General Description

The MIC94080/1/2/3/4/5 is a family of high-side load switches designed to operate from 1.7V to 5.5V input voltage. The load switch pass element is an internal 67mΩ $R_{DSON}$ P-Channel MOSFET which enables the device to support up to 2A of continuous current. Additionally, the load switch supports 1.5V logic level control and shutdown features in a tiny 0.85mm x 0.85mm 4-pin Thin MLF® package.

The MIC94080 and MIC94081 feature rapid turn on. The MIC94082 and MIC94083 provide a slew rate controlled soft-start turn-on of 800µs, while the MIC94084 and MIC94085 provide a slew rate controlled soft-start turn-on of 120µs. The soft-start feature is provided to prevent an in-rush current event from pulling down the input supply voltage.

The MIC94081, MIC94083, and MIC94085 feature an active load discharge circuit which switches in a 250Ω load when the switch is disabled to automatically discharge a capacitive load.

An active pull-down on the enable input keeps the MIC94080/1/2/3/4/5 in a default OFF state until the enable pin is pulled above 1.25V. Internal level shift circuitry allows low voltage logic signals to switch higher supply voltages. The enable voltage can be as high as 5.5V and is not limited by the input voltage.

The MIC94080/1/2/3/4/5 operating voltage range makes them ideal for Lithium ion and NiMH/NiCad/Alkaline battery powered systems, as well as non-battery powered applications. The devices provide low quiescent current and low shutdown current to maximize battery life.

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

Features

- 0.85mm x 0.85mm space saving 4-pin Thin MLF® package
- 1.7V to 5.5V input voltage range
- 2A continuous operating current
- 67mΩ $R_{DSON}$
- Internal level shift for CMOS/TTL control logic
- Ultra low quiescent current
- Micro-power shutdown current
- Soft-Start: MIC94082/3 (800µs), MIC94084/5 (120µs)
- Load discharge circuit: MIC94081, MIC94083, MIC94085
- Ultra fast turn off time
- Junction operating temperature from -40ºC to +125ºC

Applications

- Cellular phones
- Portable Navigation Devices (PND)
- Personal Media Players (PMP)
- Ultra Mobile PCs
- Portable instrumentation
- Other Portable applications
- PDAs
- GPS Modules
- Industrial and DataComm equipment

Typical Application

![Typical Application Diagram](image_url)
### Ordering Information

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Part Marking</th>
<th>Fast Turn On</th>
<th>Soft-Start</th>
<th>Load Discharge</th>
<th>Package(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIC94080YFT</td>
<td>C1</td>
<td>•</td>
<td></td>
<td></td>
<td>4-Pin 0.85mm x 0.85mm Thin MLF®</td>
</tr>
<tr>
<td>MIC94081YFT</td>
<td>C2</td>
<td>•</td>
<td></td>
<td>•</td>
<td>4-Pin 0.85mm x 0.85mm Thin MLF®</td>
</tr>
<tr>
<td>MIC94082YFT</td>
<td>C5</td>
<td>800µs</td>
<td></td>
<td></td>
<td>4-Pin 0.85mm x 0.85mm Thin MLF®</td>
</tr>
<tr>
<td>MIC94083YFT</td>
<td>C7</td>
<td>800µs</td>
<td></td>
<td>•</td>
<td>4-Pin 0.85mm x 0.85mm Thin MLF®</td>
</tr>
<tr>
<td>MIC94084YFT</td>
<td>C0</td>
<td>120µs</td>
<td></td>
<td></td>
<td>4-Pin 0.85mm x 0.85mm Thin MLF®</td>
</tr>
<tr>
<td>MIC94085YFT</td>
<td>1C</td>
<td>120µs</td>
<td></td>
<td>•</td>
<td>4-Pin 0.85mm x 0.85mm Thin MLF®</td>
</tr>
</tbody>
</table>

Notes:
1. Thin MLF® is a GREEN RoHS-compliant package. Lead finish is NiPdAu. Mold compound is Halogen Free.

