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FPF1039
Low On-Resistance, Slew-Rate-Controlled Load Switch

Features

- 1.2 V to 5.5 V Input Voltage Operating Range
- Typical \( R_{ON} \):
  - 20 mΩ at \( V_{IN}=5.5 \) V
  - 21 mΩ at \( V_{IN}=4.5 \) V
  - 37 mΩ at \( V_{IN}=1.8 \) V
  - 75 mΩ at \( V_{IN}=1.2 \) V
- Slew Rate / Inrush Control with \( t_r \): 2.7 ms (Typical)
- 3.5 A Maximum Continuous Current Capability
- Output Capacitor Discharge Function
- Low <1 μA Shutdown Current
- ESD Protected: Above 8 kV HBM, 1.5 kV CDM
- GPIO / CMOS- Compatible Enable Circuitry

Applications

- HDD, Storage, and Solid-State Memory Devices
- Portable Media Devices, UMPC, Tablets, MIDs
- Wireless LAN Cards and Modules
- SLR Digital Cameras
- Portable Medical Devices
- GPS and Navigation Equipment
- Industrial Handheld and Enterprise Equipment

Description

The FPF1039 advanced load-management switch target applications requiring a highly integrated solution for disconnecting loads powered from DC power rail (<6 V) with stringent shutdown current targets and high load capacitances (up to 200 μF). The FPF1039 consists of slew-rate controlled low-impedance MOSFET switch (21 mΩ typical) and other integrated analog features. The slew-rate controlled turn-on characteristic prevents inrush current and the resulting excessive voltage drop on power rails.

This device has exceptionally low shutdown current drain (<1 μA maximum) that facilitates compliance in low standby power applications. The input voltage range operates from 1.2 V to 5.5 V DC to support a wide range of applications in consumer, optical, medical, storage, portable, and industrial device power management.

Switch control is managed by a logic input (active HIGH) capable of interfacing directly with low-voltage control signal / GPIO with no external pull-up required. The device is packaged in advanced fully “green” 1mm x1.5 mm Wafer-Level Chip-Scale Packaging (WLCSP); providing excellent thermal conductivity, small footprint, and low electrical resistance for wider application usage.

Ordering Information

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Top Mark</th>
<th>Switch ( R_{ON} ) (Typical) at 4.5 ( V_{IN} )</th>
<th>Input Buffer</th>
<th>Output Discharge</th>
<th>ON Pin Activity</th>
<th>( t_r )</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPF1039UCX</td>
<td>QF</td>
<td>21 mΩ</td>
<td>CMOS</td>
<td>65Ω</td>
<td>Active HIGH</td>
<td>2.7 ms</td>
<td>6-Bump, WLCSP, 1.0 mm x 1.5 mm, 0.5 mm Pitch</td>
</tr>
<tr>
<td>FPF1039BUCX</td>
<td>QF</td>
<td>21 mΩ</td>
<td>CMOS</td>
<td>65Ω</td>
<td>Active HIGH</td>
<td>2.7 ms</td>
<td>6-Bump, WLCSP with Backside Laminate, 1.0 mm x 1.5 mm, 0.5 mm Pitch</td>
</tr>
</tbody>
</table>
Application Diagram

Figure 1. Typical Application

Functional Block Diagram

Figure 2. Functional Block Diagram

FPF1039 – IntelliMAX™ Advanced Slew Rate Controlled Load Switch

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FPF1039 • Rev. 1.5

www.fairchildsemi.com
Pin Configuration

Figure 3. Top View

Figure 4. Bottom View

Pin Definitions

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1, B1</td>
<td>V&lt;sub&gt;OUT&lt;/sub&gt;</td>
<td>Switch Output</td>
</tr>
<tr>
<td>A2, B2</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;</td>
<td>Supply Input: Input to the Power Switch</td>
</tr>
<tr>
<td>C1</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>C2</td>
<td>ON</td>
<td>ON/OFF Control, Active High - GPIO Compatible</td>
</tr>
</tbody>
</table>
Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameters</th>
<th>Min.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>V\textsubscript{IN}</td>
<td>( V_{\text{IN}}, V_{\text{OUT}}, V_{\text{ON}} ) to GND</td>
<td>-0.3</td>
<td>6.0</td>
<td>V</td>
</tr>
<tr>
<td>I\textsubscript{SW}</td>
<td>Maximum Continuous Switch Current</td>
<td>3.5</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>P\textsubscript{D}</td>
<td>Power Dissipation at ( T_{\text{A}}=25^\circ\text{C} )</td>
<td>1.2</td>
<td></td>
<td>W</td>
</tr>
<tr>
<td>T\textsubscript{STG}</td>
<td>Storage Junction Temperature</td>
<td>-65</td>
<td>+150</td>
<td>°C</td>
</tr>
<tr>
<td>T\textsubscript{A}</td>
<td>Operating Temperature Range</td>
<td>-40</td>
<td>+85</td>
<td>°C</td>
</tr>
<tr>
<td>( \theta_{\text{JA}} )</td>
<td>Thermal Resistance, Junction-to-Ambient</td>
<td>85(^{(1)})</td>
<td>110(^{(2)})</td>
<td>°C/W</td>
</tr>
<tr>
<td>ESD</td>
<td>Electrostatic Discharge Capability</td>
<td>Human Body Model, JESD22-A114</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Charged Device Model, JESD22-C101</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. Measured using 2S2P JEDEC std. PCB.

Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. Fairchild does not recommend exceeding them or designing to Absolute Maximum Ratings.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameters</th>
<th>Min.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>V\textsubscript{IN}</td>
<td>Input Voltage</td>
<td>1.2</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>T\textsubscript{A}</td>
<td>Ambient Operating Temperature</td>
<td>-40</td>
<td>+85</td>
<td>°C</td>
</tr>
</tbody>
</table>
# Electrical Characteristics

Unless otherwise noted, \( V_{IN} \)=1.2 to 5.5V and \( T_A\)=−40 to +85°C; typical values are at \( V_{IN} \)=4.5V and \( T_A\)=25°C.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameters</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{IN} )</td>
<td>Input Voltage</td>
<td></td>
<td>1.2</td>
<td>5.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>( I_{Q,(OFF)} )</td>
<td>Off Supply Current</td>
<td>( V_{ON}=\text{GND}, V_{OUT}=\text{Open} )</td>
<td>1.0</td>
<td>1.0</td>
<td>( \mu A )</td>
<td></td>
</tr>
<tr>
<td>( I_{SD} )</td>
<td>Shutdown Current</td>
<td>( V_{ON}=\text{GND}, V_{OUT}=\text{GND} )</td>
<td>0.2</td>
<td>1.0</td>
<td>( \mu A )</td>
<td></td>
</tr>
<tr>
<td>( I_Q )</td>
<td>Quiescent Current</td>
<td>( I_{OUT}=0 \text{ mA} )</td>
<td>5.5</td>
<td>8.0</td>
<td>( \mu A )</td>
<td></td>
</tr>
<tr>
<td>( R_{ON} )</td>
<td>On Resistance</td>
<td>( V_{IN}=5.5 \text{ V}, I_{OUT}=1 \text{ A}^{(3)} )</td>
<td>20</td>
<td>24</td>
<td>mΩ</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( V_{IN}=4.5 \text{ V}, I_{OUT}=1 \text{ A}, T_A=25°C )</td>
<td>21</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( V_{IN}=3.3 \text{ V}, I_{OUT}=500 \text{ mA}^{(3)} )</td>
<td>24</td>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( V_{IN}=2.5 \text{ V}, I_{OUT}=500 \text{ mA}^{(3)} )</td>
<td>28</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( V_{IN}=1.8 \text{ V}, I_{OUT}=250 \text{ mA}^{(3)} )</td>
<td>37</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( V_{IN}=1.2 \text{ V}, I_{OUT}=250 \text{ mA}, T_A=25°C )</td>
<td>75</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( R_{PD} )</td>
<td>Output Discharge ( R_{\text{PULL , DOWN}} )</td>
<td>( V_{IN}=4.5 \text{ V}, V_{ON}=0 \text{ V}, I_{\text{FORCE}}=20 \text{ mA}, T_A=25°C )</td>
<td>65</td>
<td>85</td>
<td>( \Omega )</td>
<td></td>
</tr>
<tr>
<td>( V_{IH} )</td>
<td>On Input Logic HIGH Voltage</td>
<td></td>
<td>1.0</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>( V_{IL} )</td>
<td>On Input Logic LOW Voltage</td>
<td></td>
<td>0.4</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>( I_{ON} )</td>
<td>On Input Leakage</td>
<td></td>
<td>1.5</td>
<td></td>
<td>( \mu A )</td>
<td></td>
</tr>
</tbody>
</table>

