DESCRIPTION

The HF500-7 is a fixed-frequency, current-mode regulator with built-in slope compensation. The HF500-7 combines a 700V MOSFET and a full-featured controller into one chip for a low-power, offline, flyback, switch-mode power supply.

At medium and heavy loads, the regulator works in a fixed frequency with frequency jittering, which helps spread energy out in a conducted mode. During a light-load condition, the regulator freezes the peak current and reduces its switching frequency to \( f_{\text{osc(min)}} \) to offer excellent efficiency at light load. At very light loads, the regulator enters burst mode to achieve low standby power consumption.

Full protection features include thermal shutdown, brown-in and brown-out, VCC undervoltage lockout (UVLO), overload protection (OLP), short-circuit protection (SCP), input and output over-voltage protection (OVP), and over-temperature protection (OTP).

The HF500-7 features timer-based fault detection and over-power compensation to ensure that the overload protection point is independent of the input voltage. The HF500-7 can also be self-supplied without any auxiliary winding to save BOM cost.

The HF500-7 is available in a SOIC8-7B package.

FEATURES

- 700V/12Ω Integrated MOSFET
- Fixed-Frequency Current-Mode Control Operation with Built-In Slope Compensation
- Frequency Foldback Down to \( f_{\text{osc(min)}} \) at Light Load
- Burst Mode for Low Standby Power Consumption
- Frequency Jittering for a Reduced EMI Signature
- Over-Power Compensation
- Internal High-Voltage Current Source
- Self-Supplied without Auxiliary Winding
- VCC Under-Voltage Lockout (UVLO) with Hysteresis
- Programmable Input B/O and Over-Voltage Protection (OVP)
- Overload Protection (OLP) with a Programmable Delay
- Latch-Off Protection on TIMER
- Thermal Shutdown (Auto-Restart with Hysteresis)
- Short-Circuit Protection (SCP)
- Programmable Soft Start (SS)
- Available in a SOIC8-7B Package

APPLICATIONS

- Power Supplies for Home Appliances
- Standby and Auxiliary Power
- Adapters

### Maximum Output Power (1)

<table>
<thead>
<tr>
<th>Vcc external supplied</th>
<th>230Vac±15%</th>
<th>85Vac–265Vac</th>
<th>Vcc self-supplied</th>
<th>115Vac±15%</th>
<th>230Vac±15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adapter (2) Open Frame (3)</td>
<td>6.5W</td>
<td>7W</td>
<td>6W</td>
<td>6.5W</td>
<td></td>
</tr>
<tr>
<td>Adapter (2) Open Frame (3)</td>
<td>5W</td>
<td>2W</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTES:

1) The junction temperature can limit the maximum output power.
2) Maximum continuous power in a non-ventilated enclosed adapter measured at 50° C ambient temperature.
3) Maximum continuous power in an open frame design at 50°C ambient temperature.
TYPICAL APPLICATION

VCC Supplied by Auxiliary Winding and Adopted Brown-In/-Out Function

VCC Self-Supplied and Disabled Brown-In/-Out Function
### ORDERING INFORMATION

<table>
<thead>
<tr>
<th>Part Number*</th>
<th>Package</th>
<th>Top Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF500GS-7</td>
<td>SOIC8-7B</td>
<td>See Below</td>
</tr>
</tbody>
</table>

* For Tape & Reel, add suffix –Z (e.g. HF500GS-7–Z)

### TOP MARKING

```
HF500-7
LLLLLLLLL
MPSYWW
```

HF500-7: Part number
LLLLLLLL: Lot number
MPS: MPS prefix
Y: Year code
WW: Week code

### PACKAGE REFERENCE

![TOP VIEW]

- **FB**
- **VCC**
- **DRAIN**
- **O**
- **TIMER**
- **B/O**
- **GND**
- **SOURCE**

**SOIC8-7B**
**ABSOLUTE MAXIMUM RATINGS**

1. **DRAIN breakdown voltage**
   - -0.3V to 700V

2. **VCC to GND**
   - -0.3V to 30V

3. **FB, TIMER, SOURCE, B/O to GND**
   - -0.3V to 7V

**Continuous power dissipation** ($T_A = +25^\circ C$)

- 1.5W

**Junction temperature**
- 150°C

**Lead temperature**
- 260°C

**Storage temperature**
- -60°C to +150°C

**ESD capability human body model** (all pins except DRAIN)

- 4.0kV

**ESD capability machine model**
- 200V

**Recommended Operating Conditions**

- **Operating junction temp.** ($T_J$)
  - -40°C to +125°C

- **Operating VCC range**
  - 12.5V to 24V

---

**NOTES:**

1. Exceeding these ratings may damage the device.

2. The maximum allowable power dissipation is a function of the maximum junction temperature ($T_J$ (MAX)), the junction-to-ambient thermal resistance ($\theta_{JA}$), and the ambient temperature ($T_A$). The maximum allowable continuous power dissipation at any ambient temperature is calculated by $P_{D} (\text{MAX}) = \frac{(T_J (\text{MAX}) - T_A)}{\theta_{JA}}$. Exceeding the maximum allowable power dissipation produces an excessive die temperature, causing the regulator to go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.