### Pin Configuration

4-Pin (0.85mm x 0.85mm) Thin MLF®

*(Top View)*

Example Showing Orientation of Part Marking

### Pin Description

<table>
<thead>
<tr>
<th>Pin Number</th>
<th>Pin Name</th>
<th>Pin Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>V&lt;sub&gt;OUT&lt;/sub&gt;</td>
<td>Drain of P-Channel MOSFET.</td>
</tr>
<tr>
<td>2</td>
<td>GND</td>
<td>Ground should be connected to electrical ground.</td>
</tr>
<tr>
<td>3</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;</td>
<td>Source of P-Channel MOSFET.</td>
</tr>
<tr>
<td>4</td>
<td>EN</td>
<td>Enable (Input): Active-high CMOS/TTL control input for switch. Internal ~2MΩ Pull down resistor. Output will be off if this pin is left floating.</td>
</tr>
</tbody>
</table>
Absolute Maximum Ratings

- Input Voltage ($V_{IN}$) .................................................. +6V
- Enable Voltage ($V_{EN}$) ............................................... +6V
- Continuous Drain Current ($I_D$) (3)
  - $T_A = 25^\circ C$ .................................................. ±2A
  - $T_A = 85^\circ C$ .................................................. ±1.5A
- Pulsed Drain Current ($I_{DP}$) (4) .................................. ±6.0A
- Continuous Diode Current ($I_S$) .................................. –50mA
- Storage Temperature ($T_S$) ........................................ –55°C to +150°C
- ESD Rating – HBM(6) ........................................... 3kV

Operating Ratings

- Input Voltage ($V_{IN}$) .................................................. +1.7 to +5.5V
- Junction Temperature ($T_J$) ........................................ –40°C to +125°C
- Package Thermal Resistance
  - 0.85mm x 0.85mm Thin MLF®
    - ($\theta_{JA}$) .............................................. 140°C/W
    - ($\theta_{JC}$) .............................................. 85°C/W

Electrical Characteristics

$T_A = 25^\circ C$, bold values indicate –40°C < $T_A$ ≤ +85°C, unless noted.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Condition</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{EN,TH}$</td>
<td>Enable Threshold Voltage</td>
<td>$V_{IN} = 1.7V$ to 4.5V, $I_D = -250\mu A$</td>
<td>0.4</td>
<td>1.25</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$I_Q$</td>
<td>Quiescent Current</td>
<td>$V_{IN} = V_{EN} = 5.5V$, $I_D = OPEN$</td>
<td>0.1</td>
<td>1</td>
<td>µA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Measured on $V_{IN} MIC94080/1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{EN}$</td>
<td>Enable Input Current</td>
<td>$V_{IN} = V_{EN} = 5.5V$, $I_D = OPEN$</td>
<td>2.8</td>
<td>4</td>
<td>µA</td>
<td></td>
</tr>
<tr>
<td>$I_{SHUT-Q}$</td>
<td>Quiescent Current (shutdown)</td>
<td>$V_{IN} = +5.5V$, $V_{EN} = 0V$, $I_D = OPEN$</td>
<td>0.02</td>
<td>1</td>
<td>µA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Measured on $V_{IN}$ (7)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$I_{SHUT-SWITCH}$</td>
<td>OFF State Leakage Current</td>
<td>$V_{IN} = +5.5V$, $V_{EN} = 0V$, $I_D = SHORT$</td>
<td>0.02</td>
<td>1</td>
<td>µA</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Measured on $V_{OUT}$ (7)</td>
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<td></td>
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<tr>
<td>$R_{DS(ON)}$</td>
<td>P-Channel Drain to Source ON Resistance</td>
<td>$V_{IN} = +5.0V$, $I_D = -100mA$, $V_{EN} = 1.5V$</td>
<td>67</td>
<td>115</td>
<td>mΩ</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>$V_{IN} = +4.5V$, $I_D = -100mA$, $V_{EN} = 1.5V$</td>
<td>70</td>
<td>130</td>
<td>mΩ</td>
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<tr>
<td></td>
<td></td>
<td>$V_{IN} = +3.6V$, $I_D = -100mA$, $V_{EN} = 1.5V$</td>
<td>80</td>
<td>165</td>
<td>mΩ</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>$V_{IN} = +2.5V$, $I_D = -100mA$, $V_{EN} = 1.5V$</td>
<td>110</td>
<td>225</td>
<td>mΩ</td>
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<tr>
<td></td>
<td></td>
<td>$V_{IN} = +1.8V$, $I_D = -100mA$, $V_{EN} = 1.5V$</td>
<td>175</td>
<td>350</td>
<td>mΩ</td>
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<td>$V_{IN} = +1.7V$, $I_D = -100mA$, $V_{EN} = 1.5V$</td>
<td>200</td>
<td>375</td>
<td>mΩ</td>
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<tr>
<td>$R_{SHUTDOWN}$</td>
<td>Turn-Off Resistance</td>
<td>$V_{IN} = +3.6V$, $I_{TEST} = 1mA$, $V_{EN} = 0V$</td>
<td>250</td>
<td>400</td>
<td>Ω</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>MIC94081/3/5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. Exceeding the absolute maximum rating may damage the device.
2. The device is not guaranteed to function outside its operating rating.
3. With thermal contact to PCB. See thermal considerations section.
4. Pulse width <300µs with < 2% duty cycle.
5. Continuous body diode current conduction (reverse conduction, i.e. $V_{OUT}$ to $V_{IN}$) is not recommended.
6. Devices are ESD sensitive. Handling precautions recommended. HBM (Human body model), 1.5kΩ in series with 100pF.
7. Measured on the MIC94080YFT.
Electrical Characteristics (Dynamic)