## Dynamic Characteristics

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameters</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_{DON} )</td>
<td>Turn-On Delay(^{4})</td>
<td>( V_{IN}=4.5 \text{ V}, R_L=5 \text{ Ω}, C_L=100 \text{ μF}, T_A=25°C )</td>
<td>1.7</td>
<td></td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>( t_R )</td>
<td>( V_{OUT} ) Rise Time(^{4})</td>
<td>( V_{IN}=4.5 \text{ V}, R_L=5 \text{ Ω}, C_L=100 \text{ μF}, T_A=25°C )</td>
<td>2.7</td>
<td></td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>( t_{ON} )</td>
<td>Turn-On Time(^{6})</td>
<td></td>
<td>4.4</td>
<td></td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>( t_{DOFF} )</td>
<td>Turn-Off Delay(^{4,5})</td>
<td>( V_{IN}=4.5 \text{ V}, R_L=150 \text{ Ω}, C_L=100 \text{ μF}, T_A=25°C )</td>
<td>0.5</td>
<td></td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>( t_F )</td>
<td>( V_{OUT} ) Fall Time(^{4,5})</td>
<td>( V_{IN}=4.5 \text{ V}, R_L=150 \text{ Ω}, C_L=100 \text{ μF}, T_A=25°C )</td>
<td>10.0</td>
<td></td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>( t_{OFF} )</td>
<td>Turn-Off (^{5,7})</td>
<td></td>
<td>10.5</td>
<td></td>
<td>ms</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
3. This parameter is guaranteed by design and characterization; not production tested.
4. \( t_{DON}/t_{DOFF}/t_{R}/t_{F} \) are defined in Figure 32.
5. Output discharge enabled during off-state.
6. \( t_{ON}=t_R+t_{DON} \)
7. \( t_{OFF}=t_F+t_{DOFF} \)
Typical Characteristics

**Figure 5. Shutdown Current vs. Temperature**

**Figure 6. Shutdown Current vs. Supply Voltage**

**Figure 7. Off Supply Current vs. Temperature (V_{OUT} = 0 V)**

**Figure 8. Off Supply Current vs. Supply Voltage (V_{OUT} = 0 V)**

**Figure 9. Quiescent Current vs. Temperature**

**Figure 10. Quiescent Current vs. Supply Voltage**
Figure 11. Quiescent Current vs. On Voltage ($V_{IN} = 4.5$ V)

Figure 12. Quiescent Current vs. On Voltage ($V_{IN} = 5.5$ V)

Figure 13. Output Discharge Resistor RPD vs. Temperature

Figure 14. Output Discharge Resistor RPD vs. Supply Voltage

Figure 15. $R_{ON}$ vs. Temperature

Figure 16. $R_{ON}$ vs. Supply Voltage
Typical Characteristics (Continued)

Figure 17. On Pin Threshold Low vs. Temperature

Figure 18. On Pin Threshold Low vs. $V_{IN}$

Figure 19. On Pin Threshold High vs. Temperature

Figure 20. On Pin Threshold High vs. $V_{IN}$

Figure 21. On Pin Threshold vs. Supply Voltage

Figure 22. $I_{SW}$ vs. $(V_{IN}-V_{OUT})$ — SOA

Figure 23. $t_{hi}/t_{rf}$ vs. Temperature
Typical Characteristics (Continued)

Figure 24. $t_r/t_{DON}$ vs. Temperature

Figure 25. $t_r$ vs. Supply Voltage

Figure 26. $t_r$ vs. Supply Voltage

Figure 27. Turn-On Response
$(V_{IN}=4.5\, V, C_{IN}=10\, \mu F, C_L=1\, \mu F, R_L=50\, \Omega)$

Figure 28. Turn-On Response
$(V_{IN}=4.5\, V, C_{IN}=10\, \mu F, C_L=100\, \mu F, R_L=50\, \Omega)$

Figure 29. Turn-Off Response
$(V_{IN}=4.5\, V, C_{IN}=10\, \mu F, C_L=100\, \mu F, \text{without External RL})$
Typical Characteristics (Continued)

Figure 30. Fall Time as a Function of External Resistive Load ($C_L$=1 μF, 10 μF, and 100 μF)

Figure 31. Fall Time as a Function of External Capacitive Load ($R_L$=5 Ω, 50 Ω, and 500 Ω)

Figure 32. Timing Diagram
Application Information

Input Capacitor
This IntelliMAX™ switch doesn’t require an input capacitor. To reduce device inrush current, a 0.1 μF ceramic capacitor, C\text{IN}, is recommended close to the VIN pin. A higher value of C\text{IN} can be used to reduce the voltage drop experienced as the switch is turned on into a large capacitive load.

Output Capacitor
While this switch works without an output capacitor: if parasitic board inductance forces V\text{OUT} below GND when switching off; a 0.1 μF capacitor, C\text{OUT}, should be placed between V\text{OUT} and GND.

Fall Time
Device output fall time can be calculated based on RC constant of the external components as follows:

\[ t_\text{F} = R_\text{L} \times C_\text{L} \times 2.2 \tag{1} \]

where tf is 90% to 10% fall time, R\text{L} is output load, and C\text{L} is output capacitor.

The same equation works for a device with a pull-down output resistor. R\text{L} is replaced by a parallel connected pull-down and an external output resistor combination as:

\[ t_\text{F} = \frac{R_\text{L} \times R_\text{PD}}{R_\text{L} + R_\text{PD}} \times C_\text{L} \times 2.2 \tag{2} \]

where tf is 90% to 10% fall time, R\text{L} is output load, R\text{PD}=65 Ω is output pull-down resistor, and C\text{L} is the output capacitor.

