DESCRIPTION

The HF920A is a flyback regulator with a monolithic 900V MOSFET. The HF920A provides excellent power regulation in AC/DC applications that require high reliability, such as smart meters, large appliances, industrial controls, and products powered by poor AC grids. It requires a minimum number of external components.

The HF920A uses peak-current-mode control to provide excellent transient response and easy loop compensation. When the output power falls below a given level, the regulator enters burst mode. The IC consumption is specially optimized. As a result, the HF920A achieves very low power consumption in a standby condition.

The MPS proprietary 900V monolithic process enables an over-temperature protection that is on the same silicon of the 900V power MOSFET, offering the most precise thermal protection. It also offers a full suite of protection features, including VCC under-voltage lockout, overload protection, over-voltage protection, under-voltage protection, and short-circuit protection.

The HF920A is designed to minimize electromagnetic interference for Power Line Communication (PLC) in home and building automation applications. The operating frequency is programmed externally with a single resistor, so the power supply’s radiated energy can be designed to avoid interference to the PLC. In addition to the programmable frequency, the HF920A employs frequency jittering that greatly reduces the noise level and the cost of the EMI filter.

The HF920A is available in SOIC8-7A and SOIC14-11 packages.

FEATURES

- Monolithic 900V/15Ω MOSFET and High Voltage Current Source
- Fixed Switching Frequency, Programmable up to 150kHz
- Current-Mode Control Scheme
- Frequency Jittering
- Low Standby Power Consumption via Active Burst Mode.
- <30mW No-Load Consumption
- Internal Leading-Edge Blanking (LEB)
- Built-In Soft-Start (SS) Function
- Internal Slope Compensation
- Over Voltage and Under Voltage Protections programmable through the PRO Pin
- Over-Temperature Protection (OTP)
- VCC Under-Voltage Lockout (UVLO) with Hysteresis
- Over-Voltage Protection (OVP) on VCC
- Time-Based Overload Protection (OLP)
- Short-Circuit Protection (SCP)

APPLICATIONS

- E-Meters
- Industrial Controls
- Large Appliances

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Table 1: Maximum Output Power

<table>
<thead>
<tr>
<th>Package</th>
<th>$P_{\text{MAX}}$ (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOIC8-7A</td>
<td>6.5</td>
</tr>
<tr>
<td>SOIC14-11</td>
<td>7</td>
</tr>
</tbody>
</table>

85Vac~420Vac | 230Vac±15%

NOTES:

- The maximum output power is limited by junction temperature.
- Test is done under $T_A = 50^\circ$C. The test board is placed into a box about 20cm*15cm*10cm.
- To reduce $V_{\text{DS}}$, the turns ratio is set to 5.
- Single output, $V_{\text{OUT}} = 12.5V$.
- GND of the SOIC8-7A package is connected to a 3cm² copper area with exposed copper strips. GND of the SOIC14-11 package is connected to a 2.5cm² copper area.
- Working condition under minimum input voltage is set to BCM.
TYPICAL APPLICATION

85-420Vac

HF920A

VCC D

PRO

FB

FSET GND

HF920A
ORDERING INFORMATION

<table>
<thead>
<tr>
<th>Part Number*</th>
<th>Package</th>
<th>Top Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF920AGSE*</td>
<td>SOIC8-7A</td>
<td>See Below</td>
</tr>
<tr>
<td>HF920AGS**</td>
<td>SOIC14-11</td>
<td>See Below</td>
</tr>
</tbody>
</table>

* For Tape & Reel, add suffix –Z (e.g. HF920AGSE–Z);
** For Tape & Reel, add suffix –Z (e.g. HF920AGS–Z);

TOP MARKING (HF920AGSE)

HF920A
LLLLLLLL
MPSWW

HF920A: Part number
LLLLLLLL: Lot number
MPS: MPS prefix
Y: Year code
WW: Week code

TOP MARKING (HF920AGS)

MPSYYWW
HF920A
LLLLLLLL

MPS: MPS prefix
YY: Year code
WW: Week code
HF920A: Part number
LLLLLLLL: Lot number
PACKAGE REFERENCE