$T_A = 25^\circ C$, bold values indicate $-40^\circ C \leq T_A \leq +85^\circ C$, unless noted.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Condition</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
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<tbody>
<tr>
<td>tON_DLY</td>
<td>Turn-On Delay Time</td>
<td>$V_{IN} = +3.6V, I_D = -100mA, V_{EN} = 1.5V$</td>
<td>0.40</td>
<td>1.5</td>
<td></td>
<td>µs</td>
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<td></td>
<td></td>
<td>MIC94080, MIC94081</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>$V_{IN} = +3.6V, I_D = -100mA, V_{EN} = 1.5V$</td>
<td>200</td>
<td>600</td>
<td>1500</td>
<td>µs</td>
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<td></td>
<td></td>
<td>MIC94082, MIC94083</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>$V_{IN} = +3.6V, I_D = -100mA, V_{EN} = 1.5V$</td>
<td>65</td>
<td>110</td>
<td>165</td>
<td>µs</td>
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<td>MIC94084, MIC94085</td>
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<tr>
<td>tON_RISE</td>
<td>Turn-On Rise Time</td>
<td>$V_{IN} = +3.6V, I_D = -100mA, V_{EN} = 1.5V$</td>
<td>0.4</td>
<td>1.5</td>
<td></td>
<td>µs</td>
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<tr>
<td></td>
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<td>MIC94080, MIC94081</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{IN} = +3.6V, I_D = -100mA, V_{EN} = 1.5V$</td>
<td>400</td>
<td>800</td>
<td>1500</td>
<td>µs</td>
</tr>
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<td></td>
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<td>MIC94082, MIC94083</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{IN} = +3.6V, I_D = -100mA, V_{EN} = 1.5V$</td>
<td>65</td>
<td>120</td>
<td>175</td>
<td>µs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MIC94084, MIC94085</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tOFF_DLY</td>
<td>Turn-Off Delay Time</td>
<td>$V_{IN} = +3.6V, I_D = -100mA, V_{EN} = 0V$</td>
<td>60</td>
<td>200</td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>tOFF_FALL</td>
<td>Turn-Off Fall Time</td>
<td>$V_{IN} = +3.6V, I_D = -100mA, V_{EN} = 0V$</td>
<td>20</td>
<td>100</td>
<td></td>
<td>ns</td>
</tr>
</tbody>
</table>
Typical Characteristics
Typical Characteristics

