MIC2006/2016

Fixed Current Limit Power Distribution Switch

General Description

The MIC2006 and the MIC2016 are current limiting, high-side power switches, designed for general purpose power distribution and control in PCs, PDAs, printers and other self-powered systems.

The MIC2006 and MIC2016's primary functions are current limiting and power switching. They are thermally protected and will shut down should their internal temperature reach unsafe levels, protecting both the device and the load, under high current or fault conditions. Both devices are fully self-contained, with the current limit value being factory set to one of several convenient levels.

The MIC2006 and the MIC2016 both feature Dynamic Load Management (DLM), a novel adaptive current limit which responds to changing system conditions while maintaining the primary fixed current limit. DLM is ideal for systems having dual mode operation (wake and sleep states) where system power supply capabilities vary depending upon operating mode.

The MIC2016 offers an additional unique new feature: Kickstart™, which allows momentary high current surges to pass unrestricted without sacrificing overall system safety.

The MIC2006 and the MIC2016 are offered in space saving 6-pin SOT-23 and 2mm x 2mm MLF packages.

Data sheets and support documentation can be found on Micrel's web site at: www.micrel.com.

Features

- 70mΩ typical on-resistance
- 2.5V - 5.5V operating range
- Pre-set current limit values; 0.5A, 0.8A and 1.2A
- Dynamic Load Management
- Kickstart™
- User adjustable output slew rate control
- Thermal Protection
- Under voltage lock-out
- Adjustable slew rate limited Turn-ON
- Low quiescent current

Applications

- USB / IEEE 1394 Power Distribution
- Desktop and Laptop PCs
- Set top boxes
- Game consoles
- PDAs
- Printers
- Docking stations
- Chargers

Typical Application

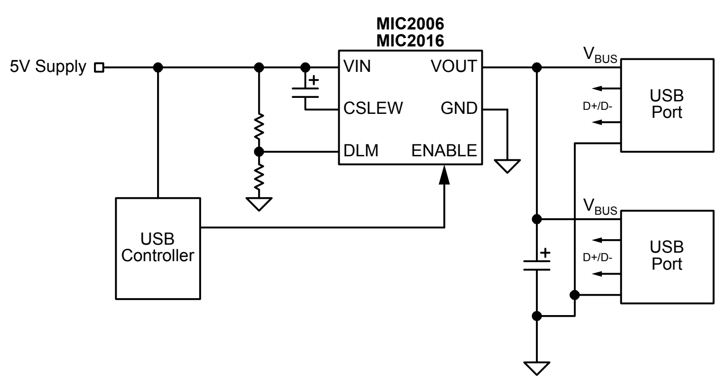


Figure 1. Typical Application Circuit

Kickstart is a trademark of Micrel, Inc
MLF and *Micro*LeadFrame are trademarks of Amkor Technology, Inc.

MIC2000 Family Members

Part Number			Pin Function					
Normal Limiting	Kickstart	I Limit	I Adj.	Enable	C_{SLEW}	FAULT/	DLM*	Load Discharge
2003	2013	**Fixed**	--	--	--	--	--	--
2004	2014		--	▲	--	--	--	▲
2005	2015		--	▲	▲	▲	--	--
2006	2016		--	▲	▲	--	▲	--
2007	2017	**Adj.**	▲	▲	▲	--	--	▲
2008	2018		▲	▲	▲	--	--	--
2009	2019		▲	▲	--	▲	--	--

* Dynamic Load Management   Adj = Adjustable current limit   Fixed = Factory programmed current limit

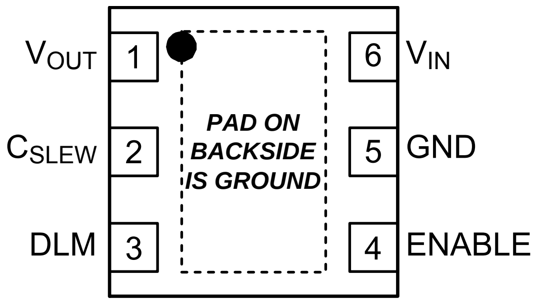
Ordering Information

Part Number	Marking[1]	Current Limit	Kickstart	Pb-Free	Package
MIC2006-0.5YM6	FG05	0.5A	No	Yes	SOT-23-6
MIC2006-0.8YM6	FG08	0.8A			
MIC2006-1.2YM6	FG12	1.2A			
MIC2006-0.5YML[2]	G05	0.5A			2mmX2mm MLF
MIC2006-0.8YML[2]	G08	0.8A			
MIC2006-1.2YML[2]	G12	1.2A			
MIC2016-0.5YM6	FP05	0.5A	Yes		SOT-23-6
MIC2016-0.8YM6	FP08	0.8A			
MIC2016-1.2YM6	FP12	1.2A			
MIC2016-0.5YML[2]	P05	0.5A			2mmX2mm MLF
MIC2016-0.8YML[2]	P09	0.8A			
MIC2016-1.2YML[2]	P12	1.2A			

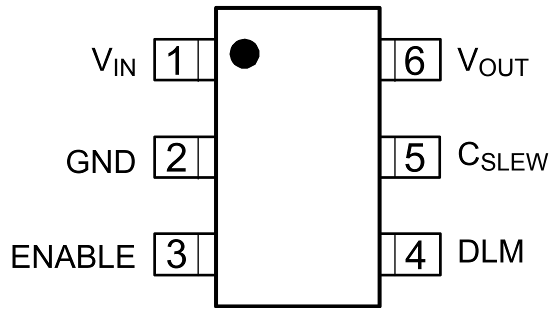
Notes:

1. Under-bar symbol (_) may not be to scale
2. Contact factory for availability.

Pin Configuration



6-Pin 2mm x 2mm MLF (ML)
Top View



SOT 23-6 (M6)
Top View

Pin Description

Pin Number SOT-23	Pin Number MLF	Pin Name	Type	Description
1	6	VIN	Input	Supply input. This pin provides power to both the output switch and the MIC2006/2016's internal control circuitry.
2	5	GND	--	Ground.
3	4	ENABLE	Input	Output enable pin. A logic HIGH activates the output switch, applying power to the load attached to V_{OUT}.
4	3	DLM	Output	Dynamic Load Management. Monitors input voltage through a resistor divider between VIN and GND. Shuts off switch if voltage falls below the threshold set by the resistor divider.
5	2	CSLEW	Input	Slew rate control. Adding a small value capacitor between this pin and VIN slows turn-ON of the power FET.
6	1	VOUT	Output	Switch output. The load being driven by MIC2006/2016 is connected to this pin.