3. The device is not guaranteed to function outside of its operating conditions.

4. Measured on JESD51-7, 4-layer PCB.

---

**Thermal Resistance**

- $\theta_{JA}$
- 85°C/W

- $\theta_{JC}$
- 40°C/W

**SOIC8-7B**

---
**ELECTRICAL CHARACTERISTICS** (5)
For typical value, VCC = 16V, TJ = -40°C to 125°C, unless otherwise noted.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Start-Up Current Source (DRAIN)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply current from DRAIN</td>
<td>IDrain,0</td>
<td>VCC = 0V, VDRAIN = 120V/400V</td>
<td>1.4</td>
<td>3.6</td>
<td>6.2</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>IDrain,11</td>
<td>VCC = 11V, VDRAIN = 120V/400V</td>
<td>1.4</td>
<td>5</td>
<td>7.8</td>
<td>mA</td>
</tr>
<tr>
<td>Leakage current from DRAIN</td>
<td>ILK</td>
<td>VCC = 10V, VDRAIN = 400V</td>
<td>4.5</td>
<td>10.5</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>Breakdown voltage</td>
<td>VBR</td>
<td>TJ = 25°C</td>
<td>700</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td><strong>Internal MOSFET (DRAIN)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-state resistance</td>
<td>RDS_ON</td>
<td>VCC = 10.5V, ID = 0.1A, TJ = 25°C</td>
<td>12</td>
<td>15.5</td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td><strong>Supply Voltage Management (VCC)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VCC level (increasing) where the internal regulator stops</td>
<td>VCCOFF</td>
<td></td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>V</td>
</tr>
<tr>
<td>VCC level (decreasing) where the IC shuts down and the internal regulator turns on</td>
<td>VCCUVLO</td>
<td></td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>V</td>
</tr>
<tr>
<td>VCC level (decreasing) where the internal regulator turns on</td>
<td>VCCON</td>
<td></td>
<td>10.4</td>
<td>11.5</td>
<td>12.6</td>
<td>V</td>
</tr>
<tr>
<td>VCC regulator on and off hysteresis</td>
<td>VHYST</td>
<td></td>
<td>400</td>
<td>500</td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>VCC UVLO hysteresis</td>
<td>VCCOFF - VCCUVLO</td>
<td></td>
<td>4</td>
<td>4.8</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>VCC recharge level when protection occurs</td>
<td>VCCPRO</td>
<td></td>
<td>4.7</td>
<td>5.3</td>
<td>5.9</td>
<td>V</td>
</tr>
<tr>
<td>VCC decreasing level where the latch-off phase ends</td>
<td>VCCLATCH</td>
<td></td>
<td>2.5</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Internal IC consumption</td>
<td>ICC</td>
<td>VFB = 3V, VCC = 12V</td>
<td>0.9</td>
<td>1.2</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Internal IC consumption, latch-off phase</td>
<td>ICCLATCH</td>
<td>VCC = 12V, TJ = 25°C</td>
<td>700</td>
<td>900</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>Voltage on VCC (upper limit) where the regulator latches off (OVP)</td>
<td>VOVP</td>
<td>VFB = 1.85V, TJ = 25°C</td>
<td>25</td>
<td>27</td>
<td>29</td>
<td>V</td>
</tr>
<tr>
<td>Blanking duration on the OVP comparator</td>
<td>TOVP</td>
<td></td>
<td>60</td>
<td></td>
<td></td>
<td>ms</td>
</tr>
<tr>
<td><strong>Oscillator</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oscillator frequency</td>
<td>fOSC</td>
<td>VFB &gt; 1.85V, TJ = 25°C</td>
<td>62</td>
<td>65</td>
<td>68</td>
<td>kHz</td>
</tr>
<tr>
<td>Frequency jittering amplitude in percentage of fOSC</td>
<td>AJitter</td>
<td>VFB &gt; 1.85V, TJ = 25°C</td>
<td>±5</td>
<td>±6.5</td>
<td>±8</td>
<td>%</td>
</tr>
<tr>
<td>Frequency jittering entry level</td>
<td>VFBJITTER</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Frequency jittering modulation period</td>
<td>TJITTER</td>
<td>CTIMER = 47nF</td>
<td>3.7</td>
<td></td>
<td></td>
<td>ms</td>
</tr>
</tbody>
</table>
ELECTRICAL CHARACTERISTICS (5) *(continued)*  
For typical value, VCC = 16V, TJ = -40°C to 125°C, unless otherwise noted.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protections (B/O)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown-in threshold voltage on B/O</td>
<td>V&lt;sub&gt;B/O_IN&lt;/sub&gt;</td>
<td>V&lt;sub&gt;B/O&lt;/sub&gt; increasing</td>
<td>0.95</td>
<td>1</td>
<td>1.05</td>
<td>V</td>
</tr>
<tr>
<td>Brownout threshold voltage on B/O</td>
<td>V&lt;sub&gt;B/O_OUT&lt;/sub&gt;</td>
<td>V&lt;sub&gt;B/O&lt;/sub&gt; decreasing</td>
<td>0.85</td>
<td>0.9</td>
<td>0.95</td>
<td>V</td>
</tr>
<tr>
<td>Brown-in/-out hysteresis</td>
<td>ΔV&lt;sub&gt;B/O&lt;/sub&gt;</td>
<td></td>
<td>0.065</td>
<td>0.1</td>
<td>0.14</td>
<td>V</td>
</tr>
<tr>
<td>Timer duration for line cycle dropout</td>
<td>T&lt;sub&gt;B/O&lt;/sub&gt;</td>
<td>C&lt;sub&gt;TIMER&lt;/sub&gt; = 47nF</td>
<td>34</td>
<td>55</td>
<td></td>
<td>ms</td>
</tr>
<tr>
<td>Input OVP threshold on B/O</td>
<td>OVP&lt;sub&gt;B/O&lt;/sub&gt;</td>
<td></td>
<td>4.2</td>
<td>4.5</td>
<td>4.8</td>
<td>V</td>
</tr>
<tr>
<td>Input OVP delay time</td>
<td>TOVPB/O</td>
<td></td>
<td>90</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>Voltage on B/O to disable B/O and input OVP function</td>
<td>V&lt;sub&gt;DIS&lt;/sub&gt;</td>
<td></td>
<td>5.4</td>
<td>6</td>
<td>6.6</td>
<td>V</td>
</tr>
<tr>
<td>Clamp voltage on B/O</td>
<td>V&lt;sub&gt;B/O_Cla&lt;/sub&gt;</td>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Input impedance</td>
<td>R&lt;sub&gt;B/O&lt;/sub&gt;</td>
<td></td>
<td>1.2</td>
<td></td>
<td></td>
<td>MΩ</td>
</tr>
<tr>
<td>Current Sense (SOURCE)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current-limit point</td>