MIC94082/3
$T_{ON}$ Delay vs. Input Voltage

MIC94080/1
Rise Time vs. Input Voltage

MIC94082/3
Rise Time vs. Input Voltage

MIC94084/5
$T_{ON}$ Delay vs. Input Voltage

MIC94084/5
Rise Time vs. Input Voltage

MIC94080/1/2/3/4/5
$T_{OFF}$ Delay vs. Input Voltage

MIC94080/1/2/3/4/5
Fall Time vs. Input Voltage
Functional Characteristics

MIC94080

**Enable**

- **V\(_{\text{out}}\)** (2V/div)
- **I\(_{\text{out}}\)** (2A/div)

**TIME**

- (4μs/div)
- (1μs/div)
- (100μs/div)
- (4μs/div)
- (1μs/div)
- (100μs/div)
- (4μs/div)

**Parameters**

- \(V_{\text{IN}} = 3.6\, \text{V}\)
- \(C_{\text{L}} = 1\, \mu\text{F}\)
- Load = 1.8Ω
- Load = 33Ω
- \(C_{\text{L}} = 10\, \mu\text{F}\)
- Load = 1.8Ω
- Load = 33Ω
MIC94081

- **Enable** (2V/div)
- **V_{out}** (2V/div)
- **I_{out}** (2A/div)

**V_{IN} = 3.6V**
- **C_{L} = 1\mu F**
- **Load = 1.8\Omega**

**TIME (100\mu s/div)**

- **Enable** (2V/div)
- **V_{out}** (2V/div)
- **I_{out}** (2A/div)

**V_{IN} = 3.6V**
- **C_{L} = 1\mu F**
- **Load = 33\Omega**

**TIME (100\mu s/div)**

- **Enable** (2V/div)
- **V_{out}** (2V/div)
- **I_{out}** (2A/div)

**V_{IN} = 3.6V**
- **C_{L} = 10\mu F**
- **Load = 1.8\Omega**

**TIME (100\mu s/div)**

- **Enable** (2V/div)
- **V_{out}** (2V/div)
- **I_{out}** (100mA/div)

**V_{IN} = 3.6V**
- **C_{L} = 1\mu F**
- **Load = open**

**TIME (400\mu s/div)**

- **Enable** (2V/div)
- **V_{out}** (2V/div)
- **I_{out}** (100mA/div)

**V_{IN} = 3.6V**
- **C_{L} = 10\mu F**
- **Load = open**

**TIME (400\mu s/div)**
MIC94082

Enable
(2V/div)

V_out
(100mV/div)(2V/div)

I_out
(100mA/div)(2A/div)

TIME (400μs/div)

V_in = 3.6V
C_i = 1μF
Load = 33Ω

TIME (400μs/div)

V_in = 3.6V
C_i = 10μF
Load = 33Ω

TIME (400μs/div)

V_in = 3.6V
C_i = 1μF
Load = 1.8Ω

TIME (1ms/div)

V_in = 3.6V
C_i = 10μF
Load = 1.8Ω

TIME (1ms/div)

V_in = 3.6V
C_i = 1μF
Load = 33Ω

TIME (200μs/div)

V_in = 3.6V
C_i = 10μF
Load = 33Ω

TIME (200μs/div)

V_in = 3.6V
C_i = 1μF
Load = 1.8Ω

TIME (400μs/div)

V_in = 3.6V
C_i = 10μF
Load = 1.8Ω

TIME (400μs/div)
MIC94084

- **Micrel, Inc. MIC94080/1/2/3/4/5**
- **January 2011**

**Graphs:**
- **MIC94084**
- **MIC94081**

**Technical Specifications:**
- **Vin**: 3.6V
- **Cf**: 1μF
- **Load**: 1.8Ω

**Time Settings:**
- **100μs/div**
- **40μs/div**

**Graph Details:**
- **Enable (2V/div)**
- **Vout (2V/div)**
- **Iout (1A/div)**
- **Iout (200mA/div)**

**Graphs showing:**
- **Voltage and current waveforms**
- **Time intervals**

**Legend:**
- **Vout and Iout**
- **Enable and Time**
Application Information

Power Switch SOA

The safe operating area (SOA) curve represents the boundary of maximum safe operating current and maximum safe operating junction temperature.

