The ISL8025, ISL8025A are highly efficient, monolithic, synchronous step-down DC/DC converters that can deliver 5A of continuous output current from a 2.7V to 5.5V input supply. The devices use current mode control architecture to deliver a very low duty cycle operation at high frequency with fast transient response and excellent loop stability.

The ISL8025, ISL8025A integrates a very low ON-resistance P-Channel (36mΩ) high-side FET and N-Channel (13mΩ) low-side FET to maximize efficiency and minimize external component count. The 100% duty-cycle operation allows less than 180mV dropout voltage at 5A output current. The operation frequency of the pulse-width modulator (PWM) is adjustable from 500kHz to 4MHz. The default switching frequency, which is set by connecting the FS pin high, is 1MHz for the ISL8025 and 2MHz for the ISL8025A.

The ISL8025, ISL8025A can be configured for discontinuous or forced continuous operation at light load. Forced continuous operation reduces noise and RF interference, while discontinuous mode provides higher efficiency by reducing switching losses at light loads.

Fault protection is provided by internal hiccup mode current limiting during short circuit and overcurrent conditions. Other protection, such as overvoltage and over-temperature, are also integrated into the device. A power-good output voltage monitor indicates when the output is in regulation.

The ISL8025, ISL8025A offers a 1ms Power-good (PG) timer at power-up. When in shutdown, the ISL8025, ISL8025A discharges the output capacitor through an internal soft-stop switch. Other features include internal fixed or adjustable soft-start and internal/external compensation.

The ISL8025, ISL8025A are offered in a space saving 16 Ld 3x3 Pb-free QFN package with an exposed pad for improved thermal performance and 1mm maximum height. The complete converter occupies less than 0.22 in² area.

**Features**

- 2.7V to 5.5V input voltage range
- Very low ON-resistance FET's - P-channel 36mΩ and N-channel 13mΩ typical values
- High efficiency synchronous buck regulator with up to 95% efficiency
- Pin-to-pin compatible with ISL8023 and ISL8024
- 0.8% reference accuracy over-temperature/load/line
- Internal soft-start: 1ms or adjustable
- Soft-stop output discharge during disable
- Adjustable frequency from 500kHz to 4MHz - default at 1MHz (ISL8025), 2MHz (ISL8025A)
- External synchronization up to 4MHz
- Over-temperature, overcurrent, overvoltage and negative overcurrent protection

**Applications**

- DC/DC POL modules
- μC/μP, FPGA and DSP power
- Plug-in DC/DC modules for routers and switchers
- Portable instruments
- Test and measurement systems
- Li-ion battery powered devices

**Related Literature**

- See AN1806, “5A Low Quiescent Current High Efficiency Synchronous Buck Regulator”
Table of Contents

Pin Configuration ................................................................. 3
Pin Descriptions ........................................................................ 3
Ordering Information ............................................................... 4
Absolute Maximum Ratings ......................................................... 6
Thermal Information ................................................................. 6
Recommended Operating Conditions ........................................... 6
Electrical Specifications ............................................................ 6
Typical Operating Performance .................................................. 8
Typical Operating Performance .................................................. 11
Theory of Operation ................................................................. 16
  PWM Control Scheme .............................................................. 16
  SKIP Mode .............................................................................. 16
  Frequency Adjust ...................................................................... 17
  Overcurrent Protection ............................................................ 17
  Negative Current Protection ...................................................... 17
  PG ......................................................................................... 17
  UVLO .................................................................................... 17
  Soft Start-Up ........................................................................... 17
  Enable ................................................................................... 17
  Discharge Mode (Soft-Stop) ....................................................... 18
  Power MOSFETs ..................................................................... 18
  100% Duty Cycle ..................................................................... 18
  Thermal Shut-Down ................................................................. 18
Application Information ............................................................. 18
  Output Inductor and Capacitor Selection .................................... 18
  Output Voltage Selection ......................................................... 18
  Input Capacitor Selection ........................................................ 18
  Loop Compensation Design ...................................................... 18
PCB Layout Recommendation .................................................... 20
Revision History ......................................................................... 21
About Intersil .............................................................................. 21
Package Outline Drawing .......................................................... 22
Pin Configuration

![Pin Configuration Diagram]

