic-controlled enable (active-high, active-low)
- Thermal shutdown
- Pin compatible with the MIC2009/MIC2019
- 6-pin 2mm × 2mm thin DFN and 6-pin SOT-23 packages
- Junction temperature range from –40°C to +125°C

Applications

- USB peripherals and USB 2.0/3.0 compatible
- DTV/STB
- Notebooks and consumer electronics
- General-purpose power distribution

Typical Application



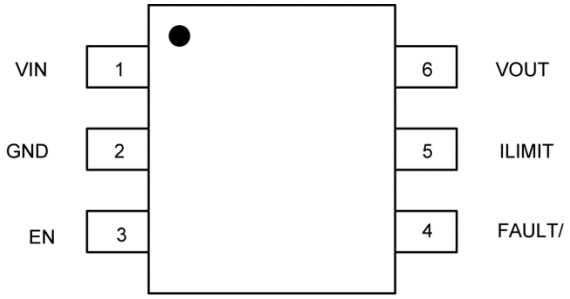
Ordering Information

Part Number	Top Mark[1]	Current Limit	Enable	Kickstart	Package
MIC2039AYM6	39AA	Adjustable	Active High	No	SOT-23-6L
MIC2039BYM6	39BB	Adjustable	Active Low	No	SOT-23-6L
MIC2039AYMT	3A9	Adjustable	Active High	No	6-pin 2mm x 2mm Thin DFN[2]
MIC2039BYMT	B39	Adjustable	Active Low	No	6-pin 2mm x 2mm Thin DFN[2]
MIC2039EYM6	39AE	Adjustable	Active High	Yes	SOT-23-6L
MIC2039FYM6	39AF	Adjustable	Active Low	Yes	SOT-23-6L
MIC2039EYMT	D39	Adjustable	Active High	Yes	6-pin 2mm x 2mm Thin DFN[2]
MIC2039FYMT	F39	Adjustable	Active Low	Yes	6-pin 2mm x 2mm Thin DFN[2]

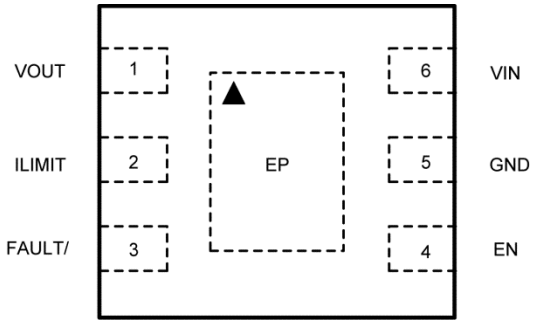
Note:

1. Under-bar symbol (_) may not be to scale.
2. Thin DFN is a GREEN RoHS-compliant package. Lead finish is NiPdAu. Mold compound is Halogen Free.

Pin Configuration



SOT-23 6-pin (M6)
Top View



2mm x 2mm 6-pin Thin DFN (MT)[3]
(Top View)

Notes:

3. Thin DFN ▲ = Pin 1 identifier.

Pin Description

Pin Number		Pin Name	Pin Function
SOT-23-6L	6-Pin 2mm x 2mm Thin DFN		
1	6	VIN	Input: Power switch and logic supply input.
2	5	GND	Ground: Input and output return pin.
3	4	EN	Enable (Input): Logic compatible, enable control input that allows switch turn-on/off. Do not leave the EN pin floating.
4	3	FAULT/	Fault Status Flag (Output): Active-low, open-drain output. A logic low state indicates an overcurrent or thermal shutdown condition. An overcurrent condition must last longer than t_{FAULT}/ to assert FAULT/. A pull-up resistor (10kΩ recommended) to an external supply is required.
5	2	ILIMIT	Current Limit Set: Current limit adjust setting. Connect a resistor from this pin to GND to set the current limit, but do not leave the ILIMIT pin floating.
6	1	VOUT	Switch Output: Power switch output.
—	EP	ePad	Exposed Pad: Exposed pad on bottom of package. Connect to electrical ground for optimum thermal dissipation.

Absolute Maximum Ratings[4]

V_{IN} to GND ..... –0.3V to +6V
V_{OUT} to GND ..... –0.3V to +6V
V_{ILIMIT} to GND ..... –0.3V to +6V
V_{EN} to GND ..... –0.3V to +6V
$V_{FAULT/}$ to GND ..... –0.3V to +6V
FAULT/ Current ($I_{FAULT/}$) 25mA
Maximum Power Dissipation (P_D) ..... Internally Limited
Lead Temperature (soldering, 10s) ..... 260°C
Storage Temperature (T_S) ..... –65°C to +150°C
ESD Rating[6]
HBM 3kV
MM 300V

Operating Ratings[5]

Supply Voltage (V_{IN}) ..... +2.5V to +5.5V
V_{EN}, $V_{FAULT/}$ ..... –0.3V to +5.5V
V_{ILIMIT}, V_{OUT} ..... –0.3V to V_{IN}
Junction Temperature (T_J) ..... –40°C to +125°C
Package Thermal Resistance
SOT-23-6 (θ_{JA}) ..... 177.2°C/W
6-pin 2mm × 2mm Thin DFN (θ_{JA}) ..... 90°C/W

Electrical Characteristics[7]

V_{IN} = V_{EN} = 5V; C_{IN} = 1µF; T_J = 25°C. **Bold** values indicate –40°C≤ T_A ≤ +85°C, unless noted.

Symbol	Parameter	Condition		Min.	Typ.	Max.	Units
Power Supply Input							
V_{IN}	Input Voltage Range			**2.5**		**5.5**	V
V_{UVLO}	Input Supply Undervoltage Lockout Threshold	V_{IN} rising		**2.0**	2.25	**2.5**	V
		V_{IN} falling		**1.9**	2.15	**2.4**	V
$V_{UVLOHYS}$	Input Supply Undervoltage Lockout Threshold Hysteresis	V_{IN} rising or V_{IN} falling			100		mV
I_{DD}	Supply Current	Switch OFF (I_{OUT} = 0A)	Active-high Enable (A): V_{EN} = 0V, V_{IN} = 5V		0.75	**5**	µA
			Active-low Enable (B): V_{EN} = V_{IN} = 5V				
		Switch ON (I_{OUT} = 0A)	Active-high Enable (A): V_{EN} = 1.5V, V_{IN} = 5V		100	**300**	
			Active-low Enable (B): V_{EN} = 0V, V_{IN} = 5V				
Power MOSFET							
$R_{DS(ON)}$	Switch On Resistance	V_{IN} = 2.5V, I_{OUT} = 350mA			100	**177**	mΩ
		V_{IN} = 3.3V, I_{OUT} = 350mA			85	**145**	
		V_{IN} = 5V, I_{OUT} = 350mA			75	**125**	
I_{LKG}	Output Leakage Current	Switch Off, V_{OUT} = 0V			0.22	**15**	µA

Notes:

4. Exceeding the absolute maximum ratings may damage the device.
5. The device is not guaranteed to function outside its operating ratings.
6. Devices are ESD sensitive. Handling precautions are recommended. Human body model, 1.5kΩ in series with 100pF.
7. Specification for packaged product only

Electrical Characteristics[7] (Continued)

$V_{IN} = V_{EN} = 5V$; $C_{IN} = 1\mu F$; $C_{OUT} = 1\mu F$ $T_J = 25°C$. **Bold** values indicate $–40°C \le T_J \le +125°C$, unless noted otherwise.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
Current Limit						
I_{LIMIT}	Current Limit (Resistor values are standard 0.1% values)	$R_{LIMIT} = 115\Omega$, $V_{IN} = 5V$, $V_{OUT} = 0.8V \times V_{IN}$	2.35	2.5	2.65	A
		$R_{LIMIT} = 115\Omega$, $V_{IN} = 2.5V$, $V_{OUT} = 0V$	2.6	2.85	3.1	
		$R_{LIMIT} = 145\Omega$, $V_{IN} = 5V$, $V_{OUT} = 0.8V \times V_{IN}$	1.90	2.0	2.10	
		$R_{LIMIT} = 287\Omega$, $V_{IN} = 5V$, $V_{OUT} = 0.8V \times V_{IN}$	0.95	1.0	1.05	
		$R_{LIMIT} = 576\Omega$, $V_{IN} = 5V$, $V_{OUT} = 0.8V \times V_{IN}$	0.475	0.50	0.525	
		$R_{LIMIT} = 1.45k\Omega$, $V_{IN} = 5V$, $V_{OUT} = 0.8V \times V_{IN}$	0.19	0.20	0.21	
I_{LIMIT_2nd}	Secondary Current Limit (Kickstart parts only)	$V_{OUT} = 0V$	2.2	3.2	6	A
I/O						
V_{EN}	Enable Voltage	Logic Low			**0.5**	V
		Logic High	**1.5**			
I_{EN}	Enable Input Current	$0V \le V_{EN} \le 5V$		1		µA
$R_{FAULT/}$	FAULT/ Output Resistance	$I_{OUT} = 10mA$			**25**	Ω
$I_{FAULT/_OFF}$	FAULT/ Off Current	$V_{FAULT/} = V_{IN}$			10	µA
Thermal Protection						
T_{SD}	Thermal-Shutdown Threshold	T_J rising		157		°C
T_{SDHYS}	Thermal-Shutdown Hysteresis			15		°C
Timing Specifications (AC Parameters)						
t_{RISE}	Output Turn-on Rise Time[8]	$R_{LOAD} = 10\Omega$; $C_{OUT} = 1\mu F$		700		µs
t_{FALL}	Output Turn-off Fall Time[8]	V_{EN} = OFF; $R_{LOAD} = 10\Omega$; $C_{OUT} = 1\mu F$		32		µs
t_{ON_DLY}	Output Turn-on Delay[8]	$R_{LOAD} = 10\Omega$; $C_{OUT} = 1\mu F$		700		µs
t_{OFF_DLY}	Output Turn-off Delay[8]	$R_{LOAD} = 10\Omega$; $C_{OUT} = 1\mu F$		5		µs
t_{SC_RESP}	Short Circuit Response Time[8]	$V_{OUT} = 0V$ (short circuit)		10		µs
$t_{FAULT/}$	Overcurrent Fault Response Delay Time[8]	Non-Kickstart parts	**16**	32	**49**	ms
$t_{KICKSTART}$	Overcurrent Fault Response Delay During Kickstart[8]	Kickstart parts only	**64**	120	**200**	ms