SOIC8-7A

SOIC14-11
## PIN FUNCTIONS

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOIC8-7A</td>
<td>SOIC14-11</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>VCC</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>FSET</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>PRO</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>FB</td>
</tr>
<tr>
<td>5</td>
<td>1,2,7,8</td>
<td>GND</td>
</tr>
<tr>
<td>6</td>
<td>9</td>
<td>S</td>
</tr>
<tr>
<td>-</td>
<td>13</td>
<td>NC</td>
</tr>
<tr>
<td>8</td>
<td>14</td>
<td>D</td>
</tr>
</tbody>
</table>

## ABSOLUTE MAXIMUM RATINGS (1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>–0.3V to 900V</td>
</tr>
<tr>
<td>VCC</td>
<td>–0.3V to 30V</td>
</tr>
<tr>
<td>All other pins</td>
<td>–0.3V to 6.5V</td>
</tr>
</tbody>
</table>

Continuous power dissipation ($T_A = +25^\circ C$) (2)

- SOIC8-7A: 1.3W
- SOIC14-11: 1.78W

Junction temperature: 150°C

Lead temperature: 260°C

Storage temperature: -60°C to +150°C

ESD capability human body model: 2.0kV

ESD capability charged device model: 2.0kV

## Recommended Operation Conditions (3)

- VCC to GND: 10 V to 24 V
- Operating junction temp ($T_J$): -40°C to +125°C

## Thermal Resistance (4)

<table>
<thead>
<tr>
<th>Package</th>
<th>$\theta_{JA}$</th>
<th>$\theta_{JC}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOIC8-7A</td>
<td>96°C/W</td>
<td>45°C/W</td>
</tr>
<tr>
<td>SOIC14-11</td>
<td>70°C/W</td>
<td>35°C/W</td>
</tr>
</tbody>
</table>

### 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 $P_D$ (MAX) = ($T_J$ (MAX) - $T_A$)/$\theta_{JA}$. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will 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.
## ELECTRICAL CHARACTERISTICS