Pin Descriptions

<table>
<thead>
<tr>
<th>PIN NUMBER</th>
<th>SYMBOL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 16</td>
<td>VIN</td>
<td>Input supply voltage. Place a minimum of two 22µF ceramic capacitors from VIN to PGND as close as possible to the IC for decoupling.</td>
</tr>
<tr>
<td>2</td>
<td>VDD</td>
<td>Input supply voltage for the logic. Connect VIN pin.</td>
</tr>
<tr>
<td>3</td>
<td>PG</td>
<td>Power-good is an open-drain output. Use a 10kΩ to 100kΩ pull-up resistor connected between VIN and PG. At power-up or EN HI, PG rising edge is delayed by 1ms upon output reached within regulation.</td>
</tr>
<tr>
<td>4</td>
<td>SYNC</td>
<td>Mode Selection pin. Connect to logic high or input voltage VIN for PWM mode. Connect to logic low or ground for PFM mode. Connect to an external function generator for synchronization with the positive edge trigger. There is an internal 1MΩ pull-down resistor to prevent an undefined logic state in case of SYNC pin float.</td>
</tr>
<tr>
<td>5</td>
<td>EN</td>
<td>Regulator enable pin. Enable the output when driven to high. Shutdown the chip and discharge output capacitor when driven to low.</td>
</tr>
<tr>
<td>6</td>
<td>FS</td>
<td>This pin sets the oscillator switching frequency, using a resistor, RFS, from the FS pin to GND. The frequency of operation may be programmed between 500kHz to 4MHz. The default frequency is 1MHz if FS is connected to VIN.</td>
</tr>
<tr>
<td>7</td>
<td>SS</td>
<td>SS is used to adjust the soft-start time. Set to SGND for internal 1ms rise time. Connect a capacitor from SS to SGND to adjust the soft-start time. Do not use more than 33nF per IC.</td>
</tr>
<tr>
<td>8, 9</td>
<td>COMP, FB</td>
<td>The feedback network of the regulator, FB, is the negative input to the transconductance error amplifier. The output voltage is set by an external resistor divider connected to FB. With a properly selected divider, the output voltage can be set to any voltage between the power rail (reduced by converter losses) and the 0.6V reference. COM P is the output of the amplifier if COMP is not tied to VDD. Otherwise, COMP is disconnected through a MOSFET for internal compensation. Must connect COMP to VDD in internal compensation mode to meet a typical application. Additional external networks across COMP and SGND might be required to improve the loop compensation of the amplifier operation. In addition, the regulator power-good and under-voltage protection circuitry use FB to monitor the regulator output voltage.</td>
</tr>
<tr>
<td>10</td>
<td>SGND</td>
<td>Signal ground.</td>
</tr>
<tr>
<td>11, 12</td>
<td>PGND</td>
<td>Power ground.</td>
</tr>
<tr>
<td>13, 14, 15</td>
<td>PHASE</td>
<td>Switching node connections. Connect to one terminal of the inductor. This pin is discharged by a 100Ω resistor when the device is disabled. See &quot;FUNCTIONAL BLOCK DIAGRAM&quot; on page 5 for more detail.</td>
</tr>
<tr>
<td>Exposed Pad</td>
<td>-</td>
<td>The exposed pad must be connected to the SGND pin for proper electrical performance. Place as many vias as possible under the pad connecting to SGND plane for optimal thermal performance.</td>
</tr>
</tbody>
</table>
## Ordering Information

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PART MARKING</th>
<th>OPERATION FREQUENCY (MHz)</th>
<th>TEMP. RANGE (°C)</th>
<th>PACKAGE (Pb-Free)</th>
<th>PKG. DWG. #</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISL8025IRTAJZ</td>
<td>025A</td>
<td>1</td>
<td>-40 to +85</td>
<td>16 Ld 3x3 TQFN</td>
<td>L16.3x3D</td>
</tr>
<tr>
<td>ISL8025AIRTAJZ</td>
<td>25AA</td>
<td>2</td>
<td>-40 to +85</td>
<td>16 Ld 3x3 TQFN</td>
<td>L16.3x3D</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Add "-T*" suffix for tape and reel. Please refer to TB347 for details on reel specifications.
2. These Intersil Pb-free plastic packaged products employ special Pb-free material sets, molding compounds/die attach materials, and 100% matte tin plate plus anneal (e3 termination finish, which is RoHS compliant and compatible with both SnPb and Pb-free soldering operations). Intersil Pb-free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J STD-020.
3. For Moisture Sensitivity Level (MSL), please see device information page for ISL8025, ISL8025A. For more information on MSL please see techbrief TB363.

### TABLE 1. SUMMARY OF KEY DIFFERENCES

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>I(_{\text{OUT}}) (MAX) (A)</th>
<th>F(_{\text{SW}}) RANGE (MHz)</th>
<th>V(_{\text{IN}}) RANGE (V)</th>
<th>V(_{\text{OUT}}) RANGE (V)</th>
<th>PART SIZE (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISL8025</td>
<td>5</td>
<td>Programmable 0.5MHz to 4MHz</td>
<td>2.7 to 5.5</td>
<td>0.6 to 5.5</td>
<td>3x3</td>
</tr>
<tr>
<td>ISL8025A</td>
<td></td>
<td>Programmable 1MHz to 4MHz</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**
4. The Evaluation Kit default configuration is V\(_{\text{OUT}}\) = 1.8V, F\(_{\text{SW}}\) = 1MHz.
5. V\(_{\text{REF}}\) is 0.6V.

### TABLE 2. ISL8025 COMPONENT SELECTION

<table>
<thead>
<tr>
<th>V(_{\text{OUT}})</th>
<th>0.8V</th>
<th>1.2V</th>
<th>1.5V</th>
<th>1.8V</th>
<th>2.5V</th>
<th>3.3V</th>
<th>3.6V</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
</tr>
<tr>
<td>C2</td>
<td>4 x 22µF</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
</tr>
<tr>
<td>C3</td>
<td>22µF</td>
<td>22µF</td>
<td>22µF</td>
<td>22µF</td>
<td>22µF</td>
<td>22µF</td>
<td>22µF</td>
</tr>
<tr>
<td>L1</td>
<td>0.47~1µH</td>
<td>0.47~1µH</td>
<td>0.47~1µH</td>
<td>0.68~1.5µH</td>
<td>0.68~1.5µH</td>
<td>1~2.2µH</td>
<td>1~2.2µH</td>
</tr>
<tr>
<td>R2</td>
<td>33kΩ</td>
<td>100kΩ</td>
<td>150kΩ</td>
<td>200kΩ</td>
<td>316kΩ</td>
<td>450kΩ</td>
<td>500kΩ</td>
</tr>
<tr>
<td>R3</td>
<td>100kΩ</td>
<td>100kΩ</td>
<td>100kΩ</td>
<td>100kΩ</td>
<td>100kΩ</td>
<td>100kΩ</td>
<td>100kΩ</td>
</tr>
</tbody>
</table>