Note:

8. See “Timing Diagrams” (Figures 1 through 4).

Timing Diagrams

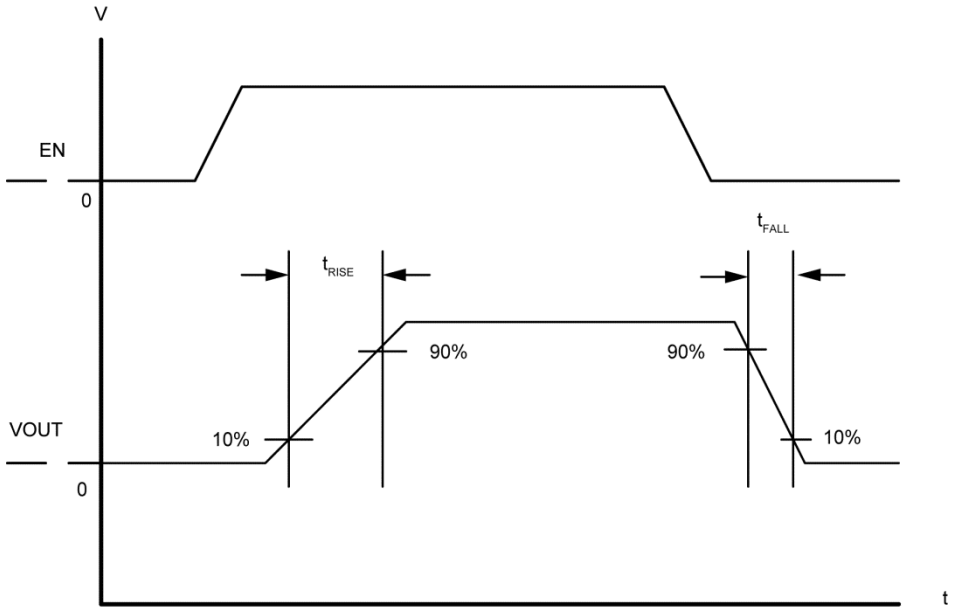


Figure 1. Output Rise/Fall Time

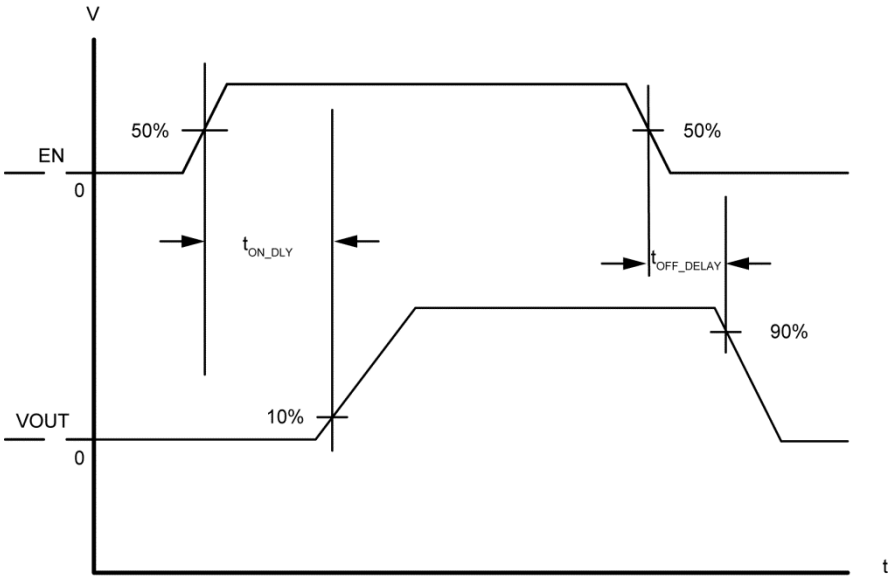


Figure 2. Turn-On/Off Delay

Timing Diagrams (Continued)

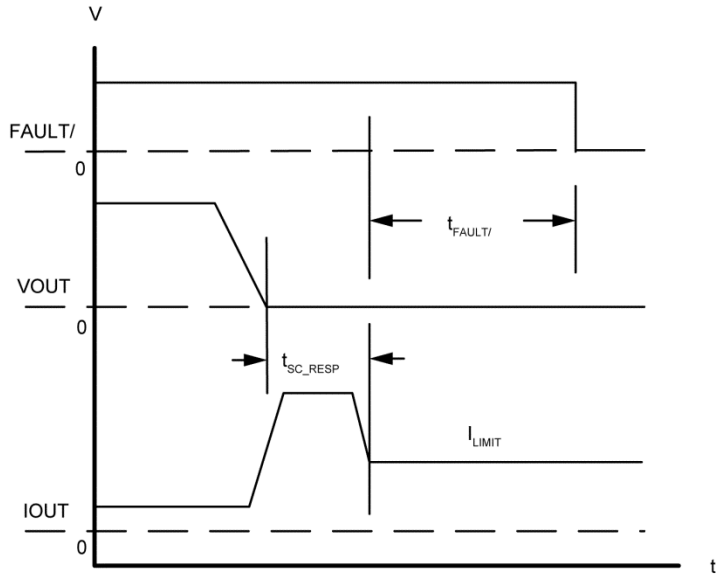


Figure 3. Short Circuit Response Time and Overcurrent Fault Flag Delay (Non-Kickstart)

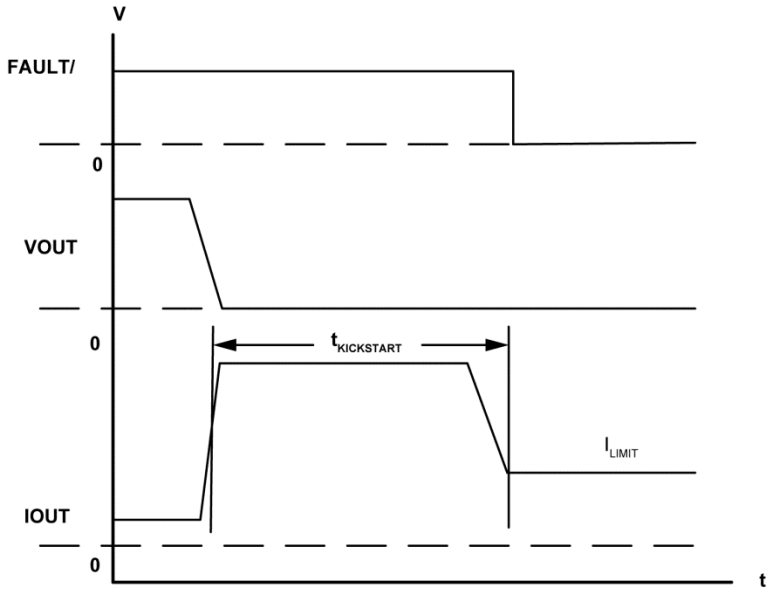
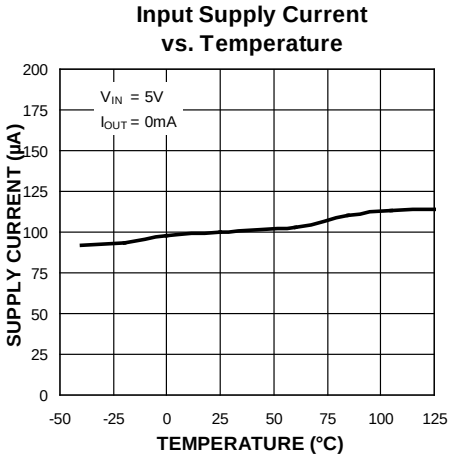
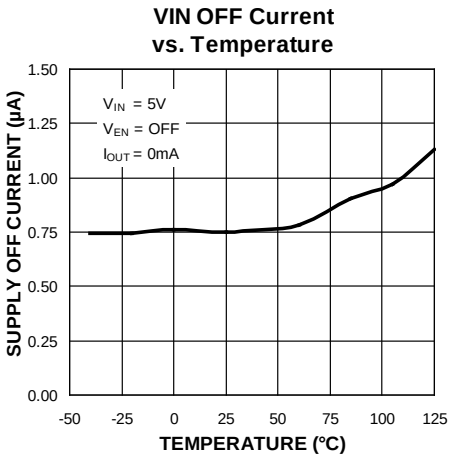
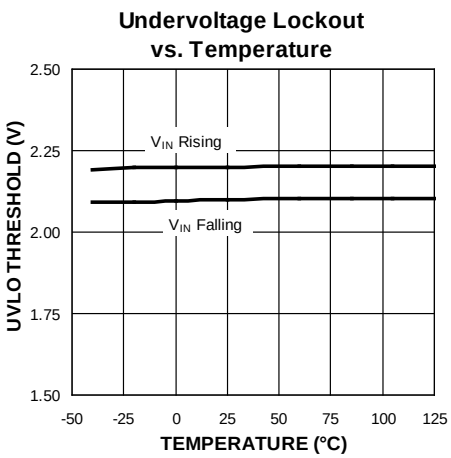