Resistive Output Load
If resistive output load is missing, the IntelliMAX switch does not discharge the output voltage. Output voltage drop depends, in that case, mainly on external device leaks.

Application Specifics

At maximum operational voltage (V_{IN}=5.5 V), device inrush current might be higher than expected. Spike current should be taken into account if V_{IN}>5 V and the output capacitor is much larger than the input capacitor. Input current can be calculated as:

\[ I_{IN}(t) = \frac{V_{OUT}(t)}{R_{LOAD}} + \frac{(C_{LOAD} - C_{IN})}{R_{PD}} \frac{dV_{OUT}(t)}{dt} \tag{3} \]

where switch and wire resistances are neglected and capacitors are assumed ideal.

Estimating V\text{OUT}=(V_{IN}/10) and using experimental formula for slew rate (dV\text{OUT}(t)/dt), spike current can be written as:

\[ \text{max}(I_{IN}) = \frac{V_{IN}}{10R_{LOAD}} + \frac{(C_{LOAD} - C_{IN})}{R_{PD}} (0.05V_{IN} - 0.255) \tag{4} \]

where supply voltage V_{IN} is in volts, capacitances are in micro farads, and resistance is in ohms.

Example: If V_{IN}=5.5 V, C_{LOAD}=100 μF, C_{IN}=10 μF, and R_{LOAD}=50 Ω; calculate the spike current by:

\[ \text{max}(I_{IN}) = \frac{5.5}{10 \times 50} + (100 - 10)(0.05 \times 5.5 - 0.255)A = 1.8A \tag{5} \]

Maximum spike current is 1.8 A, while average ramp-up current is:

\[ I_{IN}(t) = \frac{V_{OUT}(t)}{R_{LOAD}} + \frac{(C_{LOAD} - C_{IN})}{R_{PD}} \frac{dV_{IN}(t)}{dt} \]

\[ = \frac{2.75}{50} + 100 \times 0.0022 = 0.275 A \tag{6} \]

Output Discharge
FPF1039 contains a 65 Ω on-chip pull-down resistor for quick output discharge. The resistor is activated when the switch is turned off.

Recommended Layout
For best thermal performance and minimal inductance and parasitic effects, it is recommended to keep input and output traces short and capacitors as close to the device as possible. Figure 34 is a recommended layout for this device to achieve optimum performance.
Physical Dimensions

Figure 35. 6 Ball, 1.0 x 1.5 mm Wafer-Level Chip-Scale Packaging (WLCSP)

NOTES:
A. NO JEDEC REGISTRATION APPLIES.
B. DIMENSIONS ARE IN MILLIMETERS.
D. DATUM C IS DEFINED BY THE SPHERICAL CROWNS OF THE BALLS.
E. PACKAGE NOMINAL HEIGHT IS 582 MICRONS ±43 MICRONS (539-625 MICRONS).
F. FOR DIMENSIONS D, E, X, AND Y SEE PRODUCT DATASHEET.
G. DRAWING FILENAME: MKT-UC006AFrev2.
### Nominal Values

<table>
<thead>
<tr>
<th>Bump Pitch</th>
<th>Overall Package Height</th>
<th>Silicon Thickness</th>
<th>Solder Bump Height</th>
<th>Solder Bump Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 mm</td>
<td>0.582 mm</td>
<td>0.332 mm</td>
<td>0.250 mm</td>
<td>0.315 mm</td>
</tr>
</tbody>
</table>

### Product-Specific Dimensions

<table>
<thead>
<tr>
<th>Product</th>
<th>D</th>
<th>E</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPF1039UCX</td>
<td>1.46 mm ±0.03</td>
<td>0.96 mm ±0.03</td>
<td>0.230 mm</td>
<td>0.230 mm</td>
</tr>
<tr>
<td>FPF1039BUCX</td>
<td>1.46 mm ±0.03</td>
<td>0.96 mm ±0.03</td>
<td>0.230 mm</td>
<td>0.230 mm</td>
</tr>
</tbody>
</table>
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Dual Cool™
EcoSpark®
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FAS®
FlashCore™
FETBench™
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MicroFit™
MicroPak™
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MT™
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PRODUCT STATUS DEFINITIONS

Definition of Terms

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<tr>
<th>Datasheet Identification</th>
<th>Product Status</th>
<th>Definition</th>
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<td>Advanced Information</td>
<td>Formative / In Design</td>
<td>Datasheet contains the design specifications for product development. Specifications may change in any manner without notice.</td>
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<td>Preliminary</td>
<td>First Production</td>
<td>Datasheet contains preliminary data; supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve the design.</td>
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