### TABLE 3. ISL8025A COMPONENT SELECTION

<table>
<thead>
<tr>
<th>V(_{\text{OUT}})</th>
<th>0.8V</th>
<th>1.2V</th>
<th>1.5V</th>
<th>1.8V</th>
<th>2.5V</th>
<th>3.3V</th>
<th>3.6V</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>22µF</td>
<td>22µF</td>
<td>22µF</td>
<td>22µF</td>
<td>22µF</td>
<td>22µF</td>
<td>22µF</td>
</tr>
<tr>
<td>C2</td>
<td>3 x 22µF</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
<td>2 x 22µF</td>
</tr>
<tr>
<td>C3</td>
<td>22µF</td>
<td>22µF</td>
<td>22µF</td>
<td>22µF</td>
<td>22µF</td>
<td>22µF</td>
<td>22µF</td>
</tr>
<tr>
<td>L1</td>
<td>0.22~0.47µH</td>
<td>0.22~0.47µH</td>
<td>0.22~0.47µH</td>
<td>0.33~0.68µH</td>
<td>0.33~0.68µH</td>
<td>0.47~1µH</td>
<td>0.47~1µH</td>
</tr>
<tr>
<td>R2</td>
<td>33kΩ</td>
<td>100kΩ</td>
<td>150kΩ</td>
<td>200kΩ</td>
<td>316kΩ</td>
<td>450kΩ</td>
<td>500kΩ</td>
</tr>
<tr>
<td>R3</td>
<td>100kΩ</td>
<td>100kΩ</td>
<td>100kΩ</td>
<td>100kΩ</td>
<td>100kΩ</td>
<td>100kΩ</td>
<td>100kΩ</td>
</tr>
</tbody>
</table>
**Absolute Maximum Ratings** (Reference to GND)

VIN .............................. -0.3V to 5.8V (DC) or 7V (20ms)
EN, FS, PG, SYNC, VFB .............................. -0.3V to VIN + 0.3V
PHASE .............................. -1.5V (100ns)/-0.3V (DC) to 6.5V (DC) or 7V (20ms)
COMP, SS .............................. -0.3V to 2.7V

ESD Ratings
- Human Body Model (Tested per JESD22-A114) .............................. 3kV
- Charged Device Model (Tested per JESD22-C101E) .............................. 2kV
- Machine Model (Tested per JESD22-A115) .............................. 300V
- Latch Up (Tested per JESD-78A; Class 2, Level A) .............................. 100mA @ +85°C

**Thermal Information**

<table>
<thead>
<tr>
<th>Thermal Resistance</th>
<th>$\theta_{JA}$ ($^\circ$C/W)</th>
<th>$\theta_{JC}$ ($^\circ$C/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 LD TQFN Package (Notes 6, 7)</td>
<td>47</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Junction Temperature Range .............................. -55°C to +125°C
Storage Temperature Range .............................. -65°C to +150°C

**Recommended Operating Conditions**

VIN Supply Voltage Range .............................. 2.7V to 5.5V
Load Current Range .............................. 0A to 5A
Ambient Temperature Range .............................. -40°C to +85°C

**CAUTION:** Do not operate at or near the maximum ratings listed for extended periods of time. Exposure to such conditions may adversely impact product reliability and result in failures not covered by warranty.

**NOTES:**
6. $\theta_{JA}$ is measured in free air with the component mounted on a high effective thermal conductivity test board with "direct attach" features. See Tech Brief TB379.
7. $\theta_{JC}$, "case temperature" location is at the center of the exposed metal pad on the package underside.

**Electrical Specifications**

- Unless otherwise noted, all parameter limits are established over the recommended operating conditions and the typical specification are measured at the following conditions: $T_A = -40^\circ$C to +85°C, VIN = 3.6V, EN = VIN, unless otherwise noted. Typical values are at $T_A = +25^\circ$C. **Boldface limits apply over the operating temperature range, -40°C to +85°C.**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>TEST CONDITIONS</th>
<th>MIN (Note 8)</th>
<th>TYP</th>
<th>MAX (Note 8)</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INPUT SUPPLY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIN Undervoltage Lockout Threshold</td>
<td>$V_{UVLO}$</td>
<td>Rising, no load</td>
<td>2.5</td>
<td>2.7</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Falling, no load</td>
<td>2.2</td>
<td>2.4</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Quiescent Supply Current</td>
<td>$I_{VIN}$</td>
<td>SYNC = GND, no load at the output</td>
<td>50</td>
<td></td>
<td></td>
<td>$\mu$A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SYNC = GND, no load at the output and no switches switching</td>
<td>50</td>
<td>60</td>
<td></td>
<td>$\mu$A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SYNC = $V_{IN}$, $F_{SW}$ = 1MHz, no load at the output</td>
<td>8</td>
<td>15</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SYNC = $V_{IN}$, $F_{SW}$ = 2MHz, no load at the output</td>
<td>16</td>
<td>23</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Shutdown Supply Current</td>
<td>$I_{SD}$</td>
<td>SYNC = GND, $V_{IN}$ = 5.5V, EN = low</td>
<td>5</td>
<td>7</td>
<td></td>
<td>$\mu$A</td>
</tr>
</tbody>
</table>