VCC = 12V, T_J=-40°C-125°C, min and max values are guaranteed by characterization, typical values are tested under 25°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 and Internal MOSFET (Pin D)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply current from Drain</td>
<td>I_charge</td>
<td>VCC = V_CCH-0.1V; V_Drain = 400V</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>mA</td>
</tr>
<tr>
<td>Leakage current from Drain</td>
<td>I_leak</td>
<td>V_D = 400V, V_GS=0V, T_J = 25 °C</td>
<td>1</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>Breakdown voltage</td>
<td>V_(BR,DSs)</td>
<td></td>
<td>900</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>On-state resistance</td>
<td>R_(DS(ON))</td>
<td>VCC = 10 V; I_D =100 mA</td>
<td>15</td>
<td>18</td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Supply Voltage Management (Pin VCC)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VCC upper level at which the IC switches on</td>
<td>V_CCH</td>
<td></td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>V</td>
</tr>
<tr>
<td>VCC lower level at which the IC switches off</td>
<td>V_CCL</td>
<td></td>
<td>8.2</td>
<td>8.8</td>
<td>9.4</td>
<td>V</td>
</tr>
<tr>
<td>VCC hysteresis</td>
<td>V_CCH_HYS</td>
<td></td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>V</td>
</tr>
<tr>
<td>VCC OVP level</td>
<td>V_OVP</td>
<td></td>
<td>23.9</td>
<td>25.2</td>
<td>26.5</td>
<td>V</td>
</tr>
<tr>
<td>VCC OVP delay time</td>
<td>t_OVP</td>
<td></td>
<td>70</td>
<td></td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td>VCC re-charge level after protections</td>
<td>V_CCR</td>
<td></td>
<td>4.8</td>
<td>5.5</td>
<td>6.2</td>
<td>μs</td>
</tr>
<tr>
<td>Quiescent current at protections</td>
<td>I_Pro</td>
<td>VCC = V_CCL</td>
<td>300</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>Quiescent current</td>
<td>I_Q</td>
<td>VCC = V_CCH - 0.1 V</td>
<td>200</td>
<td>300</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>Operation current</td>
<td>I_CC</td>
<td>VCC =13 V; FB =0 V</td>
<td>300</td>
<td>400</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td><strong>Feedback Management (Pin FB)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal pull-up resistor</td>
<td>R_FB</td>
<td>Normal operating</td>
<td>39</td>
<td></td>
<td></td>
<td>kΩ</td>
</tr>
<tr>
<td>Internal pull-up voltage</td>
<td>V_UP</td>
<td></td>
<td>4.1</td>
<td>4.4</td>
<td>4.7</td>
<td>V</td>
</tr>
<tr>
<td>FB to current-set-point division ratio</td>
<td>K_div</td>
<td></td>
<td>3.4</td>
<td>3.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal soft-start time</td>
<td>t_SS</td>
<td></td>
<td>6.7</td>
<td></td>
<td></td>
<td>ms</td>
</tr>
<tr>
<td>FB decreasing level at which the regulator enters burst mode</td>
<td>V_BURL</td>
<td></td>
<td>0.4</td>
<td>0.5</td>
<td>0.6</td>
<td>V</td>
</tr>
<tr>
<td>FB increasing level at which the regulator leaves burst mode</td>
<td>V_BURH</td>
<td></td>
<td>0.6</td>
<td>0.7</td>
<td>0.8</td>
<td>V</td>
</tr>
<tr>
<td>Overload set point</td>
<td>V_OLP</td>
<td></td>
<td>3.3</td>
<td>3.65</td>
<td>4</td>
<td>V</td>
</tr>
<tr>
<td>Overload counter</td>
<td></td>
<td></td>
<td>8192</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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ELECTRICAL CHARACTERISTICS (continued)
VCC =12V, T_J=-40°C-125°C, Min & Max are guaranteed by characterization, typical is tested under 25°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>Frequency Setting (Pin FSET)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FSET reference voltage</td>
<td>V_{FSET}</td>
<td>1.18</td>
<td>1.25</td>
<td>1.32</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Frequency spectrum jittering range, in percentage of Fs</td>
<td>R_{Jittering}</td>
<td>±3.5</td>
<td>%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical operating frequency</td>
<td>f_s</td>
<td>43</td>
<td>49</td>
<td>55</td>
<td>kHz</td>
<td></td>
</tr>
<tr>
<td>Maximum switching duty</td>
<td>D_{max}</td>
<td>79</td>
<td>83</td>
<td>87</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td><strong>Current Sensing Management (Pin S)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leading-edge blanking for current sensor</td>
<td>t_{LEB1}</td>
<td>385</td>
<td>ns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leading-edge blanking for SCP</td>
<td>t_{LEB2}</td>
<td>350</td>
<td>ns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum current set point</td>
<td>V_{CSL}</td>
<td>0.91</td>
<td>0.97</td>
<td>1.02</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Short-circuit protection set point</td>
<td>V_{SCP}</td>
<td>1.43</td>
<td>1.5</td>
<td>1.57</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Slope compensation ramp</td>
<td>S_{Ramp}</td>
<td>21</td>
<td>mV/μs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Protection Management (Pin PRO)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper protection voltage</td>
<td>V_{PRO-OV}</td>
<td>2.92</td>
<td>3.1</td>
<td>3.32</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Upper protection hysteresis</td>
<td>V_{PRO-Hys}</td>
<td>0.2</td>
<td>V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower protection voltage</td>
<td>V_{PRO-UV}</td>
<td>0.21</td>
<td>0.25</td>
<td>0.28</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Protection delay time</td>
<td>t_{PRO}</td>
<td>20 (5)</td>
<td>μs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Thermal Shutdown</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal shutdown threshold</td>
<td></td>
<td></td>
<td>150</td>
<td>°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal shutdown recovery hysteresis</td>
<td></td>
<td></td>
<td>30</td>
<td>°C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:**
5) This parameter is guaranteed by design.
TYPICAL CHARACTERISTICS

I\textsubscript{CHARGE} @ V\textsubscript{D} = 400V vs. Temperature

\begin{tikzpicture}
\begin{axis}[
width=0.5\textwidth,
height=0.5\textwidth,
axis lines=left,
xlabel=TEMPERATURE (°C),
ylabel=I\textsubscript{CHARGE} (mA),
]
\addplot[blue,smooth] coordinates {
(-50,2.5)
(0,2)
(50,1.5)
(100,1)
(150,0.5)
};
\end{axis}
\end{tikzpicture}