<td>V&lt;sub&gt;ILIM&lt;/sub&gt;</td>
<td></td>
<td>0.93</td>
<td>1</td>
<td>1.07</td>
<td>V</td>
</tr>
<tr>
<td>Short-circuit protection point</td>
<td>V&lt;sub&gt;SCP&lt;/sub&gt;</td>
<td></td>
<td>1.3</td>
<td>1.5</td>
<td>1.7</td>
<td>V</td>
</tr>
<tr>
<td>Current limitation during frequency foldback</td>
<td>V&lt;sub&gt;FOLD&lt;/sub&gt;</td>
<td>V&lt;sub&gt;FB&lt;/sub&gt; = 1.85V</td>
<td>0.63</td>
<td>0.68</td>
<td>0.73</td>
<td>V</td>
</tr>
<tr>
<td>Current limitation when entering burst</td>
<td>V&lt;sub&gt;IBURL&lt;/sub&gt;</td>
<td>V&lt;sub&gt;FB&lt;/sub&gt; = 0.7V</td>
<td>0.18</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Current limitation when exiting burst</td>
<td>V&lt;sub&gt;IBURH&lt;/sub&gt;</td>
<td>V&lt;sub&gt;FB&lt;/sub&gt; = 0.8V</td>
<td>0.23</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Leading-edge blanking for V&lt;sub&gt;ILIM&lt;/sub&gt;</td>
<td>T&lt;sub&gt;LEB1&lt;/sub&gt;</td>
<td></td>
<td>350</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>Leading-edge blanking for V&lt;sub&gt;SCP&lt;/sub&gt;</td>
<td>T&lt;sub&gt;LEB2&lt;/sub&gt;</td>
<td></td>
<td>270</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>Slope of the compensation ramp</td>
<td>S&lt;sub&gt;RAMP&lt;/sub&gt;</td>
<td></td>
<td>18</td>
<td>25</td>
<td>31</td>
<td>mV/μs</td>
</tr>
<tr>
<td>Feedback (FB)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal pull-up resistor</td>
<td>R&lt;sub&gt;FB&lt;/sub&gt;</td>
<td>TJ = 25°C</td>
<td>12</td>
<td>13.5</td>
<td>15</td>
<td>kΩ</td>
</tr>
<tr>
<td>Internal pull-up voltage</td>
<td>V&lt;sub&gt;DD&lt;/sub&gt;</td>
<td></td>
<td>4.3</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>V&lt;sub&gt;FB&lt;/sub&gt; to internal current-set point division ratio</td>
<td>K&lt;sub&gt;FB1&lt;/sub&gt;</td>
<td>V&lt;sub&gt;FB&lt;/sub&gt; = 2V</td>
<td>2.5</td>
<td>2.8</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>V&lt;sub&gt;FB&lt;/sub&gt; to current-set point division ratio</td>
<td>K&lt;sub&gt;FB2&lt;/sub&gt;</td>
<td>V&lt;sub&gt;FB&lt;/sub&gt; = 3V</td>
<td>2.8</td>
<td>3.1</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td>FB level (decreasing) where the regulator enters burst mode</td>
<td>V&lt;sub&gt;BURL&lt;/sub&gt;</td>
<td></td>
<td>0.63</td>
<td>0.7</td>
<td>0.77</td>
<td>V</td>
</tr>
<tr>
<td>FB level (increasing) where the regulator exits burst mode</td>
<td>V&lt;sub&gt;BURH&lt;/sub&gt;</td>
<td></td>
<td>0.72</td>
<td>0.8</td>
<td>0.88</td>
<td>V</td>
</tr>
<tr>
<td>Overload Protection (FB)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FB level where the regulator enters OLP after a dedicated time</td>
<td>V&lt;sub&gt;OLP&lt;/sub&gt;</td>
<td></td>
<td>3.7</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Time duration before OLP when FB reaches the protection point</td>
<td>T&lt;sub&gt;OLP&lt;/sub&gt;</td>
<td>C&lt;sub&gt;TIMER&lt;/sub&gt; = 47nF</td>
<td>32</td>
<td></td>
<td></td>
<td>ms</td>
</tr>
</tbody>
</table>
ELECTRICAL CHARACTERISTICS (5) *(continued)*
For typical value, VCC = 16V, TJ = -40°C to 125°C, unless otherwise noted.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over-Power Compensation (B/O)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compensation voltage</td>
<td>V\text{OPC}</td>
<td>V_{B/O} = 1.1V, V_{FB} = 2.5V, TJ = 25°C</td>
<td>0</td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_{B/O} = 1.3V, V_{FB} = 2.5V, TJ = 25°C</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_{B/O} = 2.9V, V_{FB} = 2.5V, TJ = 25°C</td>
<td>153</td>
<td>200</td>
<td>247</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_{B/O} = 3.5V, V_{FB} = 2.5V, TJ = 25°C</td>
<td>205</td>
<td>270</td>
<td>335</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_{B/O} &gt; V_{DIS}, TJ = 25°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FB voltage (lower limit) when compensation is removed</td>
<td>V_{OPC(OFF)}</td>
<td></td>
<td>0.55</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>FB voltage (upper limit) when compensation is fully applied</td>
<td>V_{OPC(ON)}</td>
<td></td>
<td></td>
<td>2.5</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Frequency Foldback</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FB voltage (lower threshold) when frequency foldback starts</td>
<td>V_{FB(FOLD)}</td>
<td></td>
<td>1.8</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Minimum switching frequency</td>
<td>f_{OSC(min)}</td>
<td>TJ = 25°C</td>
<td>20.5</td>
<td>25</td>
<td>30</td>
<td>kHz</td>
</tr>
<tr>
<td>FB voltage (lower threshold) when frequency foldback ends</td>
<td>V_{FB(FOLDE)}</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Latch-Off Input (Integration in TIMER)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower threshold when the regulator is latched</td>
<td>V_{TIMER(LATCH)}</td>
<td></td>
<td>0.7</td>
<td>1</td>
<td>1.2</td>
<td>V</td>
</tr>
<tr>
<td>Blanking duration on latch detection</td>
<td>T_{LATCH}</td>
<td></td>
<td>42</td>
<td></td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td>Thermal Shutdown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal shutdown threshold</td>
<td>T_{TSD}</td>
<td></td>
<td>150</td>
<td></td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>Thermal shutdown hysteresis</td>
<td>T_{TSD(HYS)}</td>
<td></td>
<td>25</td>
<td></td>
<td></td>
<td>°C</td>
</tr>
</tbody>
</table>
TYPICAL CHARACTERISTICS