| **OUTPUT REGULATION** | | | | | | |
| Reference Voltage | $V_{REF}$ | | | 0.595 | 0.600 | 0.605 | V |
| VFB Bias Current | $I_{VFB}$ | VFB = 0.75V | | 0.1 | | $\mu$A |
| Line Regulation | | $V_{IN}$ = $V_0$ + 0.5V to 5.5V (minimal 2.7V) | | 0.2 | | %/V |
| Soft-Start Ramp Time Cycle | | SS = SGND | | 1 | | ms |
| Soft-Start Charging Current | $I_{SS}$ | $V_{SS}$ = 0.1V | | 1.45 | 1.85 | 2.25 | $\mu$A |

| **OVERCURRENT PROTECTION** | | | | | | |
| Current Limit Blanking Time | $t_{OCON}$ | | | 17 | | Clock pulses |
| Overcurrent and Auto Restart Period | $t_{OCOFF}$ | | | 8 | | SS cycle |
| Positive Peak Current Limit | $I_{PLIMIT}$ | 5A application | | 6 | 7.5 | 9 | A |
| Peak Skip Limit | $I_{SKIP}$ | 5A application (See "Application Information" on page 18 for more detail) | | 0.8 | 1 | 1.2 | A |
| Zero Cross Threshold | | | | -200 | 200 | | mA |
| Negative Current Limit | $I_{NLIMIT}$ | | | -4.5 | -3 | -1.5 | A |
### Electrical Specifications

Unless otherwise noted, all parameter limits are established over the recommended operating conditions and the typical specification are measured at the following conditions: $T_A = -40^\circ C$ to $+85^\circ C$, $V_{IN} = 3.6V$, $EN = V_{IN}$, unless otherwise noted. Typical values are at $T_A = +25^\circ C$. **Boldface limits apply over the operating temperature range, -40\degree C to +85\degree C. (Continued)**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>TEST CONDITIONS</th>
<th>MIN (Note 8)</th>
<th>TYP</th>
<th>MAX (Note 8)</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COMPENSATION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error Amplifier Trans-Conductance</td>
<td></td>
<td>Internal compensation</td>
<td>60</td>
<td>µA/V</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>External compensation</td>
<td>120</td>
<td>µA/V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trans-Resistance</td>
<td>RT</td>
<td>5A application (test at 3.6V)</td>
<td>0.155</td>
<td></td>
<td>0.195</td>
<td>Ω</td>
</tr>
<tr>
<td><strong>PHASE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-Channel MOSFET ON-Resistance</td>
<td>V_{IN} = 5V, I_{O} = 200mA</td>
<td>36</td>
<td>mΩ</td>
<td>41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N-Channel MOSFET ON-Resistance</td>
<td>V_{IN} = 5V, I_{O} = 200mA</td>
<td>52</td>
<td>mΩ</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>V_{IN} = 2.7V, I_{O} = 200mA</td>
<td>13</td>
<td>mΩ</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>V_{IN} = 2.7V, I_{O} = 200mA</td>
<td>17</td>
<td>mΩ</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>OSCILLATOR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal Switching Frequency</td>
<td>F_{SW}</td>
<td>$F_{SW} = V_{IN}$, ISL8025</td>
<td>800</td>
<td>kHz</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$F_{SW} = V_{IN}$, ISL8025A</td>
<td>1600</td>
<td>kHz</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$F_{SW}$ with $R_S = 402k\Omega$</td>
<td>490</td>
<td>kHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$F_{SW}$ with $R_S = 42.2k\Omega$</td>
<td>4200</td>
<td>kHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SYNC Logic Low-to-High Transition Range</strong></td>
<td></td>
<td>0.70</td>
<td>V</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SYNC Hysteresis</strong></td>
<td></td>
<td>0.15</td>
<td>V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SYNC Logic Input Leakage Current</strong></td>
<td>V_{IN} = 3.6V</td>
<td>3.6</td>
<td>µA</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PG</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Low Voltage</td>
<td></td>
<td>0.3</td>
<td>V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay Time (Rising Edge)</td>
<td></td>
<td>Time from $V_{OUT}$ reached regulation</td>
<td>0.5</td>
<td>ms</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>PG Pin Leakage Current</strong></td>
<td>PG = $V_{IN}$</td>
<td>0.01</td>
<td>µA</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>OVP PG Rising Threshold</strong></td>
<td></td>
<td>0.80</td>
<td>V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>UVP PG Rising Threshold</strong></td>
<td></td>
<td>0.48</td>
<td>V</td>
<td>0.51</td>
<td>0.54</td>
<td></td>
</tr>
<tr>
<td><strong>UVP PG Hysteresis</strong></td>
<td></td>
<td>30</td>
<td>mV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PGOOD Delay Time (Falling Edge)</strong></td>
<td></td>
<td>7.5</td>
<td>µs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>EN</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logic Input Low</td>
<td></td>
<td>0.4</td>
<td>V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logic Input High</td>
<td></td>
<td>0.9</td>
<td>V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>EN Logic Input Leakage Current</strong></td>
<td></td>
<td>Pulled up to 5.5V</td>
<td>0.1</td>
<td>µA</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Thermal Shutdown</strong></td>
<td></td>
<td>Temperature Rising</td>
<td>150</td>
<td>°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Thermal Shutdown Hysteresis</strong></td>
<td></td>
<td>Temperature Falling</td>
<td>25</td>
<td>°C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:**

8. Compliance to datasheet limits is assured by one or more methods: production test, characterization and/or design.
Typical Operating Performance  Unless otherwise noted, operating conditions are: \( T_A = +25^\circ C \), \( V_{IN} = 5V \), \( EN = V_{IN} \), \( SYNC = V_{IN} \), \( L = 1.0\mu H \), \( C_1 = 22\mu F \), \( C_2 = 2 \times 22\mu F \), \( I_{OUT} = 0A \) to \( 5A \). Resistor load is used in the test.