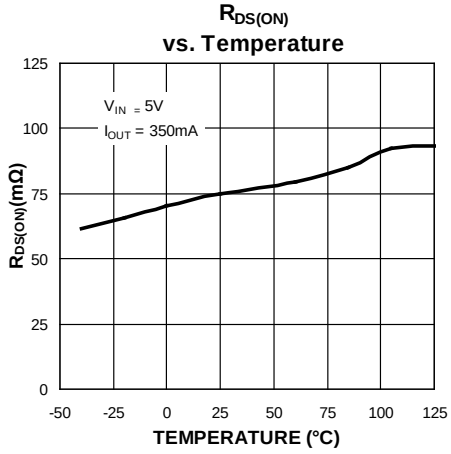
Figure 4. Overcurrent Fault Flag Delay (Kickstart)

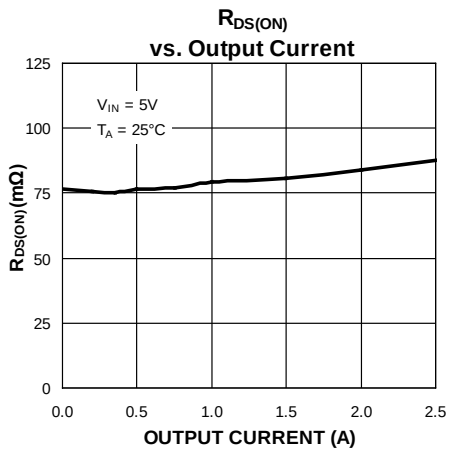
Typical Characteristics

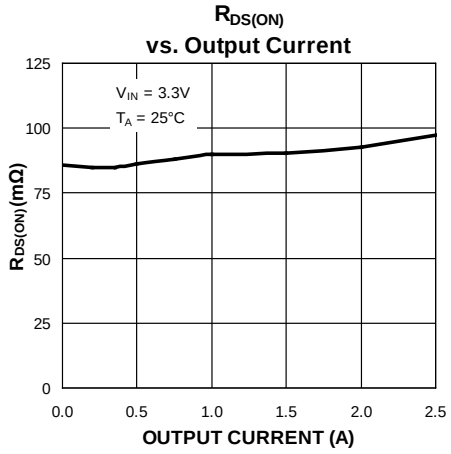


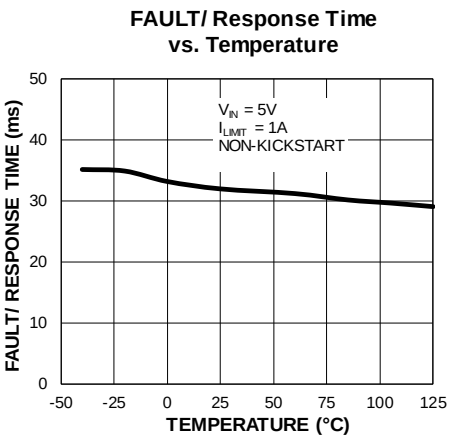


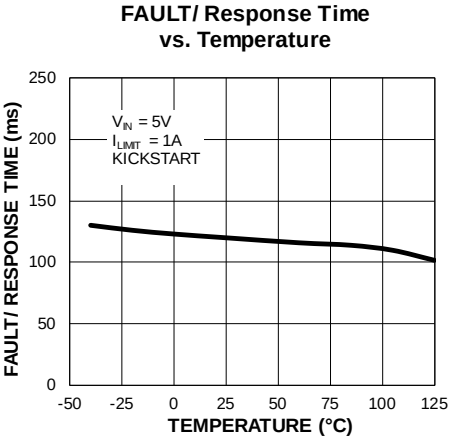


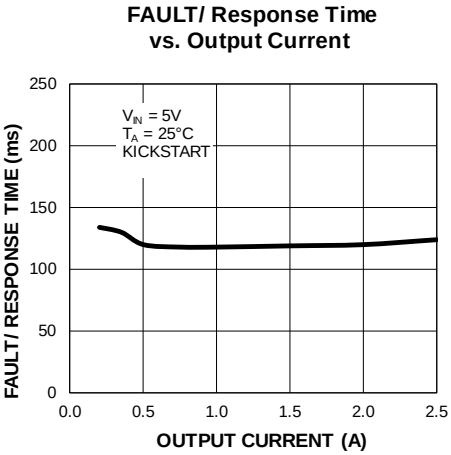




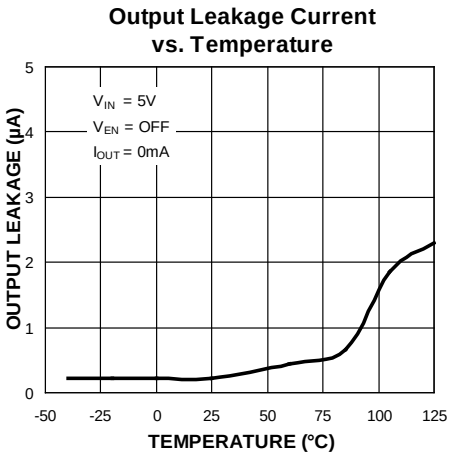


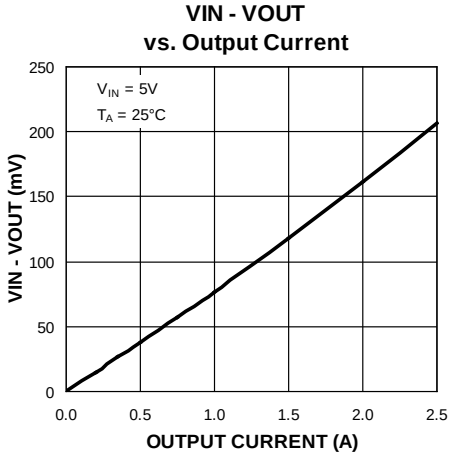


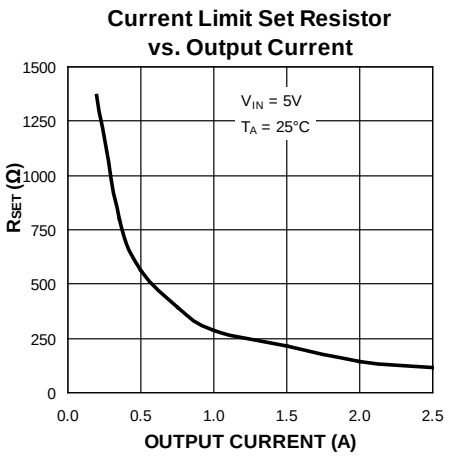




Typical Characteristics (Continued)