Absolute Maximum RatingsP[1]

V_{IN}, V_{OUT} .... –0.3 to 6V
All other pins .... –0.3 to 5.5V
Power Dissipation .... Internally Limited
Continuous Output Current 2.25A
Maximum Junction Temperature .... 150°C
Storage Temperature .... –65°C to 150°C

Operating Ratings[2]

Supply Voltage .... 2.5V to 5.5V
Continuous Output Current Range .... 0 to 2.1A
Ambient Temperature Range .... –40°C to 85°C

Package Thermal Resistance (θ_{JA})
SOT-23-6 .... 230°C/W
MLF 2mm x2mm .... 90°C/W
MLF 2mm x 2mm θ_{JC} [5] .... 45°C/W

Electrical Characteristics

V_{IN} = 5V, $T_{AMBIENT}$ = 25°C unless specified otherwise. **Bold** indicates –40°C to +85°C limits.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{IN}	Switch Input Voltage		**2.5**		**5.5**	V
I_{IN}	Internal Supply Current	Switch = OFF, ENABLE = 0V		1	**5**	µA
I_{IN}	Internal Supply Current	Switch = ON, I_{OUT} = 0 ENABLE = 1.5V		80	**330**	µA
I_{LEAK}	Output Leakage Current	V_{IN} = 5V, V_{OUT} = 0 V, ENABLE = 0		12	**100**	µA
$R_{DS(ON)}$	Power Switch Resistance	V_{IN} = 5V, I_{OUT} = 100 mA		70	100	mΩ
					125	mΩ
I_{LIMIT}	Current Limit: –0.5	V_{OUT} = 0.8V_{IN}	0.5	0.7	0.9	A
I_{LIMIT}	Current Limit: –0.8	V_{OUT} = 0.8V_{IN}	0.8	1.1	1.5	A
I_{LIMIT}	Current Limit: –1.2	V_{OUT} = 0.8V_{IN}	1.2	1.6	2.1	A
I_{LIMIT_2nd}	Secondary current limit (Kickstart)	MIC2016, V_{IN} = 2.5V	2.2	4	6	A
$DLM_{THRESHOLD}$	Dynamic Load Management threshold		**225**	250	**275**	mV
I_{IN_DLM}	Input Current – DLM pin			1	**10**	µA
V_{EN}	ENABLE Input Voltage	V_{IL}(max.)			**0.5**	V
		V_{IH}(min.)	**1.5**			
I_{EN}	ENABLE Input Current	V_{EN} = 0V to 5.0V		1	**5**	µA
$OT_{THRESHOLD}$	Over-temperature Threshold	T_J increasing		145		°C
		T_J decreasing		135		

AC Characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Units
t_{RISE}	Output turn-ON rise time	R_L = 10Ω, C_{LOAD} = 1µF, V_{OUT} = 10% to 90%	500	1000	1500	µs
t_{D_LIMIT}	Delay before current limiting	MIC2016	**77**	128	**192**	ms
t_{RESET}	Delay before resetting Kickstart current limit delay, t_{D_LIMIT}	Out of current limit following a current limit event. MIC2016	**77**	128	**192**	ms
t_{ON_DLY}	Output Turn-on Delay	R_L = 43Ω, C_L = 120µF, C_{SLEW} ≤ 10pF, V_{EN} = 50% to V_{OUT} = 10%		1000	1500	µs
t_{OFF_DLY}	Output Turn-off Delay	R_L = 43Ω, C_L = 120µF, C_{SLEW} ≤ 10pF, V_{EN} = 50% to V_{OUT} = 90%			700	µs
t_{DLY_DLM}	Delay before disengaging load		**20**	32	**49**	ms
t_{OFF_DLM}	OFF time after disengaging load		**77**	128	**192**	ms

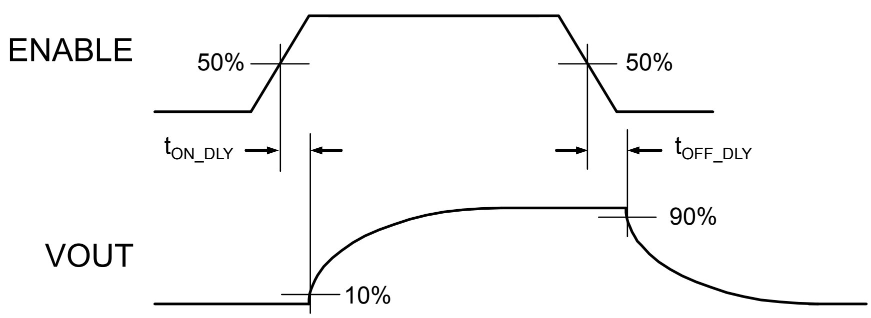
ESD

Symbol	Parameter	Condition	Min	Typ	Max	Units
V_{ESD_HB}	Electro Static Discharge Voltage: Human Body Model	V_{OUT} and GND	± 4			kV
		All other pins	± 2			kV
V_{ESD_MCHN}	Electro Static Discharge Voltage; Machine Model	All pins Machine Model	± 200			V

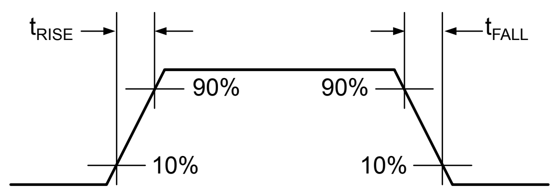
Notes:

1. Exceeding the absolute maximum rating may damage the device.
2. The device is not guaranteed to function outside its operating rating.
3. Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5k in series with 100pF.
4. Specification for packaged product only.
5. Requires proper thermal mounting to achieve this performance.

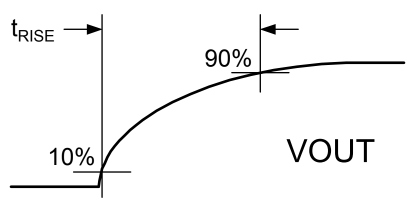
Timing Diagrams



Switching Delay Times



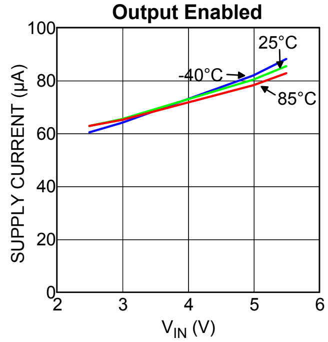
Rise and Fall Times



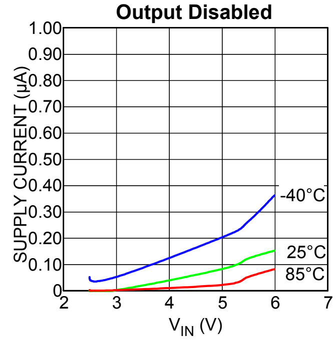
Output Rise Time

Typical Characteristics

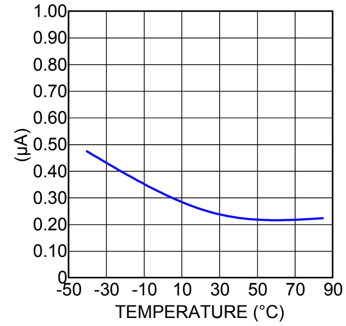
Supply Current Output Enabled



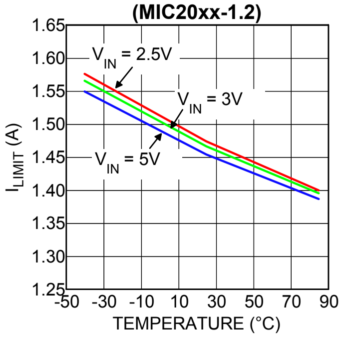
Supply Current Output Disabled



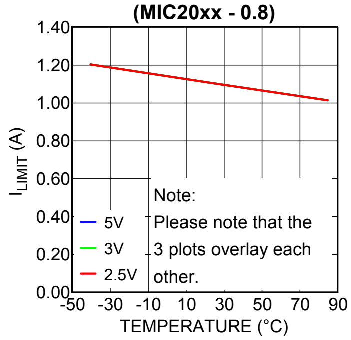
Switch Leakage Current - OFF



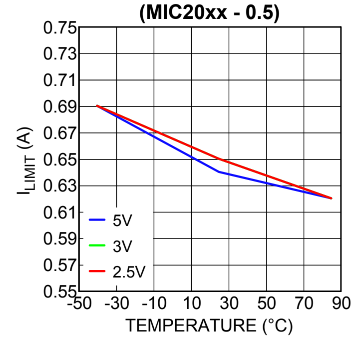
I_{LIMIT} vs. Temperature (MIC20xx-1.2)