V\textsubscript{BR}D\hspace{1pt}S\hspace{1pt}S @ I\textsubscript{Leak} = 100μA vs. Temperature

\begin{tikzpicture}
\begin{axis}[
width=0.5\textwidth,
height=0.5\textwidth,
axis lines=left,
xlabel=TEMPERATURE (°C),
ylabel=V\textsubscript{BR}D\hspace{1pt}S\hspace{1pt}S (V),
]
\addplot[blue,smooth] coordinates {
(-50,1020)
(0,1040)
(50,1060)
(100,1080)
(150,1100)
};
\end{axis}
\end{tikzpicture}

R\textsubscript{DS(ON)} vs. Temperature

\begin{tikzpicture}
\begin{axis}[
width=0.5\textwidth,
height=0.5\textwidth,
axis lines=left,
xlabel=TEMPERATURE (°C),
ylabel=R\textsubscript{DS(ON)} (Ω),
]
\addplot[blue,smooth] coordinates {
(-50,10)
(0,15)
(50,20)
(100,25)
(150,30)
};
\end{axis}
\end{tikzpicture}

V\textsubscript{CSL} vs. Temperature

\begin{tikzpicture}
\begin{axis}[
width=0.5\textwidth,
height=0.5\textwidth,
axis lines=left,
xlabel=TEMPERATURE (°C),
ylabel=V\textsubscript{CSL} (V),
]
\addplot[blue,smooth] coordinates {
(-50,1.00)
(0,0.99)
(50,0.98)
(100,0.97)
(150,0.96)
};
\end{axis}
\end{tikzpicture}

K\textsubscript{DIV} vs. Temperature

\begin{tikzpicture}
\begin{axis}[
width=0.5\textwidth,
height=0.5\textwidth,
axis lines=left,
xlabel=TEMPERATURE (°C),
ylabel=K\textsubscript{DIV} (V),
]
\addplot[blue,smooth] coordinates {
(-50,3.25)
(0,3.30)
(50,3.35)
(100,3.40)
(150,3.45)
};
\end{axis}
\end{tikzpicture}

V\textsubscript{OLP} vs. Temperature

\begin{tikzpicture}
\begin{axis}[
width=0.5\textwidth,
height=0.5\textwidth,
axis lines=left,
xlabel=TEMPERATURE (°C),
ylabel=V\textsubscript{OLP} (V),
]
\addplot[blue,smooth] coordinates {
(-50,3.50)
(0,3.55)
(50,3.60)
(100,3.65)
(150,3.70)
};
\end{axis}
\end{tikzpicture}
TYPICAL CHARACTERISTICS (continued)

- **f_S vs. Temperature**
  - Graph showing a nearly constant frequency of 50 kHz across a temperature range from -50°C to 150°C.

- **t_LEB1 vs. Temperature**
  - Graph showing a decrease in t_LEB1 (ns) as the temperature increases from -50°C to 150°C.

- **t_LEB2 vs. Temperature**
  - Graph showing a decrease in t_LEB2 (ns) as the temperature increases from -50°C to 150°C.

- **V_PRO vs. Temperature**
  - Graph showing a slight increase in V_PRO (V) as the temperature increases from -50°C to 150°C.
TYPICAL PERFORMANCE CHARACTERISTICS

Performance waveforms are tested with the evaluation board in the Design Example section. $V_{IN} = 230V$, $V_{OUT1} = 13.5V$, $I_{OUT1} = 300mA$, $V_{OUT2} = 8V$, $I_{OUT2} = 50mA$, $V_{OUT3} = 8V$, $I_{OUT3} = 50mA$, $T_A = 25^\circ C$, unless otherwise noted.

**Efficiency**

![Efficiency Graph]

**No-Load Consumption (6)**

![No-Load Consumption Graph]

**Power On**

![Power On Waveform]

**Power Off**

![Power Off Waveform]

**Normal Operation**

![Normal Operation Waveform]

**Short-Circuit Entry**

![Short-Circuit Entry Waveform]
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Performance waveforms are tested with the evaluation board in the Design Example section. 
$V_{IN} = 230V$, $V_{OUT1} = 13.5V$, $I_{OUT1} = 300mA$, $V_{OUT2} = 8V$, $I_{OUT2} = 50mA$, $V_{OUT3} = 8V$, $I_{OUT3} = 50mA$, $T_A = 25^\circ C$, unless otherwise noted.