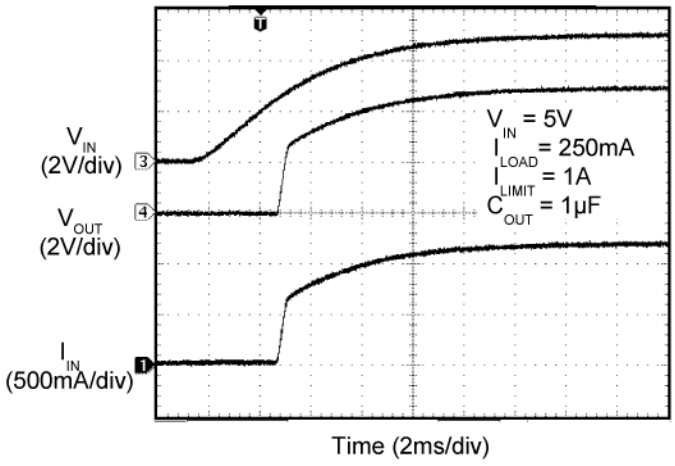




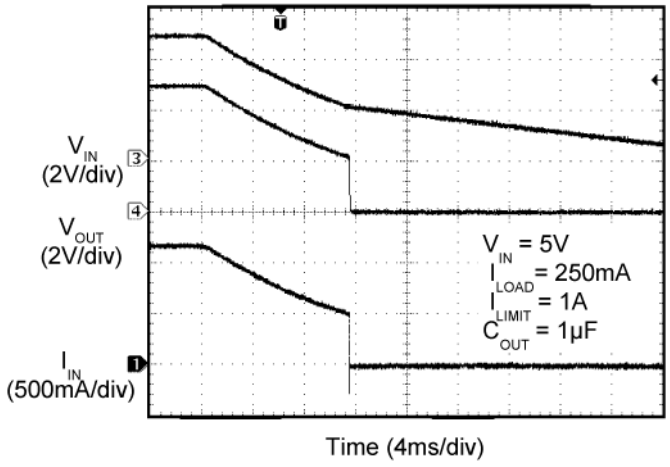


Functional Characteristics

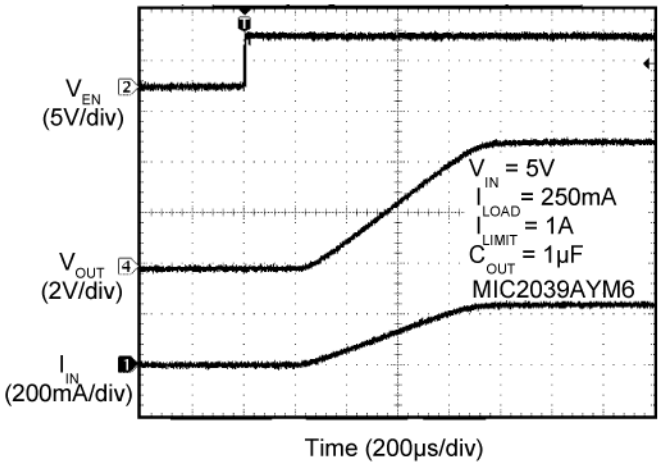
Soft-Start Turn-On



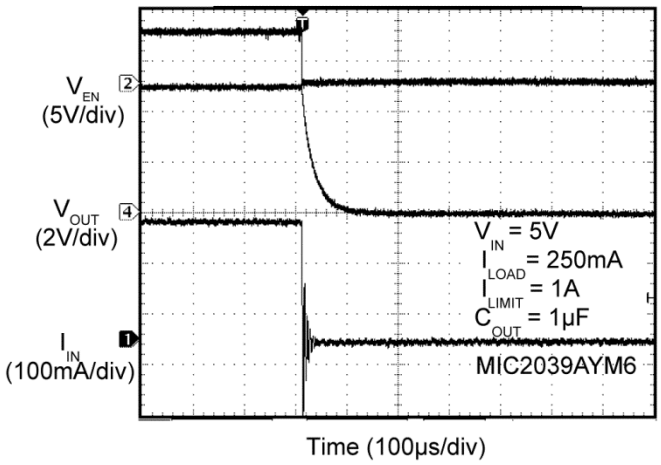
Soft-Start Turn-Off



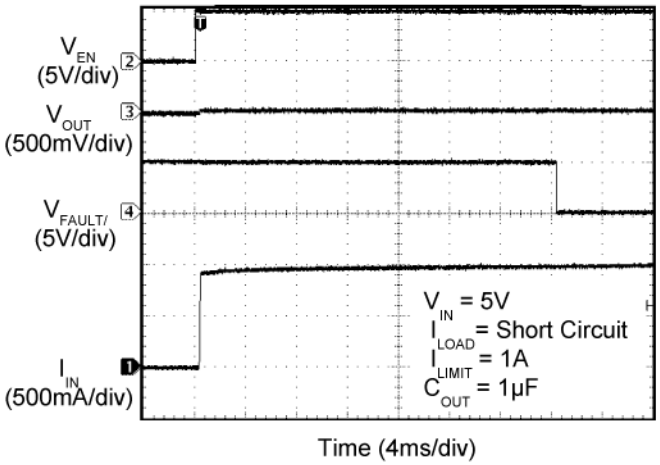
Enable Turn-On



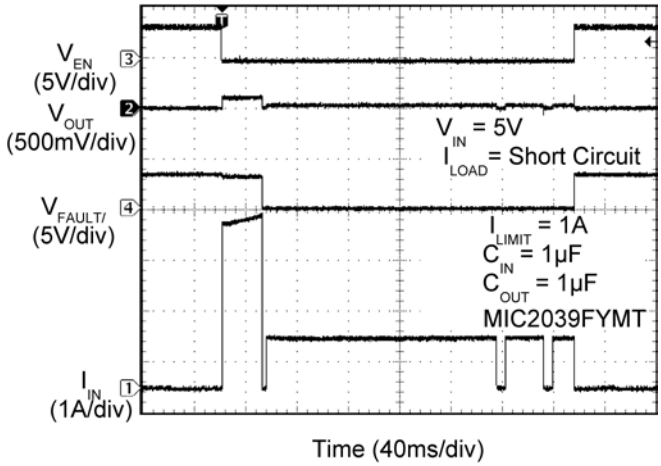
Enable Turn-Off



Turn-On Into Short Circuit

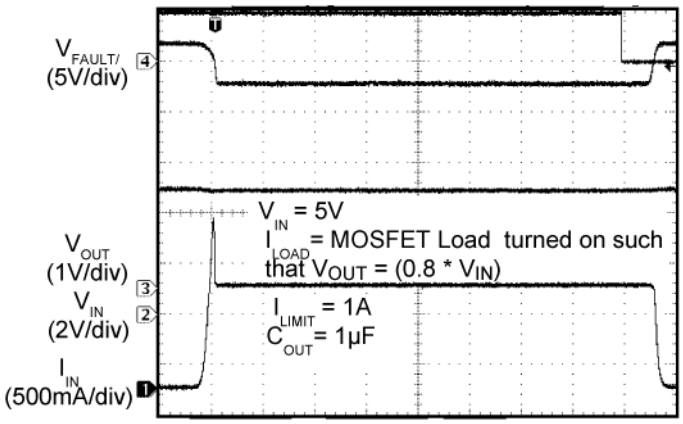


Turn-On Into Short (Kickstart)

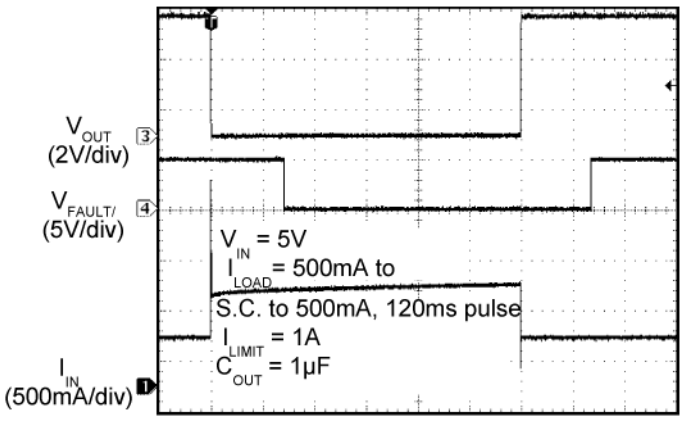


Functional Characteristics (Continued)