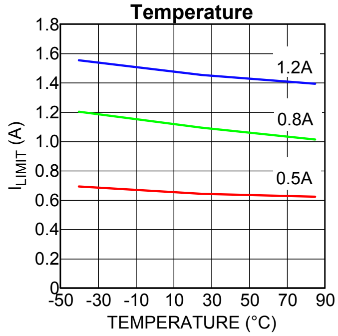
I_{LIMIT} vs. Temperature (MIC20xx - 0.8)



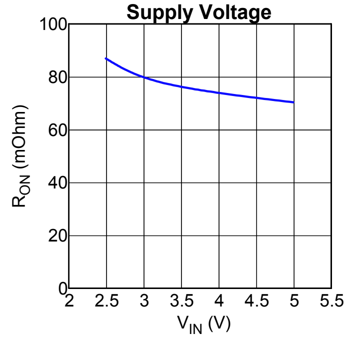
I_{LIMIT} vs. Temperature (MIC20xx - 0.5)



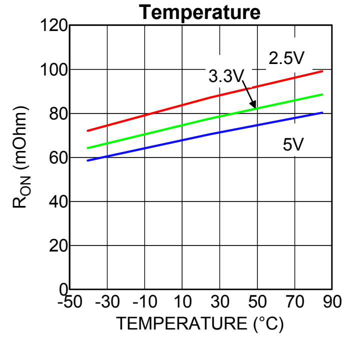
I_{LIMIT} vs. Temperature



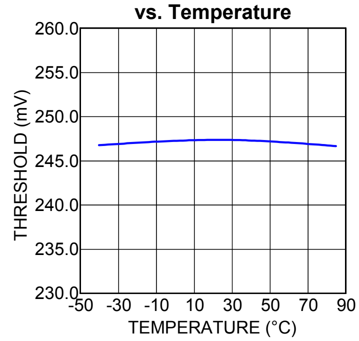
R_{ON} vs. Supply Voltage



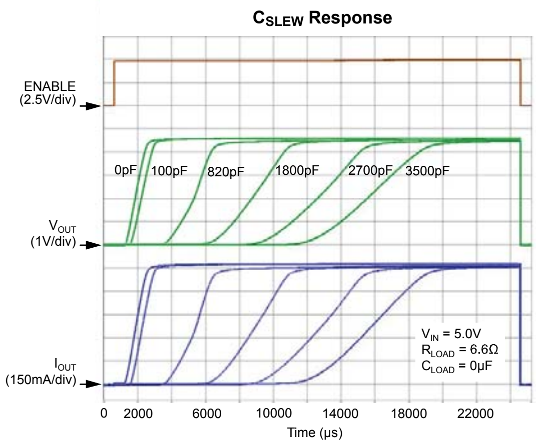
R_{ON} vs. Temperature

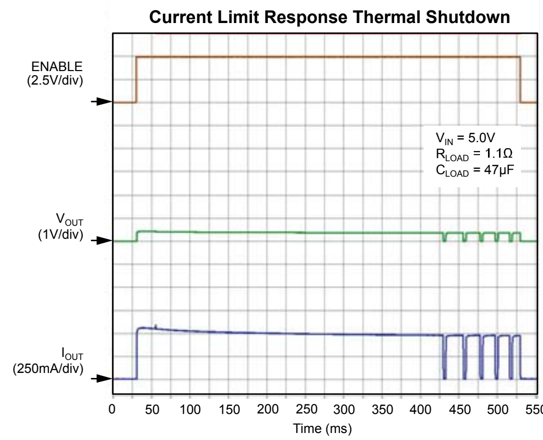


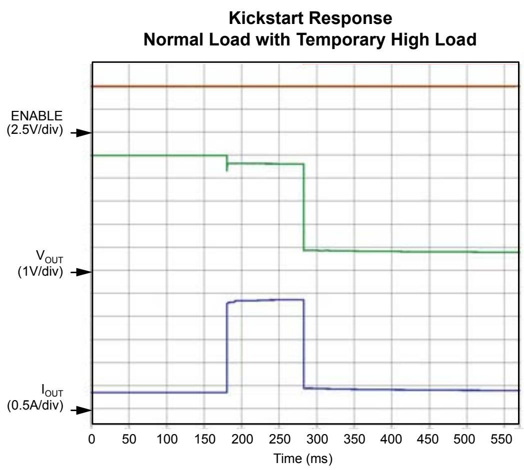
DLM Threshold vs. Temperature

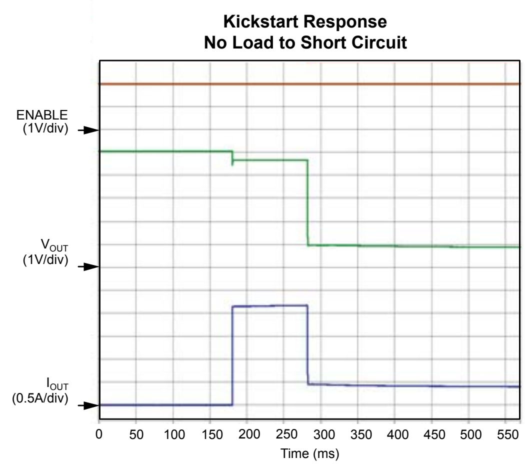


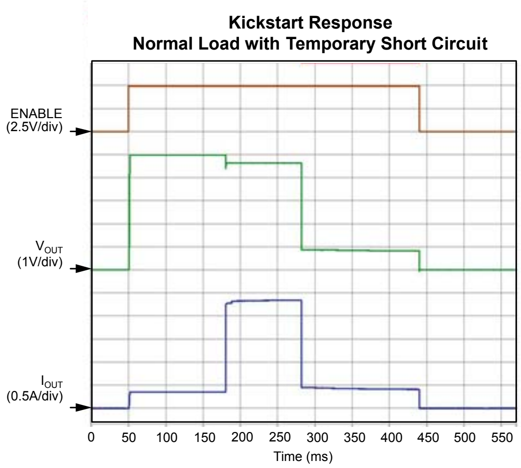
Functional Characteristics

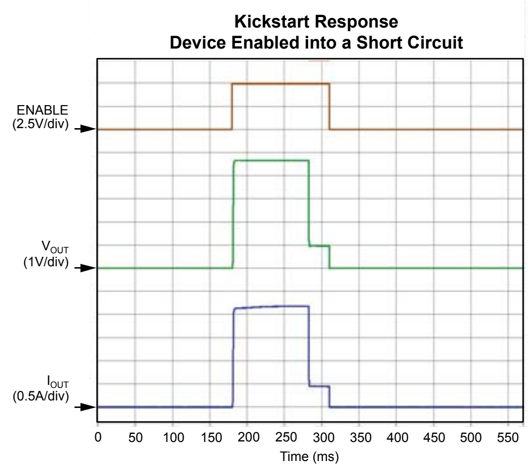


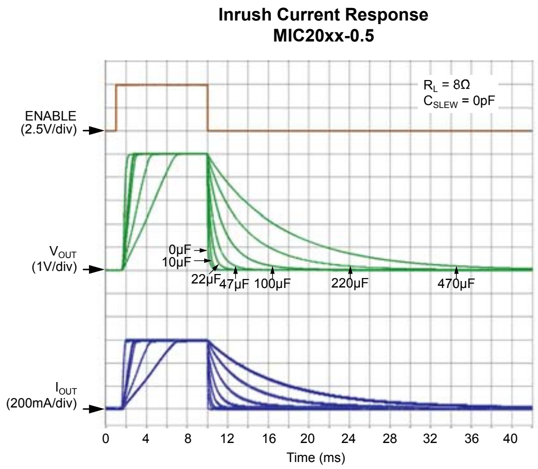


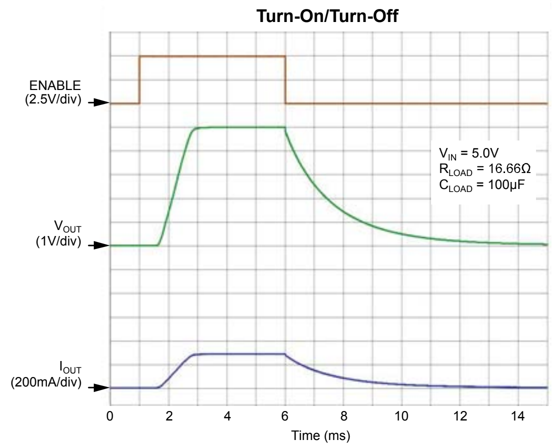


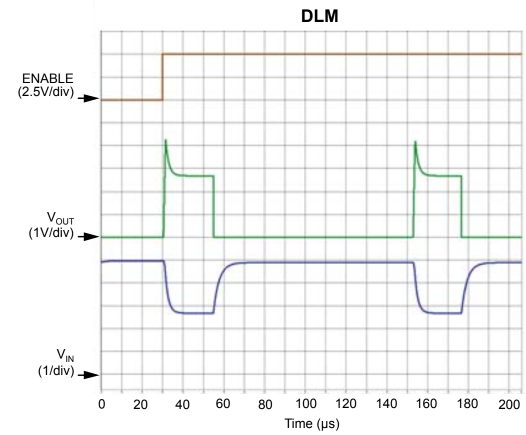







Inrush Current Response
MIC20xx-0.5
R_L = 8Ω
C_{SLEW} = 0pF
ENABLE
(2.5V/div)
V_{OUT}
(1V/div)
0µF
10µF
22µF
47µF
100µF
220µF
470µF
I_{OUT}
(200mA/div)
0 4 8 12 16 20 24 28 32 36 40
Time (ms)


Turn-On/Turn-Off
ENABLE
(2.5V/div)
V_{IN} = 5.0V
R_{LOAD} = 16.66Ω
C_{LOAD} = 100µF
V_{OUT}
(1V/div)
I_{OUT}
(200mA/div)
0 2 4 6 8 10 12 14
Time (ms)


DLM
ENABLE
(2.5V/div)
V_{OUT}
(1V/div)
V_{IN}
(1/div)
0 20 40 60 80 100 120 140 160 180 200
Time (µs)

Functional Diagram

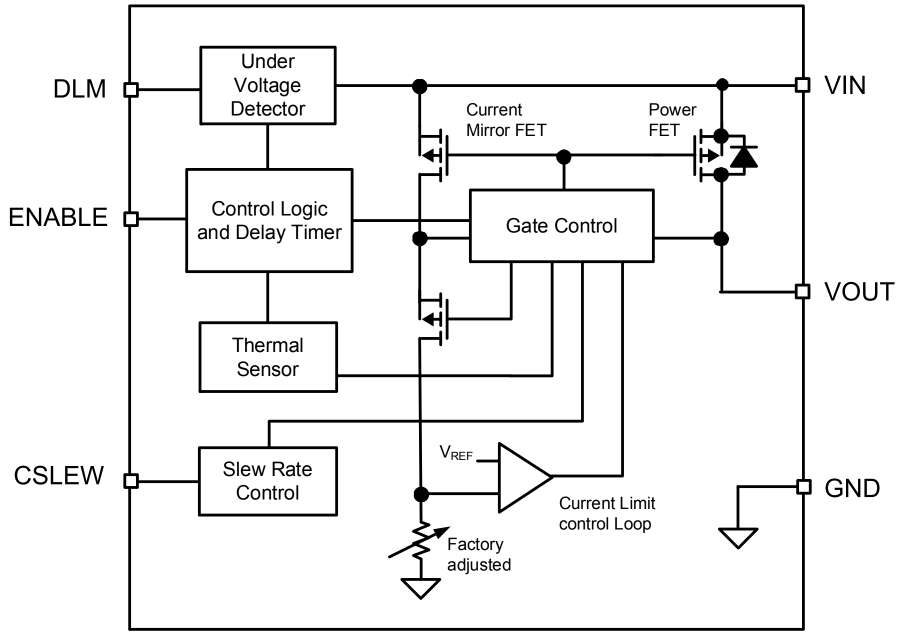


Figure 2. MIC2006/2016 Block Diagram

Functional Description

Input and Output

V_{IN} is both the power supply connection for the internal circuitry driving the switch and the input (Source connection) of the power MOSFET switch. V_{OUT} is the Drain connection of the power MOSFET and supplies power to the load. In a typical circuit, current flows from V_{IN} to V_{OUT} toward the load. Since the switch is bi-directional when enabled, if V_{OUT} is greater than V_{IN}, current will flow from V_{OUT} to V_{IN}.

When the switch is disabled, current will not flow to the load, except for a small unavoidable leakage current of a few microamps. However, should V_{OUT} exceed V_{IN} by more than a diode drop (~0.6V), while the switch is disabled, current will flow from output to input via the power MOSFET's body diode. This effect can be used to advantage when large bypass capacitors are placed on MIC2006/2016's's output. When power to the switch is removed, the output capacitor will be automatically discharged.

If discharging C_{LOAD} is required by your application, consider using the MIC2004/2014 or the MIC2007/2017 in place of the MIC2006/2016. These MIC2000 family members are equipped with a discharge FET to insure complete discharge of C_{LOAD}.

Current Sensing and Limiting

The MIC2006/2016 protects the system power supply and load from damage by continuously monitoring current through the on-chip power MOSFET. Load current is monitored by means of a current mirror in parallel with the power MOSFET switch. Current limiting is invoked when the load exceeds an internally set over-current threshold. When current limiting is activated, the output current is constrained to the limit value, and remains at this level until either the load/fault is removed, the load's current requirement drops below the limiting value, or the MIC2006/2016 goes into thermal shutdown.