**FIGURE 4. EFFICIENCY vs LOAD (1MHz 3.3V IN PWM)**

**FIGURE 5. EFFICIENCY vs LOAD (1MHz 3.3V IN PFM)**

**FIGURE 6. EFFICIENCY vs LOAD (1MHz 5V IN PWM)**

**FIGURE 7. EFFICIENCY vs LOAD (1MHz 5V IN PFM)**

**FIGURE 8. EFFICIENCY vs LOAD (2MHz 3.3V IN PWM)**

**FIGURE 9. EFFICIENCY vs LOAD (2MHz 3.3V IN PFM)**
Typical Operating Performance  Unless otherwise noted, operating conditions are: $T_A = +25^\circ C$, $V_{IN} = 5V$, $EN = V_{IN}$, $SYNC = V_{IN}$, $L = 1.0\mu H$, $C_1 = 22\mu F$, $C_2 = 2 \times 22\mu F$, $I_{OUT} = 0A$ to $5A$. Resistor load is used in the test (Continued)
**Typical Operating Performance**

Unless otherwise noted, operating conditions are: $T_A = +25^\circ C$, $V_{\text{IN}} = 5V$, $EN = V_{\text{IN}}$, $SYNC = V_{\text{IN}}$, $L = 1.0\mu H$, $C_1 = 22\mu F$, $C_2 = 2 \times 22\mu F$, $I_{\text{OUT}} = 0A$ to $5A$. Resistor load is used in the test (Continued)
Typical Operating Performance

Unless otherwise noted, operating conditions are: $T_A = +25^\circ C$, $V_{IN} = 5V$, $EN = V_{IN}$.

SYNC = $V_{IN}$, $L = 1.0\mu H$, $C_1 = 22\mu F$, $C_2 = 2 \times 22\mu F$, $I_{OUT} = 0A$ to 5A) Resistor load is used in the test.

FIGURE 19. START-UP AT NO LOAD (PFM)

FIGURE 20. START-UP AT NO LOAD (PWM)

FIGURE 21. SHUTDOWN AT NO LOAD (PFM)

FIGURE 22. SHUTDOWN AT NO LOAD (PWM)

FIGURE 23. START-UP AT 5A LOAD (PWM)

FIGURE 24. SHUTDOWN AT 5A LOAD (PWM)
Typical Operating Performance

Unless otherwise noted, operating conditions are: $T_A = +25^\circ C$, $V_{VIN} = 5V$, $EN = V_{IN}$, $SYNC = V_{IN}$, $L = 1.0\mu H$, $C_1 = 22\mu F$, $C_2 = 2 \times 22\mu F$, $I_{OUT} = 0A$ to $5A$) Resistor load is used in the test. (Continued)
**Typical Operating Performance**

Unless otherwise noted, operating conditions are: $T_A = +25^\circ C$, $V_{\text{VIN}} = 5V$, $EN = V_{\text{IN}}$, $SYNC = V_{\text{IN}}$, $L = 1.0\mu H$, $C_1 = 22\mu F$, $C_2 = 2 \times 22\mu F$, $I_{\text{OUT}} = 0A \text{ to } 5A$) Resistor load is used in the test. (Continued)
Typical Operating Performance

Unless otherwise noted, operating conditions are: $T_A = +25^\circ C$, $V_{VIN} = 5V$, $EN = V_{IN}$.

SYNC = $V_{IN}$, $L = 1.0\mu H$, $C_1 = 22\mu F$, $C_2 = 2 \times 22\mu F$, $I_{OUT} = 0A$ to $5A$) Resistor load is used in the test. (Continued)
Typical Operating Performance  Unless otherwise noted, operating conditions are: \(T_A = +25^\circ C, V_{IN} = 5V, EN = V_{IN}\). \(SYNC = V_{IN}, L = 1.0\mu H, C_1 = 22\mu F, C_2 = 2 \times 22\mu F, I_{OUT} = 0A \text{ to } 5A\) Resistor load is used in the test. (Continued)
Theory of Operation

The ISL8025, ISL8025A are step-down switching regulators optimized for battery-powered applications. The regulators operate at 1MHz or 2MHz fixed default switching frequency for high efficiency and allow smaller form factor, when FS is connected to VIN. By connecting a resistor from FS to SGND, the operational frequency adjustable range is 500kHz to 4MHz. At light load, the regulator reduces the switching frequency, unless forced to the fixed frequency, to minimize the switching loss and to maximize the battery life. The quiescent current when the output is not loaded is typically only 50µA. The supply current is typically only 5µA when the regulator is shut down.

PWM Control Scheme

Pulling the SYNC pin HI (>0.8V) forces the converter into PWM mode, regardless of output current. The ISL8025, ISL8025A employs the current-mode pulse-width modulation (PWM) control scheme for fast transient response and pulse-by-pulse current limiting. Figure 3 on page 5 shows the Functional Block Diagram. The current loop consists of the oscillator, the PWM comparator, current sensing circuit and the slope compensation for the current loop stability. The slope compensation is 440mV/Ts, which changes with frequency. The gain for the current sensing circuit is typically 200mV/A. The control reference for the current loops comes from the error amplifier's (EAMP) output.