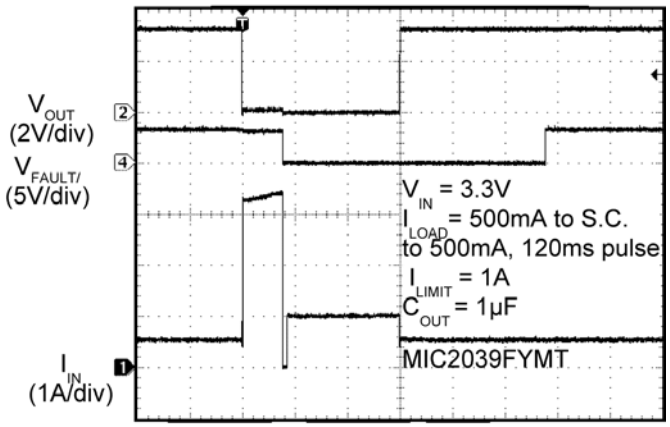
Current Limit Response



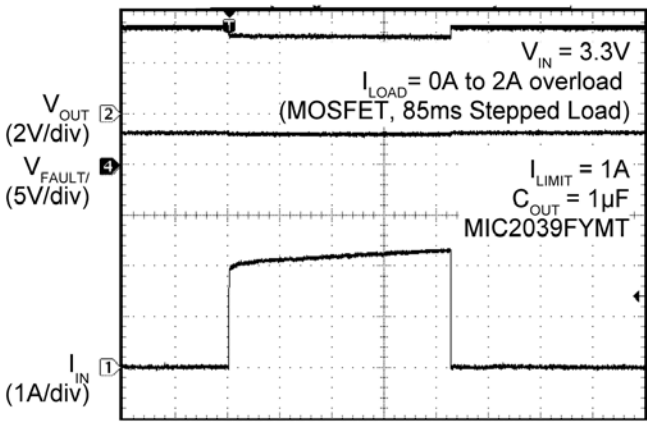
Output Recovery from Short Circuit



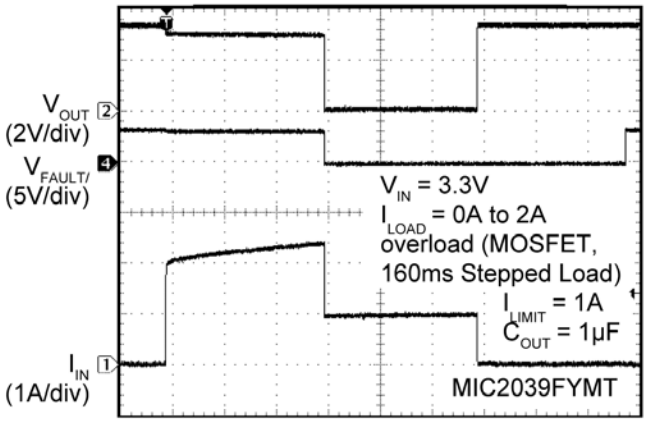
Output Recovery from S.C. - Kickstart



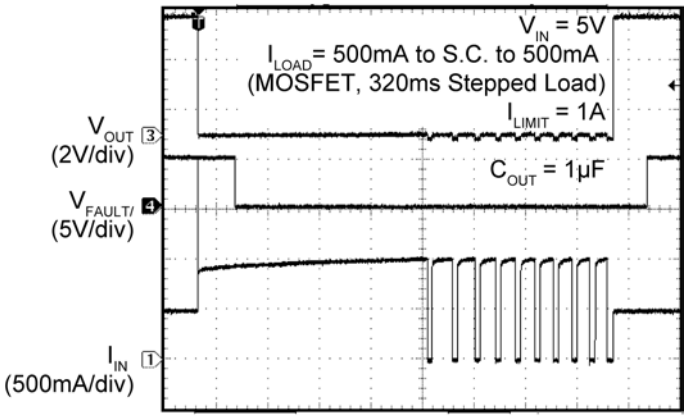
85ms Stepped Load Pulse - Kickstart



160ms Stepped Load Pulse - Kickstart

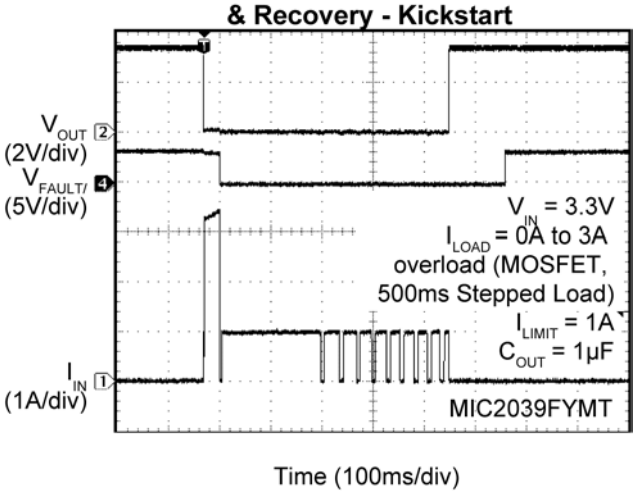


Output Thermal Shutdown & Recovery

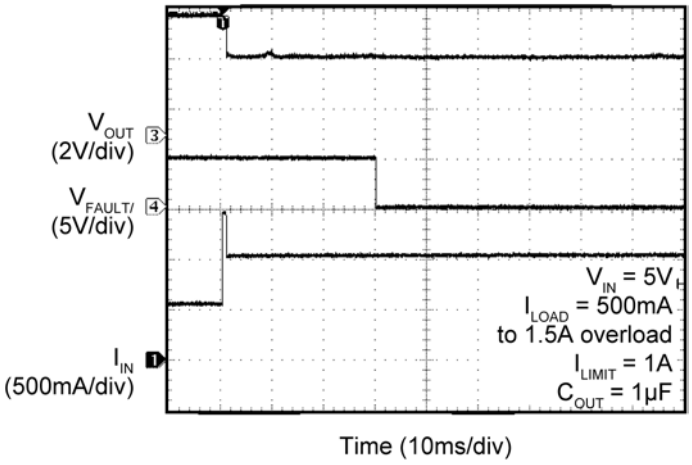


Functional Characteristics (Continued)

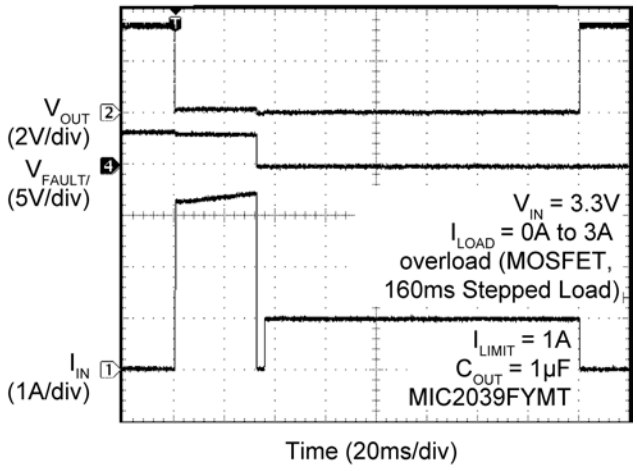
Output Thermal Shudown & Recovery - Kickstart



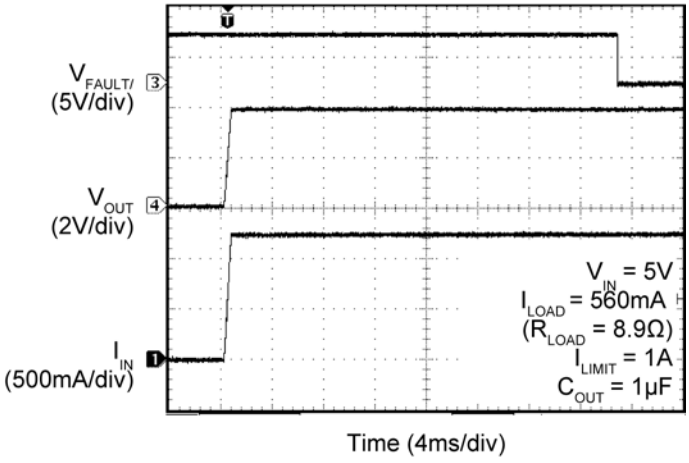
1.5A Overload Response



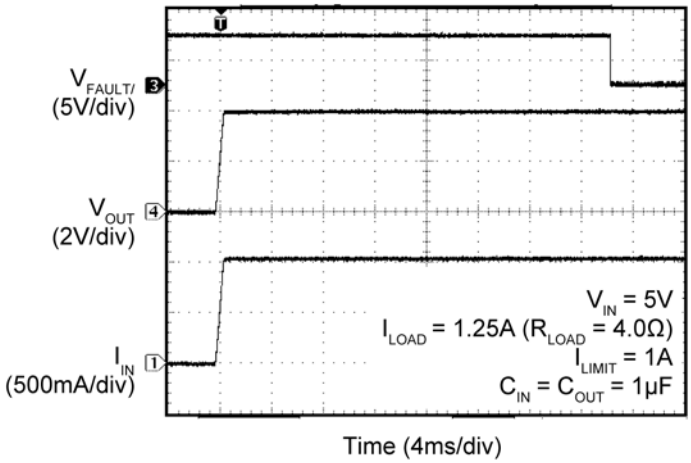
3A Overload Response - Kickstart



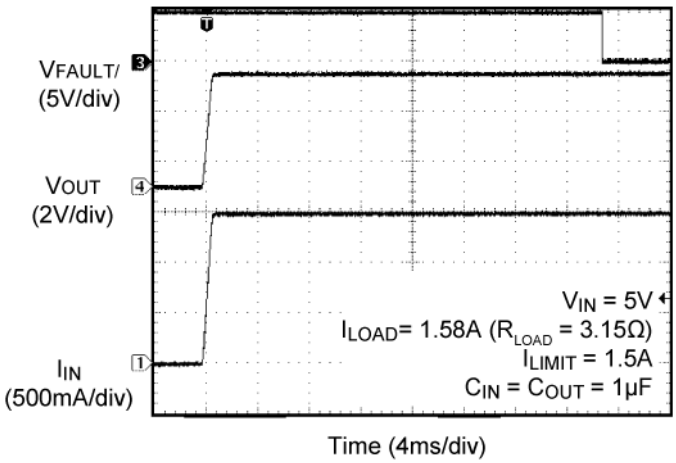
Turn-On Into 12% Overload - 500mA I_{LIMIT}