Kickstart (MIC2016 only)

The MIC2016 is designed to allow momentary current surges (Kickstart) before the onset of current limiting, which permits dynamic loads, such as small disk drives or portable printers to draw the energy needed to overcome inertial loads without sacrificing system safety. In this respect, the MIC2016 differs markedly from MIC2006 and its peers, which immediately limit load current, potentially starving the motor and causing the appliance to stall or stutter.

During this delay period, typically 128 ms, a secondary current limit is in effect. If the load demands a current in excess of the secondary limit, MIC2016 acts immediately to restrict output current to the secondary limit for the duration of the Kickstart period. After this time, the MIC2016 reverts to its normal current limit. An example of Kickstart operation is shown below.

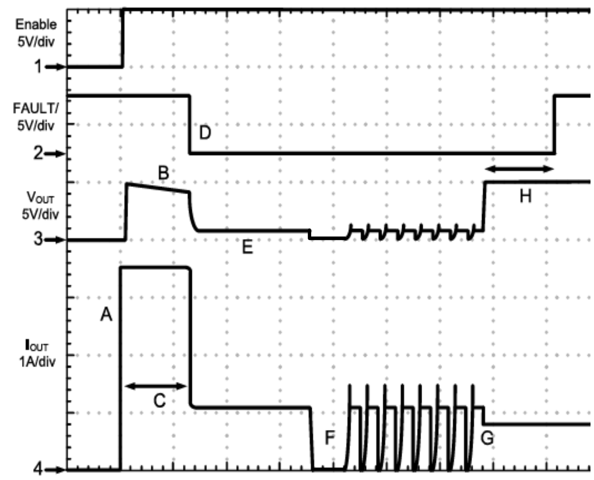


Figure 3. Kickstart Operation

Picture Key:

A) MIC2016 is enabled into an excessive load (slew rate limiting not visible at this time scale) The initial current surge is limited by either the overall circuit resistance and power supply compliance, or the secondary current limit, whichever is less.

B) R_{ON} of the power FET increases due to internal heating (effect exaggerated for emphasis).

C) Kickstart period.

D) Current limiting initiated. FAULT/ goes LOW (Note: FAULT/ output not available on MIC2016).

E) V_{OUT} is non-zero (load is heavy, but not a dead short where V_{OUT} = 0. Limiting response will be the same for dead shorts).

F) Thermal shutdown followed by thermal cycling.

G) Excessive load released, normal load remains. MIC201x drops out of current limiting.

H) FAULT/ delay period followed by FAULT/ going HIGH (FAULT/ output not available on MIC2016).

Dynamic Load Management (DLM)

Dynamic Load Management functions as a second current limit by monitoring the VIN pin and watching for a drop in voltage, indicating excessive loading of the supply. When detected MIC2006/2016 disengages the load to protect the supply and allow VIN to recover. After 128 ms has elapsed, the MIC2006/2016 re-engages the load and monitors VIN. If VIN drops again, then the

MIC2006/2019 will disengage the load and wait another 128 ms before reconnecting. The MIC2006/2016 will continue to cycle the load until either Enable → Low, the offending load is removed or sufficient power becomes available to support the load without VIN sagging.

Enable

ENABLE is a HIGH true control signal, which activates the main MOSFET switch. ENABLE will operate with logic running from supply voltages as low as 1.8V. ENABLE can be wire-OR'd with other MIC2006/2016s or similar devices without damage to the device.

ENABLE may be driven higher than V_{IN}, but no higher than 5.5V.

Slew Rate Control

Large capacitive loads can create significant current surges when charged through a high-side switch such as the MIC2006/2016. For this reason, MIC2006/2016 provides built-in slew rate control to limit the initial inrush currents upon enabling the power MOSFET switch.

Slew rate control is active upon powering up, and upon re-enabling the load. At shutdown, the discharge slew rate is controlled by the external load and output capacitor.

On the MIC2006/2016 Slew Rate is adjustable and can be further reduced by adding an external capacitance between VIN and the CSLEW pins.

Thermal Shutdown

Thermal shutdown is employed to protect the MIC2006/2016 from damage should the die temperature exceed safe operating levels. Thermal shutdown shuts off the output MOSFET if the die temperature reaches 145°C.

The MIC2006/2016 will automatically resume operation when the die temperature cools down to 135°C. If resumed operation results in reheating of the die, another shutdown cycle will occur and the MIC2006/2016 will continue cycling between ON and OFF states until the offending load has been removed.

Depending upon PCB layout, package type, ambient temperature, etc., hundreds of milliseconds may elapse from the incidence of a fault to the output MOSFET being shut off. This delay is due to thermal time constants within the system itself. In no event will the device be damaged due to thermal overload because die temperature is monitored continuously by on-chip circuitry.

Application Information

I_{LIMIT} vs. I_{OUT} measured

The MIC2006/2016's current limiting circuitry is designed to act as a constant current source to the load. As the load tries to pull more than the allotted current, V_{OUT} drops and the input to output voltage differential increases. When V_{IN} -V_{OUT} exceeds 1V, I_{OUT} drops below I_{LIMIT} to reduce the drain of fault current on the system's power supply and to limit internal heating of MIC2006/2016.

When measuring I_{OUT} it is important to bear this voltage dependence in mind, otherwise the measurement data may appear to indicate a problem when none really exists. This voltage dependence is illustrated in Figures 4 and 5.

In Figure 4, output current is measured as V_{OUT} is pulled below V_{IN}, with the test terminating when V_{OUT} is 1V below V_{IN}. Observe that once I_{LIMIT} is reached I_{OUT} remains constant throughout the remainder of the test. In Figure 5 this test is repeated but with V_{IN} - V_{OUT} exceeding 1V.

When V_{IN} - V_{OUT} > 1V, MIC2006/2016's current limiting circuitry responds by decreasing I_{OUT}, as can be seen in Figure 5. In this demonstration, V_{OUT} is being controlled and I_{OUT} is the measured quantity. In real life applications V_{OUT} is determined in accordance with Ohm's law by the load and the limiting current.