**Short-Circuit Recovery**

**Short-Circuit Power On**

**OLP Entry**

**OLP Recovery**

**OLP Power On**

**OVP Entry**
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Performance waveforms are tested with the evaluation board in the Design Example section. \( V_{IN} = 230\text{V}, V_{OUT1} = 13.5\text{V}, I_{OUT1} = 300\text{mA}, V_{OUT2} = 8\text{V}, I_{OUT2} = 50\text{mA}, V_{OUT3} = 8\text{V}, I_{OUT3} = 50\text{mA}, T_{A} = 25^\circ\text{C}, \) unless otherwise noted.

**OVP Recover**

**OVP Power On**

**Input UVP when Vin Falls to 54VDC**

**Input UVP Removed when Vin Rises to 59VDC**

**NOTE:**

6) The no load consumption is tested with OUT2 and OUT3 open.
FUNCTIONAL BLOCK DIAGRAM

Figure 1: Internal Function Block Diagram
OPERATION
The HF920A incorporates all the necessary features required by a reliable switch-mode power supply. The proprietary 900V MOSFET integration enables a highly integrated power supply solution. It has burst-mode operation to minimize the stand-by power consumption at light load. Protection features such as auto-recovery for overload protection (OLP), short-circuit protection (SCP), over-voltage protection (OVP), under voltage protection (UVP), and thermal shutdown for over-temperature protection (OTP) contribute to a safer converter design with minimal external components.

Pulse-Width Modulation (PWM) Operation
The HF920A employs peak-current-mode control. On the secondary side, the output voltage is regulated by the compensation network, and the compensation output is fed back to the primary side as an input signal to FB through an optical coupler. The FB voltage (VFB) is used to control the peak current on the primary side winding of the flyback transformer based on the current sensing on S. The integrated 900V MOSFET turns on at the beginning of each cycle based on the internal oscillator and turns off based on the peak current control.

Start-Up and VCC UVLO
Initially, the IC is driven by the internal current source drawn from the high voltage D pin. The IC starts switching and the internal high voltage current source turns off as soon as the voltage on VCC reaches VCCH. Then, the supply of the IC is taken over by the auxiliary winding of the transformer. Whenever VCC falls below VCCL, the regulator stops switching, and the internal high-voltage current source turns on again (see Figure 2).

Frequency Jittering
The HF920A provides a frequency jittering function, which simplifies the input EMI filter design and decreases the system cost. The HF920A has optimized frequency jittering with a ±3.5% frequency deviation range, and a 256T carrier cycle that effectively improves EMI by spreading the energy dissipation over the frequency range.

Peak Current Limit
The primary peak current is sensed by a sensing resistor between S and GND. When the sum of the sense resistor voltage and the slope compensation voltage reach the peak current limit (VCS), the MOSFET turns off.

Burst Operation
The HF920A implements burst-mode operation at no-load and light-load conditions. Burst-mode operation

The lower threshold of the VCC UVLO decreases from VCCL to VCCR when fault conditions such as SCP, OLP, OVP, UVP, and OTP occur.

Soft Start (SS)
The HF920A implements an internal soft-start circuit to reduce stress on both the primary side MOSFET and secondary diode, as well as smoothly establish the output voltage during start-up. The internal soft-start circuit increases the threshold of the peak current comparator gradually from a minimum level until the feedback control loop takes over. The maximum soft-start time is tSS. Within the soft-start duration, the switching frequency is increased progressively from 20% to 100% of the programmed switching frequency.

Switching Frequency
The switching frequency can be set by a resistor between FSET and GND. The oscillator frequency can be calculated with Equation (1):

$$f_s = \frac{1}{523 \times 10^{-9} + 123.4 \times 10^{-12} \times \frac{V_{FSET}}{V_{FST}}} \text{ Hz}$$  (1)

Where $V_{FSET}$ is the internal reference voltage on FSET.

