General Description
The MIC94040/1/2/3 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 28mΩ RDS(on) P-channel MOSFET which enables the device to support up to 3A of continuous current. Additionally, the load switch supports 1.5V logic level control and shutdown features in a tiny 1.2mm x 1.2mm 4-pin MLF® package.

The MIC94040 and MIC94041 feature rapid turn on, while the MIC94042 and MIC94043 provide a slew rate controlled soft-start turn-on of 100µs. The soft-start feature is provided to prevent an in-rush current event from pulling down the input supply voltage.

The MIC94041 and MIC94043 feature an active load discharge circuit which switches in a 200Ω load when the switch is disabled to automatically discharge a capacitive load.

An active pull-down on the enable input keeps the MIC94040/1/2/3 in a default OFF state until the enable pin is pulled above 1.2V. 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 MIC94040/1/2/3 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
- 28mΩ RDS(on)
- 3A continuous operating current
- 1.2mm x 1.2mm space saving 4-pin MLF® package
- 1.7V to 5.5V input voltage range
- Internal level shift for CMOS/TTL control logic
- Ultra low quiescent current
- Micro-power shutdown current
- Soft-Start: MIC94042, MIC94043
- Load discharge circuit: MIC94041, MIC94043
- 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
- Industrial and DataComm equipment

Typical Application

MLF and MicroLoadFrame is a registered trademark of Amkor Technology, Inc.

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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</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIC94040YFL</td>
<td>— P4</td>
<td>•</td>
<td></td>
<td></td>
<td>4-Pin (1.2mm x 1.2mm) MLF®</td>
</tr>
<tr>
<td>MIC94041YFL</td>
<td>— P1</td>
<td>•</td>
<td></td>
<td>•</td>
<td>4-Pin (1.2mm x 1.2mm) MLF®</td>
</tr>
<tr>
<td>MIC94042YFL</td>
<td>— P2</td>
<td></td>
<td>•</td>
<td></td>
<td>4-Pin (1.2mm x 1.2mm) MLF®</td>
</tr>
<tr>
<td>MIC94043YFL</td>
<td>— P3</td>
<td>•</td>
<td></td>
<td>•</td>
<td>4-Pin (1.2mm x 1.2mm) MLF®</td>
</tr>
</tbody>
</table>

Notes:
1. MLF® Pin 1 Identifier symbol is “●”.
2. MLF® is a GREEN RoHS-compliant package. Lead finish is NiPdAu. Mold compound is Halogen Free.

Pin Configuration

![Top View of 4-Pin (1.2mm x 1.2mm) MLF®](image)

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_OUT</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_IN</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 ($I_D$) .................................................... $\pm 3A$
- Pulsed Drain Current ($I_{DP}$) ...................................................... $\pm 6.0A$
- Storage Temperature ($T_S$) ......................................................... $-55^\circ C$ to $+150^\circ C$
- Continuous Diode Current ($I_S$) .................................................... $-50mA$

Operating Ratings

- Junction Temperature ($T_J$) ......................................................... $-40^\circ C$ to $+125^\circ C$
- Turn-Off Resistance ($R_{DS(ON)}$) .................................................. $28$ to $55$ m$\Omega$
- Turn-Off Resistance ($R_{OUT}$) ..................................................... $45$ to $90$ m$\Omega$
- Turn-Off Resistance ($R_{SHUTDOWN}$) .............................................. $72$ to $145$ m$\Omega$