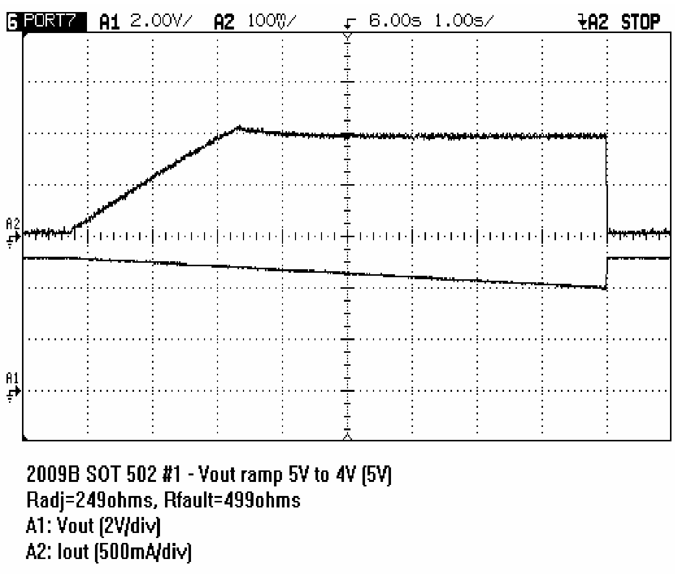


Figure 4. I_{OUT} in Current Limiting for V_{IN} - $V_{OUT} \leq 1V$

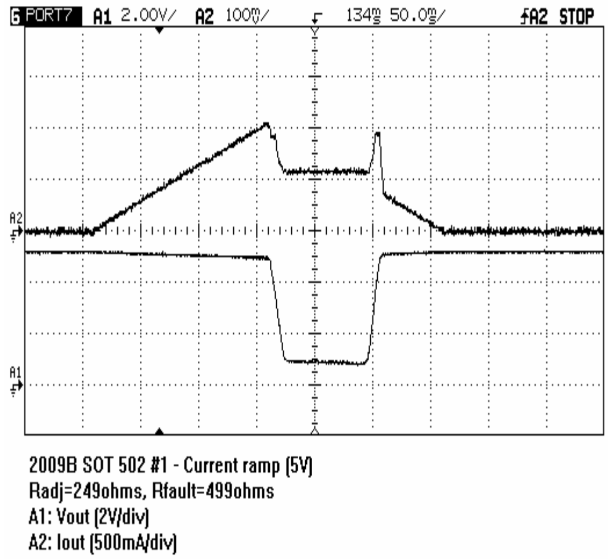


Figure 5. I_{OUT} in Current Limiting for V_{IN} - V_{OUT} >1V

This folding back of I_{LIMIT} can be generalized by plotting I_{LIMIT} as a function of V_{OUT}, as shown below. The slope of V_{OUT} between I_{OUT} = 0 and I_{OUT} = I_{LIMIT} (where I_{LIMIT} = 1) is determined by R_{ON} of MIC2006/2016 and I_{LIMIT}.

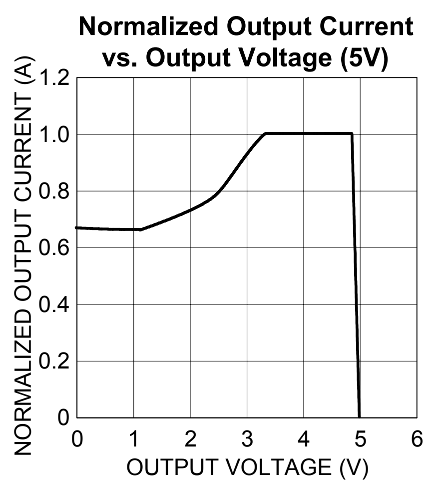


Figure 6. Caption?

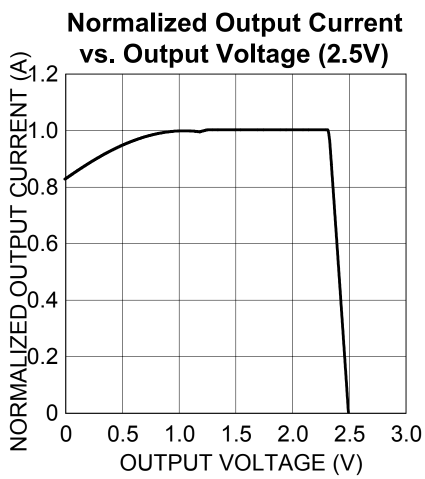


Figure 7. Caption?

C_{SLEW}

The CSLEW input is provided to increase control of the output voltage ramp at turn-on. This input allows designers the option of decreasing the output's slew rate (slowing the voltage rise) by adding an external capacitance between the pin, CSLEW, and VIN. This capacitance slows the rate at which the pass FET gate voltage increases and thus, slows both the response to an Enable command as well as V_{OUT}'s ascent to its final value.

Figure 8 illustrates effect of C_{SLEW} on turn-ON delay and output rise time.

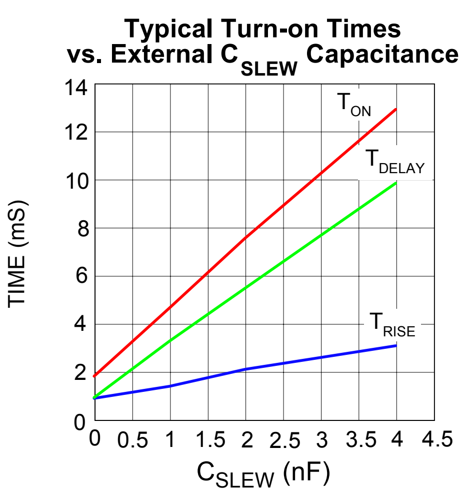


Figure 8. Caption?

C_{SLEW}'s effect on I_{LIMIT}

An unavoidable consequence of adding C_{SLEW} capacitance is a reduction in MIC2006/2016's ability to quickly limit current transients or surges. A sufficiently large capacitance can prevent the both the primary and secondary current limits from acting in time to prevent damage to MIC2006/2016 or the system from a short circuit fault. For this reason, the upper limit on the value of C_{SLEW} is 4nF.

Dynamic Load Management (DLM)

Power conscious systems, such as those implementing ACPI, will remain active even in their low power states and may require the support of external devices through both phases of operation. Under these conditions, the current allowed these external devices may vary according to the system's operating state and as such require dual current limits on their peripheral ports. The MIC2006/2016 is designed for systems demanding two primary current limiting levels but without the use of a control signal to select between current limits.

To better understand how the MIC2006/2016 provides this, imagine a system whose main power supply supports multi amp loads during normal operation, but in sleep mode is reduced to only few hundred milliamps of output current. In addition, this system has several USB ports which must remain active during sleep. In normal operation, each port can support a 500mA peripheral, but in sleep mode their combined output current is limited to what the power supply can deliver minus whatever the system itself is drawing.

If a peripheral device is plugged in which demands more current than is available, the system power supply will sag, or crash. The MIC2006/2016 prevents this by monitoring both the load current and V_{IN}. During normal operation, when the power supply can source plenty of current, the MIC2006/2016 will support any load up to its factory programmed current limit. When the weaker, standby supply is in operation, the MIC2006/2016 monitors V_{IN} and will shut off its output should V_{IN} dip below a predetermined value. This predetermined voltage is user programmable and set by the selection of the resistor divider driving the DLM pin.

To prevent false triggering of the DLM feature, the MIC2006/2016 includes a delay timer to blank out momentary excursions below the DLM trip point. If V_{IN} stays below the DLM trip point for longer than 32ms (typical), then the load is disengaged and the MIC2006/2016 will wait 128ms before reapplying power to the load. If V_{IN} remains below the DLM trip point, then the load will be powered for the 32ms blanking period and then again disengaged. This is illustrated in the scope plot below. If V_{IN} remains above the DLM trip point MIC2006/2016 resumes normal operation.