Turn-On Into 25% Overload - 1A I_{LIMIT}



Turn-On Into Minimal Overload - 1.5A I_{LIMIT}



Functional Diagram

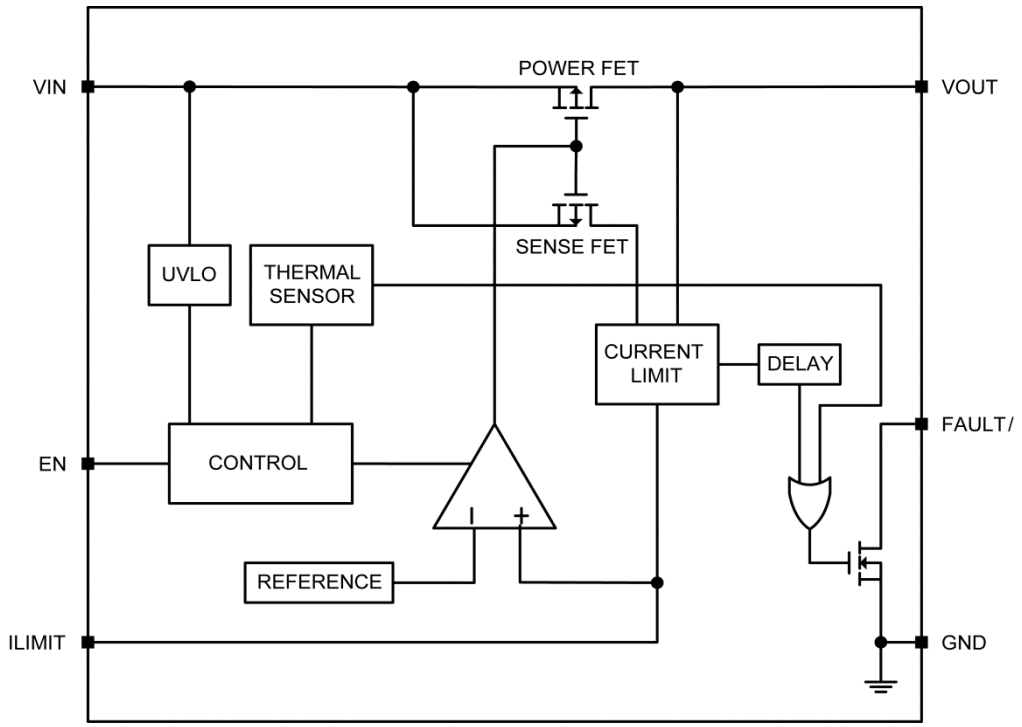


Figure 5. MIC2039 Block Diagram

Functional Description

The MIC2039 is a high-side MOSFET power-distribution switch that provides increased system reliability by using 5% current limit accuracy. The MIC2039 is internally current limited and has thermal shutdown, which protects the device and system.

The MIC2039 has a soft-start circuit that minimizes in-rush current by slowing the turn-on time. Additionally, the MIC2039 has an optional Kickstart feature, which momentarily overrides the normal current-limiting function to allow higher inrush and/or transient currents.

Soft-Start

Soft-start reduces the power-supply input surge current at startup by controlling the output voltage rise time. The input surge appears while the output capacitor is charged up. A slower output rise time draws a lower input surge current.

KICKSTART Inrush Overcurrent Filter

The MIC2039EYxx and MIC2039FYxx are equipped with a secondary current limit that allows high inrush current transients to pass for a set period before the primary current-limit circuitry becomes active. The FAULT/ status flag does not assert during the Kickstart period (typically 120ms), which eliminates any false (FAULT/) assertions. The Kickstart function is active during initial startup or while operating in steady state.

Input Capacitor

Micrel recommends a 1µF to 10µF ceramic input capacitor for most applications.

Place the input capacitor on the same side of the board and next to the MIC2039 to minimize the voltage ringing during transient and short-circuit conditions. Using two vias for each end of the capacitor to connect to the power and ground plane is also recommended.

Micrel recommends X7R or X5R dielectric ceramic capacitors because of their temperature performance. X7R-type capacitors change capacitance by 15% over their operating temperature range and are the most stable type of ceramic capacitors. Z5U and Y5V dielectric capacitors change value by as much as 50% and 60%, respectively, over their operating temperature ranges. To use a ceramic chip capacitor with Y5V dielectric, the value must be much higher than an X7R ceramic or a tantalum capacitor to ensure the same capacitance value over the operating temperature range.

Output Capacitor

The output capacitor type and placement criteria are the same as for the input capacitor. See the “Input Capacitor” section for a detailed description.

Enable

The MIC2039 offers either an active-high or active-low enable input (EN) that allows ON/OFF control of the switch output. The current through the device reduces to near “zero” when the device is shut down, with only microamperes of leakage current. The EN input can be directly tied to VIN or driven by a voltage that is equal to or less than VIN; do not leave this pin floating.

Adjustable Current Limit

The MIC2039 current limit is adjustable from 0.2A to 2.5A by connecting a resistor from the ILIMIT pin to GND. The following equation determines the resistor:

$$R_{LIMIT} \cong 289/I_{LIMIT} \quad \textbf{Eq. 1}$$

where I_{LIMIT} is the typical current limit from the electrical table. If the output current exceeds the set current limit, the MIC2039 switch enters constant current limit mode. The maximum allowable current limit can be less than the full specified and/or expected current if the MIC2039 is not mounted on a circuit board with sufficiently low thermal resistance. Table 1 shows resistor values (1%) for select current limit settings.

Table 1. Resistor Selection for Adjustable Current Limit

I_{LIMIT}	0.2A	0.5A	1.0A	2A	2.5A
R_{LIMIT}	1.45kΩ	576Ω	287Ω	145Ω	115Ω

High Current Limit Application Considerations

For higher current applications, a robust circuit design is necessary to avoid part failure due to large voltage and/or current swings. When dealing with fast AC transients at higher current limits, the use of a local bypass capacitor is critical in order to maintain a stable input supply. For proper operation, minimizing stray and/or parasitic inductance from the supply to VIN (of IC) and VOUT (of IC) to the actual load can be achieved through a compact circuit design. Table 2 below lists the recommended input/output capacitors for the higher DC current limit settings:

Table 2. Recommended C_{IN}/C_{OUT} vs I_{LIMIT}

I_{LIMIT}	*C_{IN}	C_{OUT}
1A	1µF	10µF
2A	10µF	47µF
2.5A	10µF	47µF

*These recommended values are for wire/traces less than 3 inches from the supply to the input and from the output to the load. For lengthy connections (>6 inches), use a 4.7µF (I_{LIMIT} = 1A) and 22µF (I_{LIMIT} > 2A) input capacitor.

Thermal Design

To help reduce the thermal resistance, the ePad (underneath the IC) should be soldered to the PCB ground. The placement of thermal vias either underneath or near the ePad is highly recommended. Thermal design requires the following application-specific parameters:

- Maximum ambient temperature (T_A)
- Output current (I_{OUT})
- Input voltage (V_{IN})
- Current limit (I_{LIMIT})

When the MIC2039 is in constant current limit mode, it may exceed the overtemperature threshold. If this occurs, the overtemperature condition will shut down the MIC2039 switch and the fault status flag will go active (assert low). After the switch cools down, it automatically turns on again. The user can maximize the MIC2039 power dissipation by either lowering the thermal resistance on the exposed pad (only the DFN package has an exposed pad) on the printed circuit board, or by limiting the maximum allowable ambient temperature.