- **LKGDRAIN** vs. **Temperature Chart**
- **BV_DRAIN** vs. **Temperature Chart**
- **I_DRAIN_0** vs. **Temperature Chart**
- **I_DRAIN_11** vs. **Temperature Chart**
- **V_OPC4** vs. **Temperature Chart**
- **VCC_OFF** vs. **Temperature Chart**
- **VCC_UVLO** vs. **Temperature Chart**
- **VCC_OVP** vs. **Temperature Chart**
- **VCC_Latch** vs. **Temperature Chart**
TYPICAL CHARACTERISTICS (continued)

- **VCC_PRO vs. Temperature**
- **VBO_IN vs. Temperature**
- **VBO_OUT vs. Temperature**
- **BO_OVP vs. Temperature**
- **VDIS vs. Temperature**
- **V_BURL vs. Temperature**
- **V_BURH vs. Temperature**
- **V_IBURL vs. Temperature**
- **V_IBURH vs. Temperature**
TYPICAL CHARACTERISTICS (continued)

- **VFB_OLP vs. Temperature**
- **VCS_MAX vs. Temperature**
- **V_SCP vs. Temperature**
- **F_OSC vs. Temperature**
- **F_OSC_MIN vs. Temperature**
- **Slope_Comp vs. Temperature**
- **T_LEB1 vs. Temperature**
- **T_LEB2_LOW vs. Temperature**
- **RDS_ON vs. Temperature**
TYPICAL PERFORMANCE CHARACTERISTICS

\[ V_{\text{IN}} = 230V_{\text{AC}}, \ V_{\text{OUT1}}/V_{\text{OUT2}} = 12V/5V, \ I_{\text{OUT1}}/I_{\text{OUT2}} = 0.3A/0.3A, \] unless otherwise noted.

**Input Power On**

- \( V_{\text{BUS}} \)
- \( V_{\text{DS}} \)
- \( V_{\text{OUT1}} \)
- \( V_{\text{OUT2}} \)

20ms/div.

**Input Power Off**

- \( V_{\text{DS}} \)
- \( V_{\text{OUT1}} \)
- \( V_{\text{OUT2}} \)

20ms/div.