The PWM operation is initialized by the clock from the oscillator. The P-Channel MOSFET is turned on at the beginning of a PWM cycle and the current in the MOSFET starts to ramp up. When the sum of the current amplifier CSA and the slope compensation reaches the control reference of the current loop, the PWM comparator COMP sends a signal to the PWM logic to turn off the P-FET and turn on the N-Channel MOSFET. The N-FET stays on until the end of the PWM cycle. Figure 48 shows the typical operating waveforms during the PWM operation. The dotted lines illustrate the sum of the slope compensation ramp and the current-sense amplifier’s CSA output.

The output voltage is regulated by controlling the $V_{EAMP}$ voltage to the current loop. The bandgap circuit outputs a 0.6V reference voltage to the voltage loop. The feedback signal comes from the VFB pin. The soft-start block only affects the operation during the start-up and will be discussed separately. The error amplifier is a transconductance amplifier that converts the voltage error signal to a current output. The voltage loop is internally compensated with the 55pF and 100kΩ RC network. The maximum EAMP voltage output is precisely clamped to 1.6V.

SKIP Mode

Pulling the SYNC pin LO (<0.4V) forces the converter into PFM mode. The ISL8025, ISL8025A enters a pulse-skipping mode at light load to minimize the switching loss by reducing the switching frequency. Figure 49 illustrates the skip-mode operation. A zero-cross sensing circuit shown in Figure 3 on page 5 monitors the N-FET current for zero crossing. When 16 consecutive cycles are detected, the regulator enters the skip mode. During the sixteen detecting cycles, the current in the inductor is allowed to become negative. The counter is reset to zero when the current in any cycle does not cross zero.

Once the skip mode is entered, the pulse modulation starts being controlled by the SKIP comparator shown in Figure 3 on page 5. Each pulse cycle is still synchronized by the PWM clock. The P-FET is turned on at the clock’s rising edge and turned off when the output is higher than 1.2% of the nominal regulation or when its current reaches the peak Skip current limit value. Then, the inductor current is discharging to 0A and stays at zero (the internal clock is disabled), and the output voltage reduces gradually due to the load current discharging the output capacitor. When the output voltage drops to the nominal voltage, the P-FET will be turned on again at the rising edge of the internal clock as it repeats the previous operations.

The regulator resumes normal PWM mode operation when the output voltage drops 2.5% (1.2% for 2MHz) below the nominal voltage.
Frequency Adjust

The frequency of operation is fixed at 1MHz when FS is tied to VIN. Adjustable frequency ranges from 500kHz to 4MHz via a simple resistor connecting FS to SGND, according to Equation 2:

$$R_{FS}[\Omega] = \frac{220 \times 10^3}{f_{OSC}[kHz]} - 14$$  \hspace{1cm} (EQ. 2)

Overcurrent Protection

The overcurrent protection is realized by monitoring the CSA output with the OCP comparator, as shown in Figure 3. The current sensing circuit has a gain of 200mV/A, from the P-FET current to the CSA output. When the CSA output reaches the threshold, the OCP comparator is tripped to turn off the P-FET immediately. The overcurrent function protects the switching converter from a shorted output by monitoring the current flowing through the upper MOSFET.

Upon detection of an overcurrent condition, the upper MOSFET will be immediately turned off and will not be turned on again until the next switching cycle. Upon detection of the initial overcurrent condition, the overcurrent fault counter is set to 1. If, on the subsequent cycle, another overcurrent condition is detected, the OC fault counter will be incremented. If there are 17 sequential OC fault detections, the regulator will be shut down under an overcurrent fault condition. An overcurrent fault condition will result in the regulator attempting to restart in a hiccup mode within the delay of eight soft-start periods. At the end of the 8th soft-start wait period, the fault counters are reset and soft-start is attempted again. If the overcurrent condition goes away during the delay of 8 soft-start periods, the output will resume back into regulation point after hiccup mode expires.

Negative Current Protection

Similar to overcurrent, the negative current protection is realized by monitoring the current across the low-side N-FET, as shown in Figure 3 on page 5. When the valley point of the inductor current reaches -3A for 4 consecutive cycles, both P-FET and N-FET are off. The 100Ω in parallel to the N-FET will activate discharging the output into regulation. The control will begin to switch when output is within regulation. The regulator will be in PFM for 20μs before switching to PWM if necessary.

PG

PG is an open-drain output of a window comparator that continuously monitors the buck regulator output voltage. PG is actively held low when EN is low and during the buck regulator soft-start period. After 1ms delay of the soft-start period, PG becomes high impedance as long as the output voltage is within nominal regulation voltage set by VFB. When VFB drops 15% below or raises 0.8V above the nominal regulation voltage, the ISL8025, ISL8025A pulls PG low. Any fault condition forces PG low until the fault condition is cleared by attempts to soft-start. For logic level output voltages, connect an external pull-up resistor, R1, between PG and VIN. A 100kΩ resistor works well in most applications.

UVLO

When the input voltage is below the undervoltage lock-out (UVLO) threshold, the regulator is disabled.