Electrical Characteristics

$T_A = 25^\circ C$, 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>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{EN,TH}$</td>
<td>Enable Threshold Voltage</td>
<td>$V_{IN} = 1.7V$ to $4.5V$, $I_D = -250mA$</td>
</tr>
<tr>
<td>$I_Q$</td>
<td>Quiescent Current</td>
<td>$V_{IN} = V_{EN} = 5.5V$, $I_D = OPEN$ Measured on $V_{IN}$ MIC94040, MIC94041</td>
</tr>
<tr>
<td>$I_{EN}$</td>
<td>Enable Input Current</td>
<td>$V_{IN} = V_{EN} = 5.5V$, $I_D = OPEN$ Measured on $V_{IN}$ MIC94042, MIC94043</td>
</tr>
<tr>
<td>$I_{SHUT-Q}$</td>
<td>Quiescent Current (shutdown)</td>
<td>$V_{IN} = +5.5V$, $V_{EN} = 0V$, $I_D = OPEN$ Measured on $V_{IN}$</td>
</tr>
<tr>
<td>$I_{SHUT-SWITCH}$</td>
<td>OFF State Leakage Current</td>
<td>$V_{IN} = +5.5V$, $V_{EN} = 0V$, $I_D = SHORT$ Measured on $V_{OUT}$, (7)</td>
</tr>
<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>
</tr>
<tr>
<td>$R_{SHUTDOWN}$</td>
<td>Turn-Off Resistance (MIC94041, MIC94043)</td>
<td>$V_{IN} = +3.6V$, $I_{TEST} = 1mA$, $V_{EN} = 0V$</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 <300$\mu$s 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), 1.5k$\Omega$ in series with 100pF.
7. Measured on the MIC94040YFL and MIC94042YFL.
## 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>
</thead>
<tbody>
<tr>
<td>$t_{ON_DLY}$</td>
<td>Turn-On Delay Time</td>
<td>$V_{IN} = +3.6V, I_D = -100mA, V_{EN} = 1.5V$ $\text{MIC94040, MIC94041}$</td>
<td>0.97</td>
<td>1.5</td>
<td></td>
<td>$\mu s$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{IN} = +3.6V, I_D = -100mA, V_{EN} = 1.5V$ $\text{MIC94042, MIC94043}$</td>
<td>50</td>
<td>106</td>
<td>185</td>
<td>$\mu s$</td>
</tr>
<tr>
<td>$t_{ON_RISE}$</td>
<td>Turn-On Rise Time</td>
<td>$V_{IN} = +3.6V, I_D = -100mA, V_{EN} = 1.5V$ $\text{MIC94040, MIC94041}$</td>
<td>0.5</td>
<td>0.9</td>
<td>5</td>
<td>$\mu s$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{IN} = +3.6V, I_D = -100mA, V_{EN} = 1.5V$ $\text{MIC94042, MIC94043}$</td>
<td>50</td>
<td>116</td>
<td>200</td>
<td>$\mu s$</td>
</tr>
<tr>
<td>$t_{OFF_DLY}$</td>
<td>Turn-Off Delay Time</td>
<td>$V_{IN} = +3.6V, I_D = -100mA, V_{EN} = 0V$</td>
<td>100</td>
<td>200</td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>$t_{OFF_FALL}$</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

- **R\textsubscript{escoll} Variance vs. Temperature**
  - Graph showing the variation of \( R_{\text{escoll}} \) with temperature.

- **Voltage Drop vs. Load Current**
  - Graph showing voltage drop for different load current values at various \( V_{\text{IN}} \).

- **On Resistance vs. Input Voltage**
  - Graph showing on resistance for different input voltages.

- **Enable Threshold vs. Input Voltage**
  - Graph showing enable voltage for different input voltages.

- **Quiescent Current vs. Temperature**
  - Graph showing quiescent current for different temperatures at various \( V_{\text{IN}} \).

- **Enable Current vs. Temperature**
  - Graph showing enable current for different temperatures at various \( V_{\text{IN}} \).