**Output Ripple**

- \( V_{\text{OUT1}} \)
- \( V_{\text{OUT2}} \)

10µs/div.

---

**SCP Power On**

- \( V_{\text{DS}} \)
- \( V_{\text{OUT1}} \)
- \( V_{\text{OUT2}} \)

200ms/div.

**SCP Power Off**

- \( V_{\text{DS}} \)
- \( V_{\text{OUT1}} \)
- \( V_{\text{OUT2}} \)

200ms/div.

**SCP Release**

- \( V_{\text{OUT1}} \)
- \( V_{\text{OUT2}} \)

200ms/div.

---

**OLP Entry, No Load**

- \( V_{\text{DS}} \)
- \( V_{\text{OUT1}} \)
- \( V_{\text{OUT2}} \)

400ms/div.

**OLP Entry, Full Load**

- \( V_{\text{DS}} \)
- \( V_{\text{OUT1}} \)
- \( V_{\text{OUT2}} \)

400ms/div.

**Brown In, Full Load**

- \( V_{\text{DS}} \)
- \( V_{\text{CC}} \)

600µV/div.
TYPICAL PERFORMANCE CHARACTERISTICS (continued)
$V_{IN} = 230V_{AC}$, $V_{OUT1}/V_{OUT2} = 12V/5V$, $I_{OUT1}/I_{OUT2} = 0.3A/0.3A$, unless otherwise noted.

Brown Out, Full Load

OVP Entry, No Load

OVP Recovery, No Load

OVP Power On, No Load

OTP Entry

OTP Recovery

Stress

Conducted EMI, L

Conducted EMI, N
## PIN FUNCTIONS

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FB</td>
<td>Feedback. A pull-down optocoupler controls the output regulation.</td>
</tr>
<tr>
<td>2</td>
<td>VCC</td>
<td>Power supply of the IC. VCC enters over-voltage protection (OVP) if the VCC voltage rises above $V_{OVP}$.</td>
</tr>
<tr>
<td>4</td>
<td>DRAIN</td>
<td>Drain of the internal MOSFET. DRAIN is the input for the start-up, high-voltage current source.</td>
</tr>
<tr>
<td>5</td>
<td>SOURCE</td>
<td>Source of the internal MOSFET. SOURCE is the input of the primary current-sense signal.</td>
</tr>
<tr>
<td>6</td>
<td>GND</td>
<td>Ground.</td>
</tr>
<tr>
<td>7</td>
<td>B/O</td>
<td>Brown-in/-out, input OVP, and over-power compensation detection. Brown-in/-out, input OVP, and over-power compensation are achieved by detecting the voltage on B/O. All functions are disabled when B/O is pulled higher than $V_{DIS}$.</td>
</tr>
<tr>
<td>8</td>
<td>TIMER</td>
<td>Combined soft start, frequency jittering, and timer functions for overload protection (OLP) and brown-out protection. The IC is latched by pulling TIMER down. TIMER allows for external OVP and over-temperature protection (OTP) detection.</td>
</tr>
</tbody>
</table>
BLOCK DIAGRAM

Figure 1: Functional Block Diagram
OPERATION

The HF500-7 is a fixed-frequency, current-mode regulator with built-in slope compensation that incorporates all of the necessary features to build a reliable switch-mode power supply. In light-load conditions, the regulator freezes the peak current and reduces its switching frequency to 25kHz to minimize switching loss. When the output power falls below a given level, the regulator enters burst mode. The HF500-7 uses frequency jittering to improve EMI performance.

Fixed Frequency with Jittering

Frequency jittering reduces EMI by spreading out the energy (see Figure 2).

![Figure 2: Frequency Jitter Circuit](image)

An internal capacitor is charged with a controlled current source, which is fixed when FB is greater than 2V, and its voltage is compared with the TIMER voltage (V_{TIMER}). V_{TIMER} is a triangular wave between 2.8V and 3.2V with a charging/discharging current (see Figure 3). The switching frequency can be calculated using Equation (1):

\[ f_s = \frac{1 \cdot 10^6}{5.28 \cdot V_{\text{TIMER}} / V + 0.2} \text{Hz} \]  

(1)

T_{jitter} can be calculated using Equation (2):

\[ T_{jitter} = 8 \cdot C_{\text{TIMER}} / \text{nF} \cdot 10^{-5} \text{s} \]  

(2)

Figure 3: Frequency Jittering

Frequency Foldback

To achieve high efficiency during all load conditions, the HF500-7 implements frequency foldback during light-load conditions. When the load decreases to a given level, the regulator freezes the V_{FOLD} peak current and reduces the charging current, dropping its switching frequency down to 25kHz and reducing switching loss. If the load continues to decrease, the peak current decreases with a 25kHz fixed frequency to avoid audible noise. Figure 4 shows the frequency and peak current vs. FB.