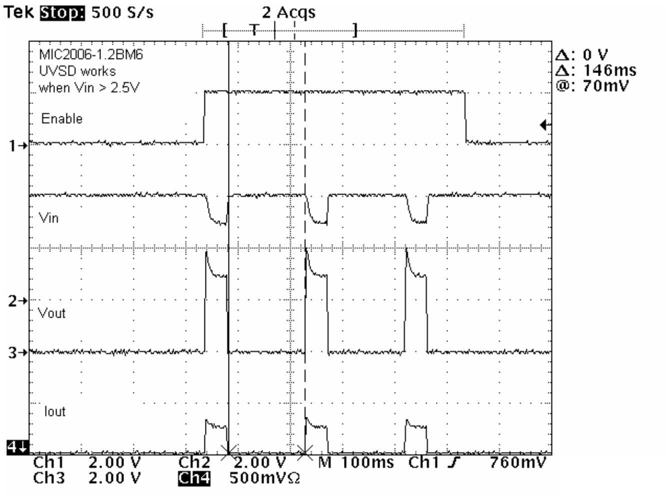
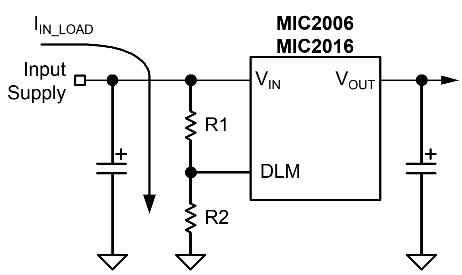


Figure 9. DLM Operation

DLM and Kickstart operate independently in the MIC2016. If the high current surge allowed by Kickstart causes V_{IN} to dip below the DLM trip point for more than 32ms, DLM will disengage the load even though the Kickstart timer has not timed out.

Calculating DLM resistor divider values



Selection of R_1 and R_2 is driven by the input voltage at which DLM should go into effect and the allowed loading of the input supply. The DLM comparator has a CMOS input and as such applies minimal loading to the resistor divider. For this reason its effect can be ignored for all practical values of R_1 and R_2. Starting with the loading requirements:

$$I_{IN\_LOAD} = \frac{V_{IN\_MAX}}{(R_2 + R_1)}$$

And then the DLM trip voltage as it relates to the comparator threshold and the resistor divider:

$$V_{DLM\_THRESHOLD} = \frac{V_{TRIP} \times R_2}{(R_2 + R_1)}$$

Rearranging these:

$$(R_2 + R_1) = \frac{V_{IN\_MAX}}{I_{IN\_LOAD}} \text{ and}$$

$$R2 = \frac{V_{DLM\_THRESHOLD} \times (R_2 + R_1)}{V_{TRIP}}$$

Then substituting:

$$R_2 = \frac{V_{DLM\_THRESHOLD} \times V_{IN\_MAX}}{V_{TRIP} \times I_{IN\_LOAD}}$$

Putting some real life values to this:

V_{TRIP} = 4.75V for a nominal 5V supply.

V_{IN_MAX} = 5.25V for a nominal 5V supply.

I_{IN_Load} = 100µA.

Then from the Electrical specifications we find:

$V_{DLM\_Threshold}$.= 250mV.

Substituting these values into the equation above:

$$R_2 = \frac{250mV \times 5.25V}{4.75 \times 100\mu A} \text{ or}$$

R_2 = 2.76kΩ

Then solving for R_1

$$(R_2 + R_1)\frac{V_{IN\_MAX}}{I_{IN\_LOAD}} = \frac{5.25V}{100\mu A} = 52.5k\Omega$$

R_1 = (52.5kΩ -2.76kΩ) = 49.7kΩ

I_{IN_LOAD} 100µA

In this example we have used the nominal value of $V_{DLM\_Threshold}$. By substituting in the min and max values of $V_{DLM\_Threshold}$,R1 and R2 the DLM trip point window can be established.

The DLM comparator uses no hysteresis. This is because the DLM blanking timer prevents any chattering that might otherwise occur if V_{IN} fluxuates about the trigger point. The timer is reset by upward crossings of the trip point such that V_{IN} must remain below the trip point for the full 32ms period for load disengagement to occur.

In selecting a DLM trigger voltage the designer is cautioned to not make this value less than 2.5V. A minimum of 2.5V is required for the MIC2006/2016's internal circuitry to operate properly. DLM tip points below 2.5V will result in erratic or unpredictable operation.

Kickstart (MIC2016)

Kickstart allows brief current surges to pass to the load before the onset of normal current limiting, which permits dynamic loads to draw bursts of energy without sacrificing system safety.

Functionally, Kickstart is a forced override of the normal current limiting function provided by the MIC2016. The Kickstart period is governed by an internal timer which allows current to pass unimpeded to the load for 128ms and then normal (primary) current limiting goes into action.

During Kickstart, a secondary current limiting circuit monitors output current to prevent damage to the the MIC2016, as a hard short combined with a robust power supply can result in currents of many tens of amperes. This secondary current limit is nominally set at 4 Amps and reacts immediately and independently of the Kickstart period. Once the Kickstart timer has finished its count, then the primary current limiting circuit takes over and holds I_{OUT} to its programmed limit for as long as the excessive load persists.

Once MIC2016 drops out of current limiting the Kickstart timer initiates a lock-out period of 128ms such that no further bursts of current above the primary current limit, will be allowed until the lock-out period has expired.

Kickstart may be over-ridden by the thermal protection circuit and if sufficient internal heating occurs, Kickstart will be terminated and $I_{OUT} \rightarrow 0$. Upon cooling, if the load is still present $I_{OUT} \rightarrow I_{LIMIT}$, not $I_{KICKSTART}$.

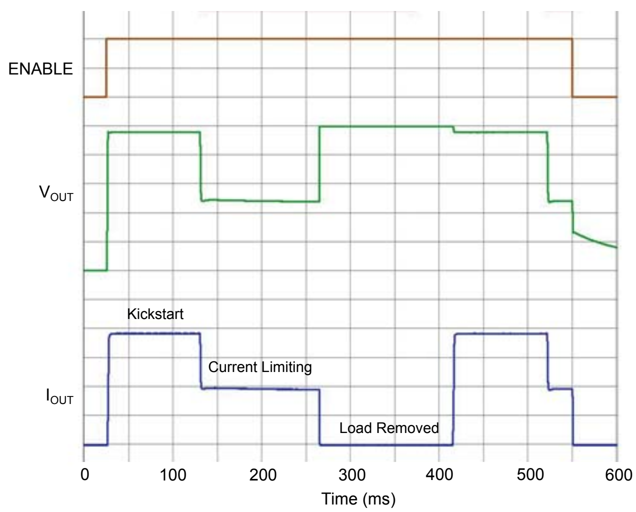


Figure 9. Kickstart

Supply Filtering

A 0.1µF to 1µF bypass capacitor positioned close to the V_{IN} and GND pins of MIC2006/2016 is both good design practice and required for proper operation of MIC2006/2016. This will control supply transients and ringing. Without a bypass capacitor, large current surges or an output short may cause sufficient ringing on V_{IN} (from supply lead inductance) to cause erratic operation of MIC2006/2016's control circuitry. Good quality, low ESR capacitors, such as Panasonic's TE or ECJ series, are suggested.

When bypassing with capacitors of 10µF and up, it is good practice to place a smaller value capacitor in parallel with the larger to handle the high frequency components of any line transients. Values in the range of 0.01µF to 0.1µF are recommended. Again, good quality, low ESR capacitors should be chosen.