Soft Start-Up

The soft-start-up reduces the in-rush current during the start-up. The soft-start block outputs a ramp reference to the input of the error amplifier. This voltage ramp limits the inductor current as well as the output voltage speed, so that the output voltage rises in a controlled fashion. When VFB is less than 0.1V at the beginning of the soft-start, the switching frequency is reduced to 200kHz, so that the output can start-up smoothly at light load condition. During soft-start, the IC operates in the SKIP mode to support pre-biased output condition.

Tie SS to SGND for internal soft-start is approximately 1ms. Connect a capacitor from SS to SGND to adjust the soft-start time. This capacitor, along with an internal 1.85μA current source sets the soft-start interval of the converter, \(t_{SS}\), as shown by Equation 3.

$$C_{SS}[\mu F] = 3.1 \cdot t_{SS}[s]$$  \hspace{1cm} (EQ. 3)

\(C_{SS}\) must be less than 33nF to insure proper soft-start reset after fault condition.

Enable

The enable (EN) input allows the user to control the turning on or off of the regulator for purposes, such as power-up sequencing. When the regulator is enabled, there is typically a 600μs delay for waking up the bandgap reference and then the soft-start-up begins.
Discharge Mode (Soft-Stop)
When a transition to shutdown mode occurs or the VIN UVLO is set, the outputs discharge to GND through an internal 100Ω switch.

Power MOSFETs
The power MOSFETs are optimized for best efficiency. The ON-resistance for the P-FET is typically 36mΩ and the ON-resistance for the N-FET is typically 13mΩ.

100% Duty Cycle
The ISL8025, ISL8025A features a 100% duty cycle operation to maximize the battery life. When the battery voltage drops to a level that the ISL8025, ISL8025A can no longer maintain the regulation at the output, the regulator completely turns on the P-FET. The maximum dropout voltage under the 100% duty-cycle operation is the product of the load current and the ON-resistance of the P-FET.

Thermal Shut-Down
The ISL8025, ISL8025A has built-in thermal protection. When the internal temperature reaches +150 °C, the regulator is completely shut down. As the temperature drops to +125 °C, the ISL8025, ISL8025A resumes operation by stepping through the soft-start.

Application Information
Output Inductor and Capacitor Selection
To consider steady state and transient operations, the ISL8025 typically uses a 1.0µH output inductor and the ISL8025A uses a 0.47µH. The higher or lower inductor value can be used to optimize the total converter system performance. For example, for higher output voltage 3.3V application, in order to decrease the inductor current ripple and output voltage ripple, the output inductor value can be increased. It is recommended to set the inductor current ripple approximately 30% of the maximum output current for optimized performance. The inductor ripple current can be expressed, as shown in Equation 4:

\[
\Delta I = \frac{V_D \cdot (1 - \frac{V_O}{V_IN})}{L \cdot f_S} \quad (EQ. 4)
\]

The inductor’s saturation current rating needs to be at least larger than the peak current. The ISL8025, ISL8025A protects the typical peak current 6A. The saturation current needs to be over 7A for maximum output current application.

The ISL8025, ISL8025A uses an internal compensation network and the output capacitor value is dependent on the output voltage. The ceramic capacitor is recommended to be X5R or X7R. The recommended X5R or X7R minimum output capacitor values are shown in Table 2.

In Table 2, the minimum output capacitor value is given for the different output voltage to make sure that the whole converter system is stable. Additional output capacitance should be added for better performances in applications where high load transient or low output ripple is required. It is recommended to check the system level performance along with the simulation model.

Output Voltage Selection
The output voltage of the regulator can be programmed via an external resistor divider that is used to scale the output voltage, relative to the internal reference voltage, and feed it back to the inverting input of the error amplifier (refer to Figure 1).

The output voltage programming resistor, \( R_2 \), will depend on the value chosen for the feedback resistor and the desired output voltage of the regulator. The value for the feedback resistor, \( R_3 \), is typically between 10kΩ and 100kΩ, as shown in Equation 5.

\[
R_2 = R_3 \left( \frac{V_O}{V_{FB}} - 1 \right) \quad (EQ. 5)
\]

If the output voltage desired is 0.6V, then \( R_3 \) is left unpopulated and \( R_2 \) is shorted. There is a leakage current from \( V_{IN} \) to PHASE. It is recommended to preload the output with 10µA minimum. For better performance, add 22pF in parallel with \( R_2 \) (200kΩ). Check loop analysis before use in application.

Input Capacitor Selection
The main functions for the input capacitor are to provide decoupling of the parasitic inductance and to provide a filtering function to prevent the switching current flowing back to the battery rail. At least two 22µF X5R or X7R ceramic capacitors are a good starting point for the input capacitor selection.

Loop Compensation Design
When COMP is not connected to VDD, the COMP pin is active for external loop compensation. The ISL8025, ISL8025A uses constant frequency peak current mode control architecture to achieve a fast loop transient response. An accurate current sensing pilot device in parallel with the upper MOSFET is used for peak current control signal and overcurrent protection. The inductor is not considered as a state variable since its peak current is constant, and the system becomes a single order system. It is much easier to design a type II compensator to stabilize the loop than to implement voltage mode control. Peak current mode control has an inherent input voltage feed-forward function to achieve good line regulation. Figure 50 shows the small signal model of the synchronous buck regulator.
Figure 51 shows the type II compensator and its transfer function is expressed, as shown in Equation 6:

\[
A_V(S) = \frac{V_{\text{comp}}}{V_{\text{FB}}} = \frac{\text{GM} \cdot R_3}{(C_6 + C_7) \cdot (R_2 + R_3)} \left(1 + \frac{S}{\omega_{c1}}\right) \left(1 + \frac{S}{\omega_{c2}}\right) S \left(1 + \frac{S}{\omega_{cp1}}\right) \left(1 + \frac{S}{\omega_{cp2}}\right)
\]  

where,

\[
\omega_{c1} = \frac{1}{R_6 C_6}, \quad \omega_{c2} = \frac{1}{R_2 C_3}, \quad \omega_{cp1} = \frac{C_6 + C_7}{R_6 C_6 C_7}, \quad \omega_{cp2} = \frac{R_2 + R_3}{C_3 R_2 R_3}
\]