Figure 4: Frequency and Peak Current vs. FB

Current-Mode Operation with Slope Compensation

The primary peak current is controlled by the FB voltage (V_{FB}). When the peak current reaches the level determined by FB, the MOSFET turns off. The regulator can also operate in continuous conduction mode (CCM) with a wide input voltage range. Its internal synchronous slope compensation (S_{RAMP}) helps avoid subharmonic oscillation when the duty cycle is larger than 50% at CCM.
High-Voltage Start-Up Current Source

Initially, the IC is self supplied by the internal high-voltage current source, which is drawn from DRAIN. The IC turns off the current source once VCC reaches VCCOFF. If VCC falls below VCCON, the high-voltage current source turns on again.

The lower threshold of VCC is pulled down from VCCUVLO to VCCPRO when a fault condition occurs, such as overload protection (OLP), short-circuit protection (SCP), brown-out, over-voltage protection (OVP), and over-temperature protection (OTP), etc.

Self-Power Supply

The IC can be self-supplied by the internal high-voltage current source. The IC starts switching and the internal high-voltage current source turns off once the VCC voltage reaches VCCOFF (typically 12V). Then the VCC voltage decreases. The internal high-voltage current source turns on again to charge the external VCC capacitor when the VCC voltage decreases below VCCON (typically 11.5V) (see Figure 5). A small capacitor (several μF) is enough to hold the VCC voltage. The self-supply function can lower the total BOM cost by removing auxiliary winding and decreasing the capacitance of the VCC capacitor.

![Figure 5: Self-Power Supply](image)

Self-power supply leads to higher no-load power consumption. If tough no-load power consumption performance is required, the self-supply function should be disabled.

Soft Start (SS)

To reduce the stress on the power components and smoothly establish the output voltage, the TIMER voltage increases from 1V to 1.75V with a 1/4 charge current during normal operation during every start-up. The TIMER voltage increases the peak current from 0.25V to 1V gradually. The switching frequency also increases gradually. Figure 6 shows the typical waveform of a soft start.

![Figure 6: Soft Start](image)

The start-up duration can be adjusted by the capacitor connected to TIMER. The TIMER capacitor determines the start-up duration, shown in Equation (3):

\[
T_{\text{Soft-start}} = 0.3 \cdot C_{\text{TIMER}} / nF \cdot 10^{-3}s \tag{3}
\]

Burst Operation

The HF500-7 uses burst-mode operation to minimize the power dissipation in no-load or light-load conditions. As the load decreases, VFB decreases. The IC stops the switching cycle when VFB drops below the lower threshold (VBURL). VFB increases again once the output voltage drops, and switching resumes once VFB exceeds the threshold (VBURH). VFB then falls and rises repeatedly. Burst-mode operation alternately enables and disables the switching cycle of the MOSFET, thereby reducing switching loss at no-load or light-load conditions.

Over-Power Compensation (OPC)

An offset voltage proportional to the B/O voltage is added to the sensing voltage. The B/O voltage is proportional to the input voltage. Figure 7 shows the compensation in relation to the voltage on FB and B/O. The over-power compensation (OPC) voltage (VOPC) can be calculated using Equation (4):

\[
V_{\text{OPC}} = 0.094 \cdot (V_{\text{B/O}} - 1.1V) \tag{4}
\]
**Timer-Based Overload Protection (OLP)**

If the switching frequency is fixed in a flyback converter, the maximum output power is limited by the peak current. When the output consumes more than the limited power, the output voltage drops below the set value. The current flowing through the primary and secondary optocoupler is reduced, and V_FB is pulled high (see Figure 8).

**Figure 8: Overload Protection Block**

FB rising higher than V_OLP is considered to be an error flag and causes the timer to start counting the rising edge of V_Q. When the error flag is removed, the timer resets. When the timer completes after it has counted to 16, the HR500-7 enters OLP. This timer duration does not trigger the OLP function when the power supply is starting up or during a load transition phase (see Figure 9).

**Figure 9: Overload Protection Function**

**Input Brown-Out and Input OVP**

The input brown-out and input OVP are performed by B/O. If the B/O voltage is higher than V_BIO_IN during the input voltage rising period, the IC begins operating. If the B/O voltage is lower than V_BIO_OUT for T_B/O (C_TIMER = 47nF), the IC stops operation. If the voltage on B/O is higher than OVP_B/O for T_OVPB/O, the IC stops operating, achieving input OVP. If the voltage on B/O is higher than V_DIS, input brown-out and input OVP are disabled. To simplify the external circuit, connect B/O to VCC through a resistor if input brown-out, over-power compensation, and input OVP are not needed.

**Short-Circuit Protection (SCP)**

The HF500-7 features a short-circuit protection (SCP) that senses the SOURCE voltage and stops switching if VSOURCE reaches V_SCP after a reduced leading-edge blanking time (T_LEB2). Once the fault disappears, the power supply resumes operation.

**Thermal Shutdown**

The HF500-7 uses thermal shutdown to turn off the switching cycle when the inner temperature exceeds T_OTP. Once the inner temperature drops below T_OTP(HYS), the power supply resumes operation. During thermal shutdown, the VCC UVLO lower threshold is pulled down from VCCUVLO to VCCPRO.

**Vcc Over-Voltage Protection (OVP)**

The HF500-7 enters a latched fault condition if the VCC voltage rises above V_OVP for T_OVP. The regulator remains fully latched until VCC drops below VCLATCH, such as when the power supply is unplugged from the main input and plugged back in. Usually, this situation occurs when the optocoupler fails, resulting in the loss of the output voltage regulation.