Power Dissipation

Power dissipation depends on several factors such as the load, PCB layout, ambient temperature, and supply voltage. Calculation of power dissipation can be accomplished by the following equation:

$$P_D = R_{DS(ON)} \times (I_{OUT})^2$$

To relate this to junction temperature, the following equation can be used:

$$T_J = P_D \times R_{\theta(J\text{-}A)} + T_A$$

Where: T_J = junction temperature,

T_A = ambient temperature

$R_{\theta(J\text{-}A)}$ is the thermal resistance of the package

In normal operation, the MIC2006/2016's Ron is low enough that no significant I^2R heating occurs. Device heating is most often caused by a short circuit, or very heavy load, when a significant portion of the input supply voltage appears across the MIC2006/2016's power MOSFET. Under these conditions, the heat generated will exceed the package and PCB's ability to cool the device and thermal limiting will be invoked.

In Figure 10, die temperature is plotted against I_{OUT} assuming a constant case temperature of 85°C. The plots also assume a worst case R_{ON} of 140 mΩ at a die temperature of 135°C. Under these conditions, it is clear that an SOT-23 packaged device will be on the verge of thermal shutdown, typically 145°C die temperature, when operating at a load current of 1.25A. For this reason, it is recommend that a MLF package be used for any MIC2006/2016s designs intending to supply continuous currents of 1A or more.

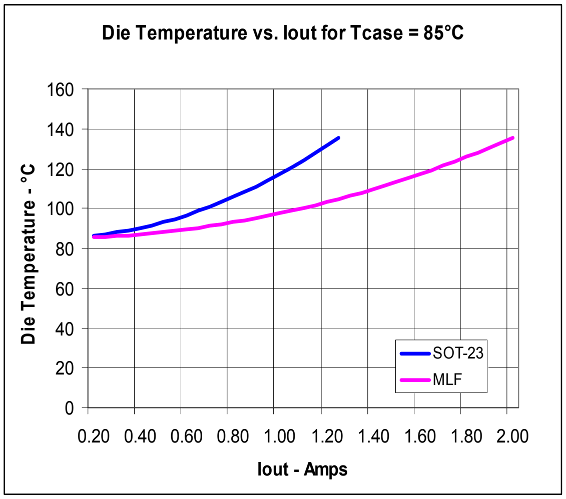


Figure 10. Die Temperature vs. I_{OUT}

Figure 10 assumes no backside contact is made to the thermal pad provided on the MLF package. For optimal performance at higher current levels, or in higher temperature environments, thermal contact with the PCB and the exposed power paddle on the back side of the MLF package should be made. This significantly reduces the package's thermal resistance and thus extends the MIC2006/2016's operating range. It should be noted that this backside paddle is electrically active and is connected to MIC2006/2016's GND pin.

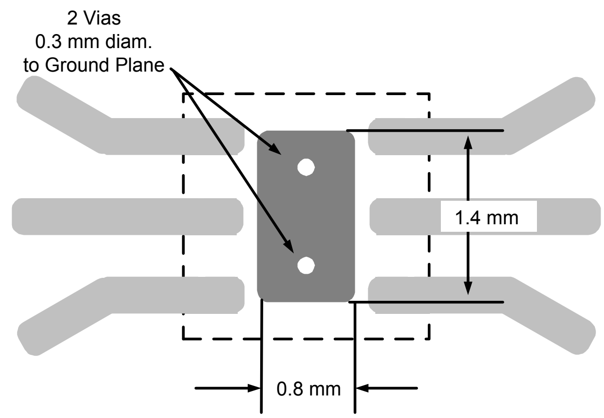
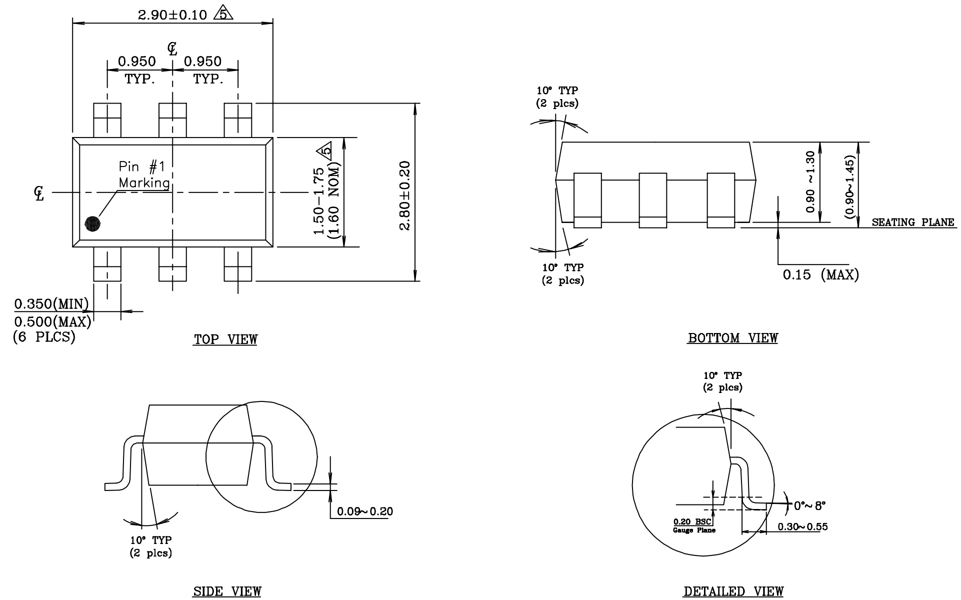
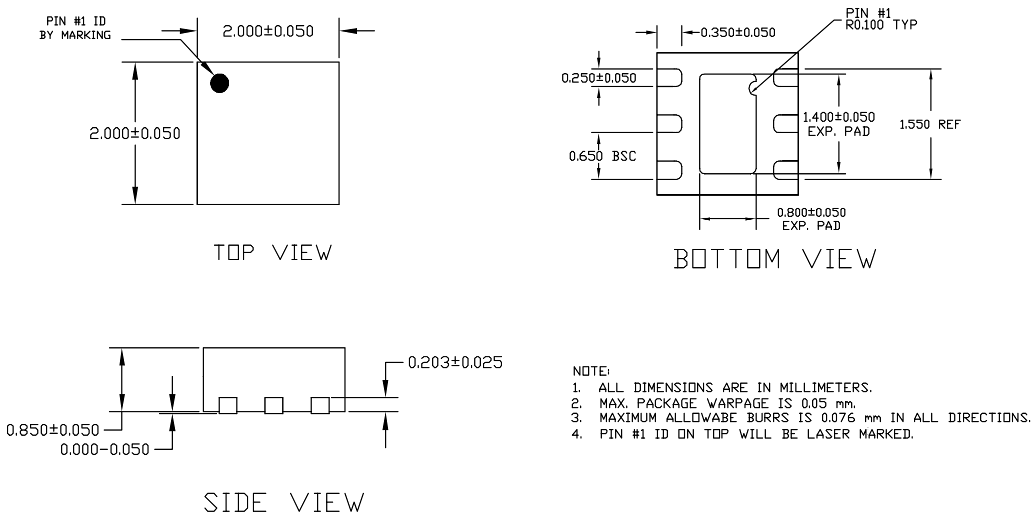


Figure 11. Pad for thermal mounting to PCB

Package Information



6-Pin SOT-23 (M6)



6 Pin 2mmX2mm MLF (ML)

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