Compensator design goal:

High DC gain

Choose Loop bandwidth \(f_c\) less than 100kHz

Gain margin: >10dB

Phase margin: >40°

The compensator design procedure is as follows:

The loop gain at crossover frequency of \(f_c\) has a unity gain. Therefore, the compensator resistance \(R_6\) is determined by Equation 7.

\[
R_6 = \frac{2\pi f_c V_O C_0 R_1}{\text{GM} \cdot V_{\text{FB}}} = 15.3 \times 10^{-3} \cdot f_c V_O C_0
\]  

Where GM is the sum of the trans-conductance, \(g_m\), of the voltage error amplifier in each phase. Compensator capacitor \(C_6\) is then given by Equation 8.

\[
C_6 = \frac{R_6 C_0}{R_6} = \frac{V_O C_0}{I_o R_6 C_7} = \max\left(\frac{R_6 C_0}{R_6}, \frac{1}{\pi f_c R_6}\right)
\]  

Put one compensator pole at zero frequency to achieve high DC gain, and put another compensator pole at either ESR zero frequency or half switching frequency, whichever is lower in Equation 8. An optional zero can boost the phase margin. \(\omega_{cz2}\) is a zero due to \(R_2\) and \(C_3\).

Put compensator zero 2 to 5 times \(f_c\)

\[
C_3 = \frac{1}{\pi f_c R_2}
\]  

Example: \(V_{IN} = 5V, V_O = 1.8V, I_O = 5A, f_s = 1MHz, R_2 = 200k\Omega, R_3 = 100k\Omega, C_0 = 2x22\mu F/3m\Omega, L = 1\mu H, f_c = 100kHz\), then compensator resistance \(R_6\):

\[
R_6 = 15.3 \times 10^{-3} \cdot 100kHz \cdot 1.8V \cdot 44\mu F = 121k\Omega
\]  

\[
C_6 = \frac{1.8V \cdot 44\mu F}{5A \cdot 121k\Omega} = 131pF
\]  

\[
C_7 = \max\left(\frac{3m\Omega \cdot 44\mu F}{121k\Omega}, \frac{1}{\pi \cdot 1MHz(121k\Omega)}\right) = (1pF, 2.6pF)
\]  

It is also acceptable to use the closest standard values for \(C_6\) and \(C_7\). There is approximately 3pF parasitic capacitance from \(V_{COMP}\) to GND; Therefore, \(C_7\) is optional. Use \(C_6 = 150pF\) and \(C_7 = \text{OPEN}\).

Use \(C_3 = 15pF\). Note that \(C_3\) may increase the loop bandwidth from previous estimated value. Figure 52 shows the simulated voltage loop gain. It is shown that it has a 150kHz loop bandwidth with a 42° phase margin and 10dB gain margin. It may be more desirable to achieve an increased phase margin. This can be accomplished by lowering \(R_6\) by 20% to 30%.

![Figure 51. Type II Compensator](image)

![Figure 52. Simulated Loop Gain](image)
PCB Layout Recommendation

The PCB layout is a very important converter design step to make sure the designed converter works well. For ISL8025, ISL8025A, the power loop is composed of the output inductor L's, the output capacitor (COUT), the PHASE pins, and the PGND pin. It is necessary to make the power loop as small as possible and the connecting traces among them should be direct, short and wide. The switching node of the converter, the PHASE pins, and the traces connected to the node are very noisy, so keep the voltage feedback trace away from these noisy traces. The input capacitor should be placed as close as possible to the VIN pin. The ground of input and output capacitors should be connected as close as possible. The heat of the IC is mainly dissipated through the thermal pad. Maximizing the copper area connected to the thermal pad is preferable. In addition, a solid ground plane is helpful for better EMI performance. It is recommended to add at least 5 vias ground connection within the pad for the best thermal relief.
About Intersil

Intersil Corporation is a leader in the design and manufacture of high-performance analog, mixed-signal and power management semiconductors. The company’s products address some of the largest markets within the industrial and infrastructure, personal computing and high-end consumer markets. For more information about Intersil, visit our website at www.intersil.com.

Package Outline Drawing

L16.3x3D
16 LEAD THIN QUAD FLAT NO-LEAD PLASTIC PACKAGE
Rev 0, 3/10

NOTES:

1. Dimensions are in millimeters. Dimensions in ( ) for Reference Only.
3. Unless otherwise specified, tolerance: Decimal ± 0.05
4. Dimension applies to the metallized terminal and is measured between 0.15mm and 0.25mm from the terminal tip.
5. Tiebar shown (if present) is a non-functional feature.
6. The configuration of the pin #1 identifier is optional, but must be located within the zone indicated. The pin #1 identifier may be either a mold or mark feature.
7. JEDEC reference drawing: MO-220 WEED.