**TIMER Protection**

The HF500-7 is latched off by pulling TIMER below V_TIMER(LATCH) for T_LATCH. This allows TIMER to be used for external OVP and OTP functions by adding an external compact circuit.
Leading-Edge Blanking (LEB)

An internal leading-edge blanking (LEB) unit containing two LEB times is placed between SOURCE and the current comparator input to avoid premature switching pulse termination due to parasitic capacitances. During the blanking time, the current comparator is disabled and cannot turn off the external MOSFET (see Figure 10).

![Diagram showing V_{Limit} vs. t with T_{LEB1} and T_{LEB2} highlighted for SCP.](image)

Figure 10: Leading-Edge Blanking
APPLICATION INFORMATION

VCC Capacitor Selection

When the input voltage is supplied, the VCC capacitor is charged up by the IC internal high-voltage current source. Due to the self-supply function, the start-up period is not affected by the VCC capacitor selection. The main concern is that the self-supply function should always be disabled during burst mode if VCC is supplied by the auxiliary winding. The value for the VCC capacitor can be estimated with Equation (5):

$$C_{VCC} > \frac{I_{CC} \cdot T_{burst}}{V_{CC_{OFF}} - V_{CC_{ON}}} \quad (5)$$

Where $I_{CC}$ is the internal consumption, and $T_{burst}$ is the interval during the burst period.

Primary-Side Inductor Design ($L_m$)

The HF500-7 uses an internal slope compensation to support CCM when the duty cycle exceeds 50%. Set a ratio ($K_P$) of the primary inductor’s ripple current amplitude vs. the peak current value to $0 < K_P \leq 1$, where $K_P = 1$ for discontinuous conduction mode (DCM) (see Figure 11). A larger inductor leads to a smaller $K_P$, which reduces the RMS current but increases transformer size. An optimal $K_P$ value is between 0.7 and 0.8 for the universal input range and under CrCM or under DCM for the 230VAC input range.

![Figure 11: Typical Primary Current Waveform](image)

For CCM at a minimum input, calculate the converter duty cycle with Equation (7):

$$D = \frac{(V_O + V_F) \cdot N}{(V_O + V_F) \cdot N + V_{in(min)}} \quad (7)$$

Where $V_F$ is the secondary diode’s forward voltage, $N$ is the transformer turn ratio, and $V_{in(min)}$ is the minimum voltage on the bulk capacitor.

The MOSFET turn-on time is calculated with Equation (8):

$$T_{on} = D \cdot T_s \quad (8)$$

Where $T_s$ is the frequency jitter’s dominant switching period, and $\frac{1}{T_s} = f_s = 65kHz$. The average value of the primary current can be calculated with Equation (9):

$$I_{av} = \frac{P_{in}}{V_{in(min)}} \quad (9)$$

The peak value of the primary current can be calculated with Equation (10):

$$I_{peak} = \frac{I_{av}}{(1 - K_p^2) \cdot D} \quad (10)$$

The ripple value of the primary current can be calculated with Equation (11):

$$I_{ripple} = K_p \cdot I_{peak} \quad (11)$$

The valley value of the primary current can be calculated with Equation (12):

$$I_{valley} = (1 - K_p) \cdot I_{peak} \quad (12)$$

$L_m$ can be calculated with Equation (13):

$$L_m = \frac{V_{in(min)} \cdot T_{on}}{I_{ripple}} \quad (13)$$

Current-Sense Resistor

Figure 12 shows the peak current comparator logic and the subsequent waveform. When the sum of the sensing resistor voltage and the slope compensator reaches $V_{peak}$, the comparator goes high to reset the RS flip-flop, and the MOSFET is turned off.
The maximum current limit is \( V_{ILIM} \). The ramp of the slope compensator is \( S_{ramp} \). Given a certain margin, use \( 0.95 \times V_{ILIM} \) as \( V_{peak} \) at full load. Calculate the voltage on the sensing resistor with Equation (14):

\[
V_{sense} = 95\% \cdot V_{ILIM} - S_{ramp} \cdot T_{on}
\]

The value of the sense resistor is then calculated with Equation (15):

\[
R_{sense} = \frac{V_{sense}}{I_{peak}}
\]

Select a current-sense resistor with an appropriate power rating. Estimate the sense resistor power loss with Equation (16):

\[
P = \left(\frac{I_{peak} + I_{valley}}{2}\right)^2 + \frac{1}{12} \left(\frac{I_{peak} - I_{valley}}{2}\right)^2 \cdot D \cdot R_{sense}
\]

**Jitter Period**

Frequency jitter is used as an effective method for reducing EMI by dissipating energy. The 1st order harmonic noise bandwidth is \( B_{Tn} = n \cdot (2 \cdot \Delta f + f_{jitter}) \), where \( \Delta f \) is the frequency jitter amplitude. If \( B_{Tn} \) exceeds the resolution bandwidth \( (R_{BW}) \) of the spectrum analyzer (200Hz for noise frequency less than 150kHz, 9kHz for noise frequency between 150kHz and 30MHz), the spectrum analyzer receives less noise energy.