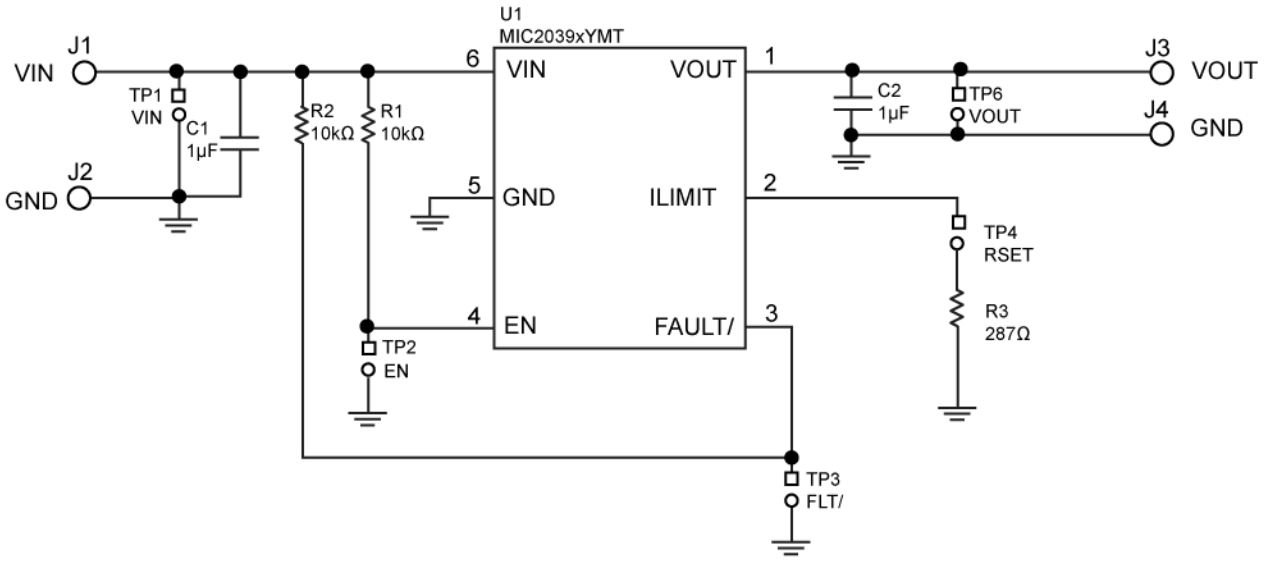
Thermal Measurements

It is always wise to measure the IC's case temperature to make sure that it is within its operating limits. Although this might seem like an elementary task, it is very easy to get false results. The most common mistake is to use the standard thermal couple that comes with the thermal voltage meter. This thermal couple wire gauge is large, typically 22 gauge, and behaves like a heatsink, resulting in a lower case measurement.

There are two suggested methods for measuring the IC case temperature: a thermal couple or an infrared thermometer. If a thermal couple is used, it must be constructed of 36 gauge wire or higher to minimize the wire heatsinking effect. In addition, the thermal couple tip must be covered in either thermal grease or thermal glue to make sure that the thermal couple junction is making good contact to the case of the IC. Thermal couple 5SC-TT-K-36-36 from Omega is adequate for most applications.

To avoid using messy thermal couple grease or glue, an infrared thermometer is recommended. Most infrared thermometers' spot size is too large for an accurate reading on small form factor ICs. However, an IR thermometer from Optris has a 1mm spot size, which makes it ideal for the 2mm × 2mm thin DFN package. Also, get the optional stand. The stand makes it easy to hold the beam on the IC for long periods of time.

Evaluation Board Schematic



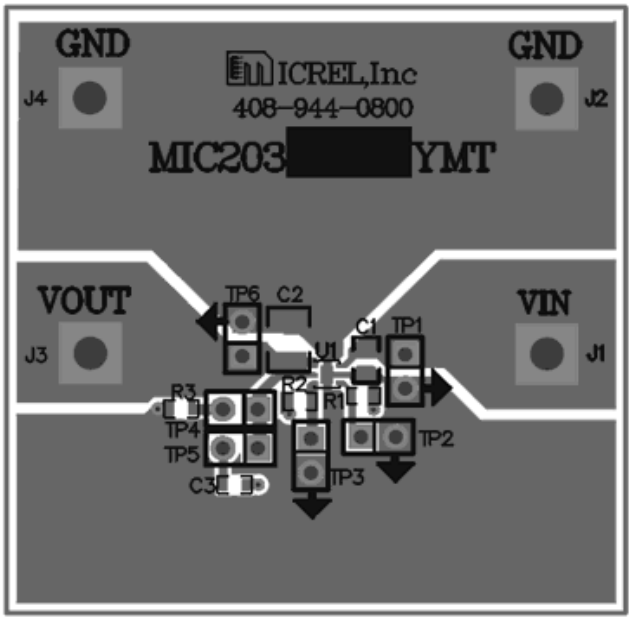
Bill of Materials

Item	Part Number	Manufacturer	Description	Qty.
C1, C2	C1608X5R0J105K	TDK[9]	1µF/6.3V ceramic capacitor, X5R, 0603	2
	06036D105KAT2A	AVX[10]		
R1, R2	CRCW060310K0FKEA	Vishay/Dale[11]	10kΩ, film resistor, 0603, 1%	2
R3	CRCW06032870FKEA	Vishay/Dale	287Ω film resistor, 0603, 1%	1
U1	MIC2039xYMT	**Micrel**[12]	High-accuracy, high-side, adjustable current-limit power switch	1

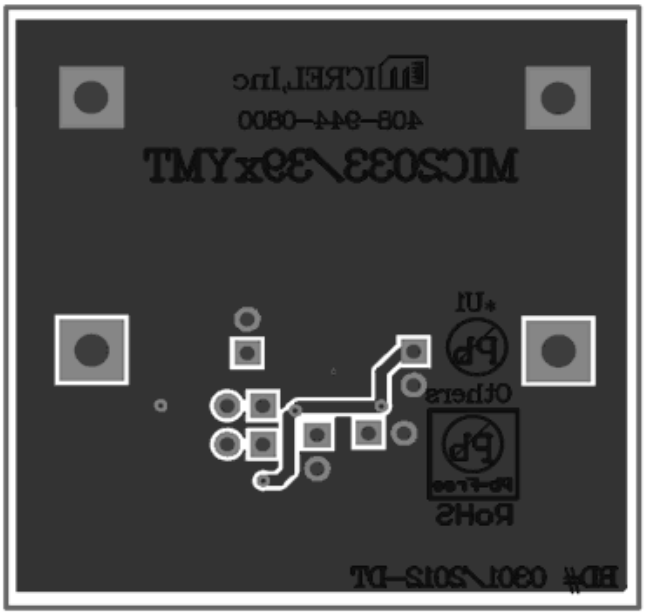
Notes:

9. TDK: www.tdk.com.
10. AVX.: www.avx.com.
11. Vishay: www.vishay.com.
12. **Micrel, Inc.: www.micrel.com.**

PCB Layout (MIC2039xYMT Evaluation Board)

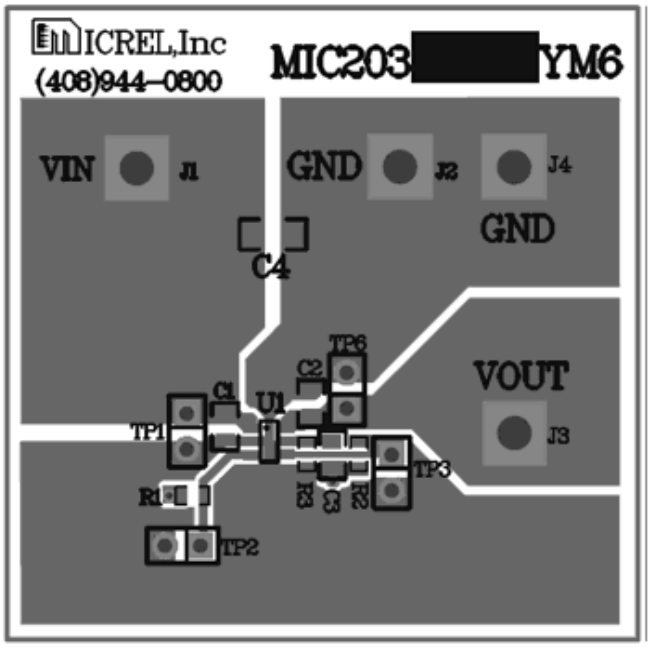


MIC2039xYMT Evaluation Board – Top Layer

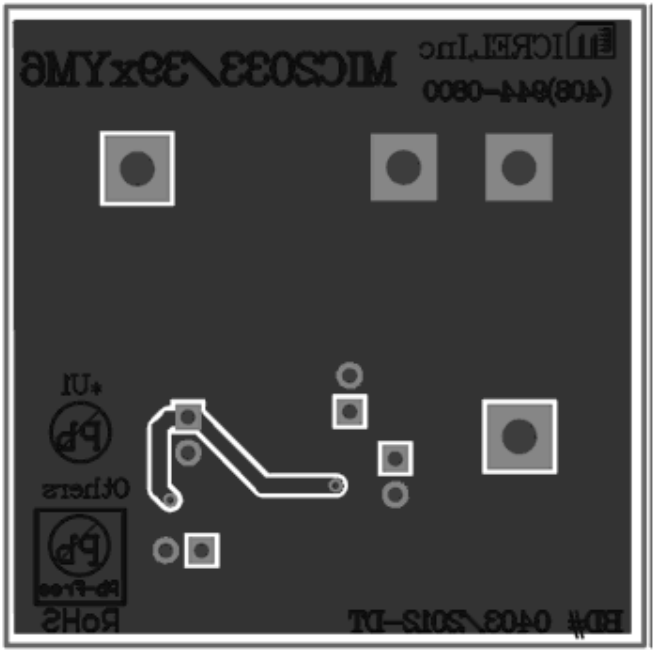


MIC2039xYMT Evaluation Board – Bottom Layer

PCB Layout (MIC2039xYM6 Evaluation Board)