![SOA Graph](image1)

The curves above show the SOA for various V_in's mounted on a typical 1 layer, 1 square inch copper board.

Power Dissipation Considerations

As with all power switches, the current rating of the switch is limited mostly by the thermal properties of the package and the PCB it is mounted on. There is a simple ohms law type relationship between thermal resistance, power dissipation and temperature, which are analogous to an electrical circuit:

![Simple Electrical Circuit](image2)

From this simple circuit we can calculate Vx if we know Isource, Vz and the resistor values, Rx and Ry using the equation:

\[ V_x = I_{source} \cdot (R_{xy} + R_{yz}) + V_z \]

Thermal circuits can be considered using these same rules and can be drawn similarly by replacing current sources with power dissipation (in Watts), resistance with thermal resistance (in °C/W) and voltage sources with temperature (in °C).

![Simple Thermal Circuit](image3)

Now replacing the variables in the equation for Vx, we can find the junction temperature (T_j) from power dissipation, ambient temperature and the known thermal resistance of the PCB (R_{θCA}) and the package (R_{θJC}).

\[ T_j = P_{Diss} \times (R_{θJC} + R_{θCA}) + T_A \]

P_{Diss} is calculated as \( I_{SW}^2 \times R_{SWmax} \). R_{θJC} is found in the operating ratings section of the datasheet and R_{θCA} (the PCB thermal resistance) values for various PCB copper areas is discussed in the document "Designing with Low Dropout Voltage Regulators" available from the Micrel website (LDO Application Hints).

Example:

A switch is intended to drive a 1A load and is placed on a printed circuit board which has a ground plane area of at least 25mm by 25mm (625mm²). The Voltage source is a Li-ion battery with a lower operating threshold of 3V and the ambient temperature of the assembly can be up to 50°C.

Summary of variables:

- I_{SW} = 1A
- V_{IN} = 3V to 4.2V
- T_A = 50°C
- R_{θJC} = 85°C/W
- R_{θCA} = 53°C/W Read from Graph in Figure 4

![PC Board Heat Sink Thermal Resistance vs. Area](image4)
The worst case switch resistance \( R_{SW_{\text{max}}} \) at the lowest \( V_{IN} \) of 3V is not available in the datasheet, so the next lower value of \( V_{IN} \) is used.

\[ R_{SW_{\text{max}}} @ 2.5v = 200m\Omega \]

If this were a figure for worst case \( R_{SW_{\text{max}}} \) for 25ºC, an additional consideration is to allow for the maximum junction temperature of 125ºC, the actual worst case resistance in this case can be 30% higher (See \( R_{DSON} \) variance vs. temperature graph). However, 200m\( \Omega \) is the maximum over temperature.

Therefore:

\[ T_J = t^2 \times 0.2 \times (85+53) + 50 \]
\[ T_J = 78ºC \]

This is below the maximum 125ºC.
Package Information

4-Pin (0.85mm x 0.85mm) Thin MLF⁰ (FT)

NOTE:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. MAX. PACKAGE WARPAGE IS 0.05 mm.
3. MAXIMUM ALLOWABLE BURRS IS 0.076 mm IN ALL DIRECTIONS.
4. PIN #1 ID ON TOP WILL BE LASER/INK MARKED.
5. DIMENSION APPLIES TO METALIZED TERMINAL AND IS MEASURED BETWEEN 0.20 AND 0.25 mm FROM TERMINAL TIP.
6. APPLIED ONLY FOR TERMINALS.
7. APPLIED FOR EXPOSED PAD AND TERMINALS.
Recommended Land Pattern

4-Pin (0.85mm x 0.85mm) Thin MLF® (FT)

Disclaimer: This is only a recommendation based on information available to Micrel from its suppliers. Actual land pattern may have to be significantly different due to various materials and processes used in PCB assembly. Micrel makes no representation or warranty of performance based on the recommended land pattern.

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