The TIMER capacitor determines the frequency jitter period. A 10µA current source charges the capacitor when the TIMER voltage reaches 3.2V, and another 10µA current source discharges the capacitor to 2.8V. This charging and discharging cycle is repeated.

Equation (2) describes the jitter period in theory. A smaller \( f_{jitter} \) is more effective for EMI reduction. However, the measurement bandwidth requires \( f_{jitter} \) to be large compared to the spectrum analyzer \( R_{BW} \) for effective EMI reduction. \( f_{jitter} \) should also be less than the control loop gain crossover frequency to avoid disturbing the output voltage regulation.

The TIMER capacitor must be selected carefully. A capacitor that is too large may cause the start-up to fail at full load because of the long, soft start-up duration, shown in Equation (3). However, a TIMER capacitor that is too small causes the timer period to decrease, which overloads the timer count capability and may cause logic problems. For most applications, an \( f_{jitter} \) value between 200Hz and 400Hz is recommended.

**Ramp Compensation**

In peak current control, subharmonic oscillation occurs when \( D \) is greater than 0.5 in CCM. The HF500-7 solves this problem with internal ramp compensation. Calculate \( \alpha \) with Equation (17):

\[
\alpha = \frac{D_{max} \cdot V_{in(min)} \cdot R_{sense} \cdot m_a}{(1 - D_{max}) \cdot L_m \cdot R_{sense} + m_a}
\]

Where \( m_a = 20mV/\mu s \) is the minimum internal slope value of the compensation ramp, and \( V_{in(min)} \) and \( D_{max} \) are the slew rates of the primary-side and equivalent secondary-side voltages sensed by the current-sensing resistor respectively. For stable operation, \( \alpha \) must be less than 1.
PCB Layout Guidelines

Efficient PCB layout is critical for stable operation, good EMI performance, and good thermal performance. For best results refer to Figure 13 and follow the guidelines below:

1. Minimize the power stage loop area for better EMI performance. This includes the input loop (C4 - T1 - U1 - R1A/R1B - C4), the auxiliary winding loop (T1 - D6 - R8 - C7 - T1), the output loop (T1 - D7 - C12 - T1, T1 – D8 - C11 - T1), and the RCD snubber loop (T1 - R6 - D5 - R7/C6 - T1).

2. Keep the input loop GND and the control circuit GND separate and only connect them at C4. Otherwise, the IC operation may be influenced by noise.

3. Place one ceramic capacitor close to the sensitive IC pin (such as those for FB, B/O, and VCC) to decouple noise effectively.

4. Place a larger source area around the IC to improve thermal performance, if needed.

Design Example

Table 1 shows a design example of the HF500-7 for power adapter applications.

<table>
<thead>
<tr>
<th>V_IN</th>
<th>85 to 265VAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_OUT1/ V_OUT2</td>
<td>12V/5V</td>
</tr>
<tr>
<td>I_OUT1/ I_OUT2</td>
<td>0.3A/0.3A</td>
</tr>
</tbody>
</table>

Table 1: Design Example

Figure 13: Recommended PCB Layout
TYPICAL APPLICATION CIRCUITS

Figure 14: Example of a Typical Application

Connection Diagram

Winding Diagram

Figure 15: Transformer Structure
Table 2: Winding Order

<table>
<thead>
<tr>
<th>Tape (T)</th>
<th>Winding</th>
<th>Start-End</th>
<th>Wire Size (Φ)</th>
<th>Turns (T)</th>
<th>Tube</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>N1</td>
<td>5 → NC Clockwise</td>
<td>0.15*2</td>
<td>22</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>N2</td>
<td>3 → 5 Clockwise</td>
<td>0.15*1</td>
<td>168</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>N3</td>
<td>6 → 10 Clockwise</td>
<td>0.32*1 TIW</td>
<td>12</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>N4</td>
<td>8 → 10 Anticlockwise</td>
<td>0.45*1 TIW</td>
<td>9</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>N5</td>
<td>2 → 1 Clockwise</td>
<td>0.12*1</td>
<td>27</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>N6</td>
<td>1 → NC Clockwise</td>
<td>0.12*1</td>
<td>27</td>
<td>None</td>
</tr>
</tbody>
</table>
FLOW CHART

Figure 16: Control Flow Chart
**HF500-7 – FULL-FEATURED FLYBACK REGULATOR**

**PACKAGE INFORMATION**

**SOIC8-7B**

**TOP VIEW**

**RECOMMENDED LAND PATTERN**

**FRONT VIEW**

**SIDE VIEW**

**DETAIL "A"**

**NOTE:**
1. CONTROL DIMENSION IS IN INCHES. DIMENSION IN BRACKET IS IN MILLIMETERS.
2. PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS, OR GATE BURRS.
3. PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.
4. LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.004" INCHES MAX.
5. JEDEC REFERENCE IS MS-012.
6. DRAWING IS NOT TO SCALE.

**NOTICE:** The information in this document is subject to change without notice. Please contact MPS for current specifications. Users should warrant and guarantee that third party Intellectual Property rights are not infringed upon when integrating MPS products into any application. MPS will not assume any legal responsibility for any said applications.

HF500-7 Rev. 1.0
9/27/2017
© 2017 MPS. All Rights Reserved.