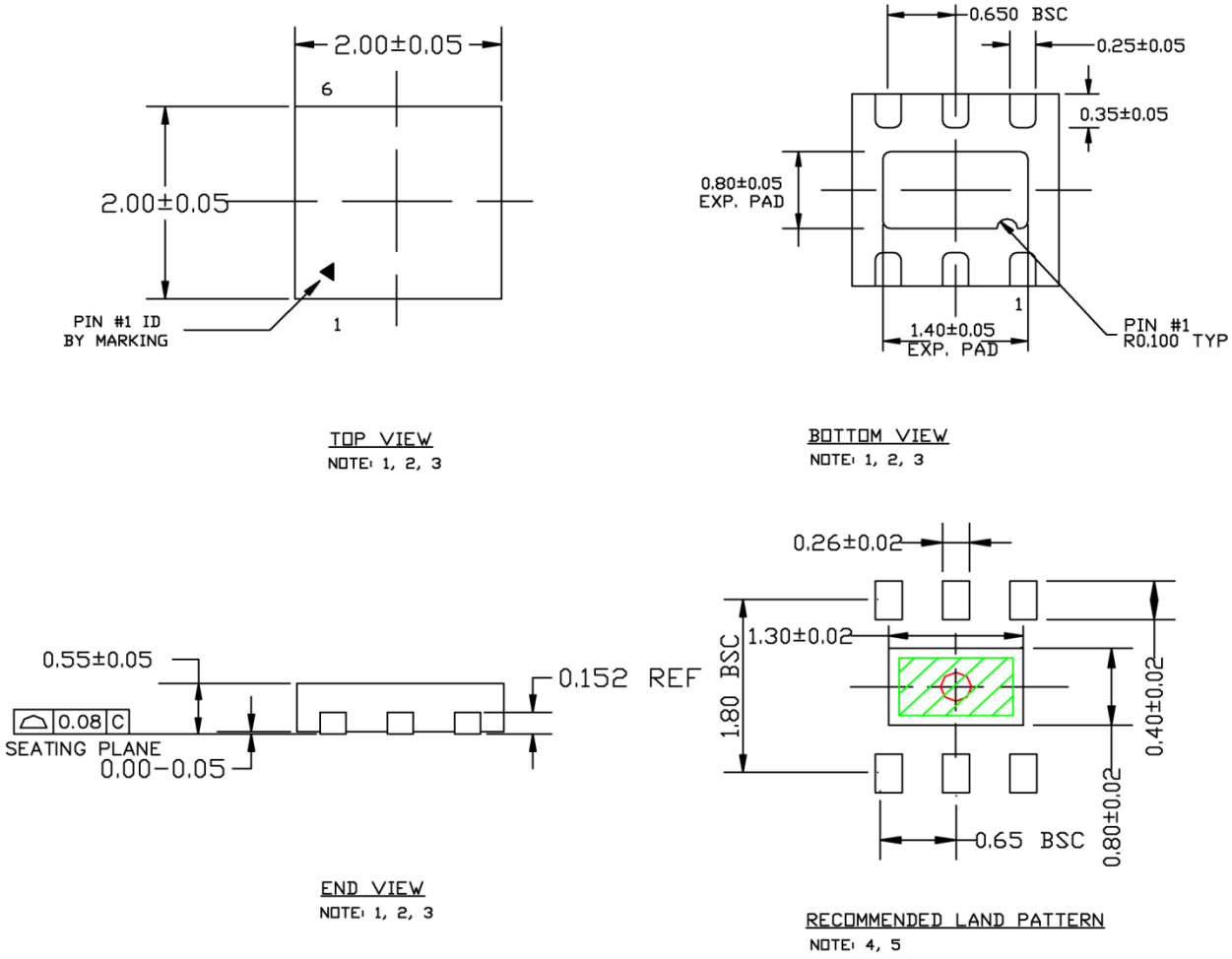


MIC2039xYM6 Evaluation Board – Top Layer



MIC2039xYM6 Evaluation Board – Bottom Layer

Package Information and Recommended Landing Pattern[13]



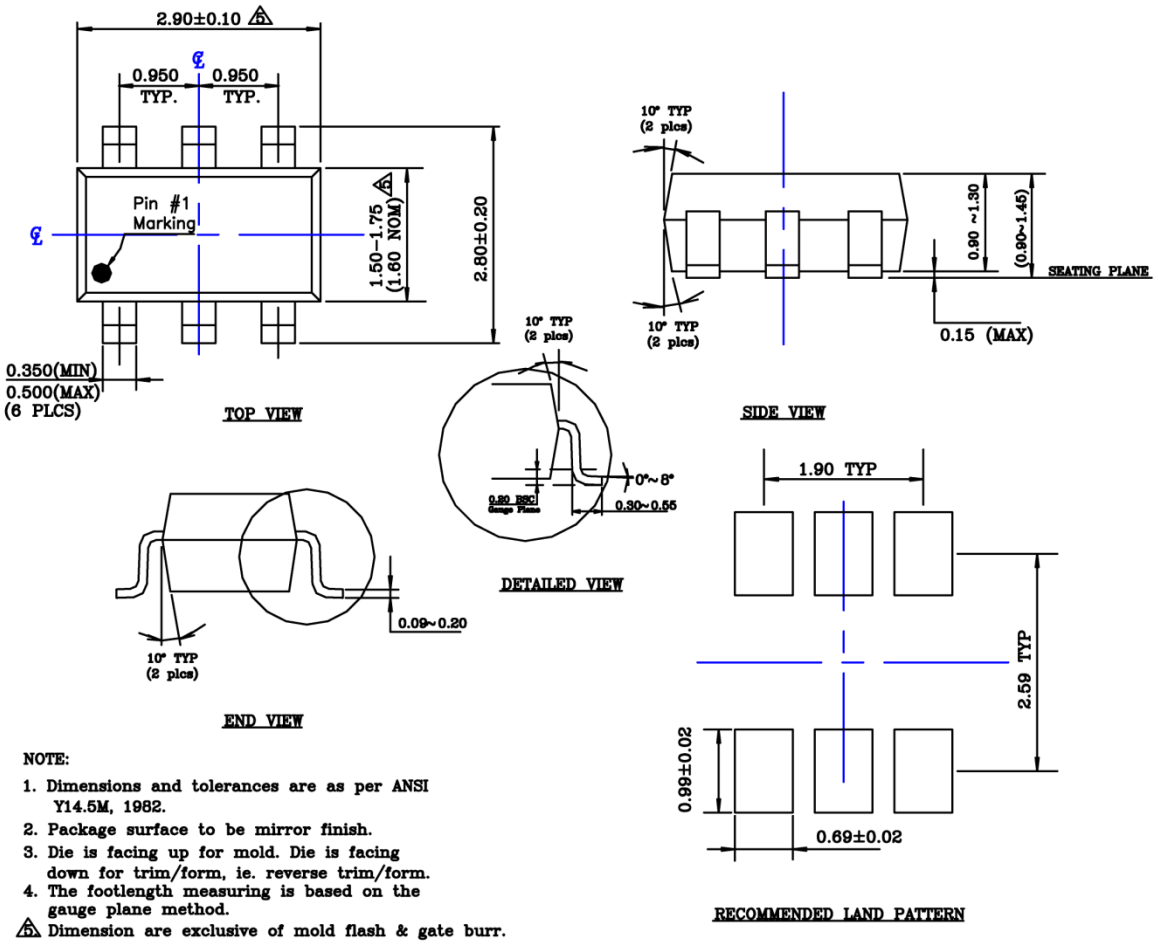
NOTE:
1. MAX PACKAGE WARPAGE IS 0.08 MM
2. MAX ALLOWABLE BURR IS 0.076MM IN ALL DIRECTIONS
3. PIN #1 IS ON TOP WILL BE LASER MARKED
4. RED CIRCLE IN LAND PATTERN REPRESENTS THERMAL VIA. SIZE SHOULD BE 0.30-0.3 MM IN DIAMETER AND SHOULD BE CONNECTED TO GND FOR MAX THERMAL PERFORMANCE
5. GREEN RECTANGLES (SHADED AREA) REPRESENTS SOLDER STENCIL OPENING ON EXPOSED PAD AREA. SIZE SHOULD BE 1.10x0.60 MM.

6-Pin 2mm x 2mm Thin DFN (MT)

Note:

13. Package information is correct as of the publication date. For updates and most current information, go to www.micrel.com.

Package Information and Recommended Landing Pattern[13] (Continued)



NOTE:

1. Dimensions and tolerances are as per ANSI Y14.5M, 1982.
2. Package surface to be mirror finish.
3. Die is facing up for mold. Die is facing down for trim/form, ie. reverse trim/form.
4. The footlength measuring is based on the gauge plane method.

⚠5 Dimension are exclusive of mold flash & gate burr.

SOT23-6L (M6)

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