- **\( T_{\text{ON}} \) Delay vs. Input Voltage**
  - Graph showing \( T_{\text{ON}} \) delay for different input voltages with 100mA resistor load.
Typical Characteristics

- **MIC94042/3**: $T_{on}$ Delay vs. Input Voltage
- **MIC94040/1**: Rise Time vs. Input Voltage
- **MIC94042/3**: Rise Time vs. Input Voltage
- **MIC94040/1**: Turn on Rise Time vs. Temperature
- **MIC94042/3**: $T_{off}$ Delay vs. Input Voltage
- **MIC94040/1/2/3**: $T_{off}$ Delay vs. Input Voltage
- **MIC94042/3**: Fall Time vs. Input Voltage
Functional Characteristics

MIC94040

Turn On/Turn Off Timing

- ENABLE (2V/div)
- VOUT (2V/div)
- IOUT (2A/div)

Time constants:
- \( V_{IN} = 3.6V \)
- \( R_L = 1.2\Omega \)
- \( C_L = 1\mu F \)

Time scales:
- (4µs/Box)
- (1µs/Box)
- (100µs/Box)
- (4µs/Box)
- (100µs/Box)

Time units:
- TIME (4µs/Box)
- TIME (1µs/Box)
- TIME (100µs/Box)
- TIME (4µs/Box)
- TIME (100µs/Box)
**Application Information**

**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:

\[ P_{Diss} = I_{SW}^2 \times R_{SW\max} \]

The worst case switch resistance \( R_{SW\max} \) at the lowest \( V_{IN} \) of 3V is not available in the datasheet, so the next lower value of \( V_{IN} \) is used.

\[ R_{SW\max@2.5V} = 90 \text{m} \Omega \]

If this were a figure for worst case \( R_{SW\max} \) for 25°C, an additional consideration is to allow for the maximum junction temperature of 125°C, the actual worst case resistance in this case can be 30% higher (See \( R_{DS\text{ON}} \) variance vs. temperature graph). However, 90m\( \Omega \) is the maximum over temperature.

Therefore:

\[ T_J = 2^2 \times 0.090 \times (90 + 53) + 50 \]

\[ T_J = 101^\circ C \]

This is below the maximum 125°C.

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**Example:**

A switch is intended to drive a 2A 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:**

- \( I_{SW} = 2A \)
- \( V_{IN} = 3V \) to 4.2V
- \( T_A = 50^\circ C \)
- \( R_{\theta JC} = 90^\circ C/W \) from Datasheet
- \( R_{\theta CA} = 53^\circ C/W \) Read from Graph in Figure 3

---

**Figure 1. Simple Electrical Circuit**

From this simple circuit we can calculate \( V_x \) if we know \( I_{Source} \), \( V_z \) and the resistor values, \( R_{xy} \) and \( R_{yz} \) using the equation:

\[ V_x = I_{Source} \times (R_{xy} + R_{yz}) + V_z \]

**Figure 2. Simple Thermal Circuit**

Now replacing the variables in the equation for \( V_x \), we can find the junction temperature \( T_J \) from power dissipation, ambient temperature and the known thermal resistance of the PCB \( (R_{\theta CA}) \) and the package \( (R_{\theta JC}) \).

\[ T_J = P_{Diss} \times (R_{\theta JC} + R_{\theta CA}) + T_A \]

\( P_{Diss} \) is calculated as \( I_{SW}^2 \times R_{SW\max} \). \( R_{\theta JC} \) is found in the operating ratings section of the datasheet and \( R_{\theta CA} \) (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).
Package Information

**TOP VIEW**

**BOTTOM VIEW**

**SIDE VIEW**

4-Pin (1.2mm x 1.2mm) MLF®

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**NOTE:**
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. MAX. PACKAGE WARPAGE IS 200mm.
3. MAXIMUM ALLOWABLE BURRS IS 0.076mm IN ALL DIRECTIONS.
4. PIN #1 IS ON TOP WILL BE LASER/LC MARKED.
5. DIMENSION APPLIES TO METALIZED TERMINAL AND IS MEASURED BETWEEN 0.025 AND 0.025mm FROM TERMINAL TIP.
6. APPLIED ONLY FOR TERMINALS.
7. APPLIED FOR EXPOSED PAD AND TERMINALS.
Suggested Landing Pattern for 4 Pin (1.2mm x 1.2mm) MLF®