Driver
Switching Pluses

Figure 2: VCC Start-Up
operation alternately enables and disables the switching pulse of the MOSFET to reduce the switching loss. This helps to minimize the standby power consumption and achieve high light-load efficiency.

As the load decreases, \( V_{FB} \) decreases. The IC stops switching when \( V_{FB} \) drops below \( V_{BURL} \). As the converter stops and the output voltage drops, \( V_{FB} \) rises again due to the negative feedback control loop. Once \( V_{FB} \) rises above \( V_{BURH} \), the switching pulse resumes. If the load condition remains the same, \( V_{FB} \) decreases and the whole process is repeated.

Figure 3 shows the burst mode operation of HF920A.

**Over-Voltage Protection (OVP)**

The HF920A shuts down via OVP when the VCC voltage is higher than \( V_{OVP} \) for \( t_{OVP} \). In a flyback application, the auxiliary winding output voltage is proportional to the output voltage, so OVP protects the circuit from overstress during an output over-voltage condition. The HF920A restarts automatically after VCC drops to \( V_{CCR} \). The regulator resumes normal operation once the fault disappears.

**Overload Protection (OLP)**

The HF920A shuts down when OLP is triggered. The OLP fault occurs when \( V_{FB} \) is pulled up to \( V_{OLP} \) for 8192 switching cycles. The HF920A restarts automatically when VCC drops to \( V_{CCR} \). When the fault disappears, the power supply resumes operation.

**Short-Circuit Protection (SCP)**

The HF920A shuts down when voltage on S is higher than \( V_{SCP} \), which indicates a short-circuit condition. The HF920A enters SCP, which prevents any thermal or stress damage. The HF920A restarts when VCC drops to \( V_{CCR} \). Once the fault disappears, the power supply resumes operation.

**Thermal Shutdown (OTP)**

When the junction temperature of the IC exceeds 150°C, the over-temperature protection is activated, and the main power MOSFET stops switching to protect the HF920A from thermal damage. During the protection period, the regulator is latched off. VCC is discharged to \( V_{CCR} \) and recharged to \( V_{CCH} \) by the internal high voltage current source. Once the junction temperature drop exceeds the thermal shutdown recovery hysteresis, the HF920A resumes operation.

**PRO**

PRO provides an external protection. The HF920A shuts down when the PRO voltage exceeds \( V_{PRO-OV} \) or is below \( V_{PRO-UV} \). Once the fault disappears, it resumes operation. PRO protection can be used for input OVP, input UVP, or any other protections (such as over-temperature protection for key components).

**Leading Edge Blanking (LEB)**

The HF920A implements a leading edge blanking unit in order to avoid the MOSFET turning off prematurely due to its high turn on current spike. During the blanking time, the current sensing signal on S is blocked.

The LEB unit contains two LEB times. The current sensor LEB inhibits the current limitation comparator for \( T_{LEB1} \), and the SCP LEB inhibits the SCP current comparator for \( T_{LEB2} \). Figure 4 shows the primary current sense waveform and the LEB.

![Figure 4: Leading Edge Blanking](image-url)
APPLICATION INFORMATION

Selecting the Input Capacitor

The input bulk capacitor filters the rectified AC input voltage and holds the bus voltage for the converter. Figure 5 shows the typical DC bus voltage waveform of a full-bridge rectifier.

![Figure 5: Input Voltage Waveform](image)

When the full-bridge rectifier is used, the input capacitor is set at 2μF/W for the universal input condition (85~265VAC). For high voltage input (>185VAC) application, cut the capacitor values in half. A very low DC input voltage can cause thermal problems under a heavy load. It is recommended that the minimum DC voltage is higher than 70V. Estimate the minimum DC voltage following the guidelines below:

First, estimate the input power \( P_{in} \) with Equation (2):

\[
P_{in} = \frac{V_O \times I_O}{\eta}
\]

(2)

Where \( V_O \) is the output voltage, \( I_O \) is the rated output current, and \( \eta \) is the estimated efficiency. Generally, \( \eta \) is between 0.75 and 0.85, depending on the input range and output application.

Next, the linear part of the DC input voltage \( V_{DC} \) can be calculated with Equation (3):

\[
V_{DC}(t) = \sqrt{\frac{V_{AC(peak)}}{C_n}} \times t - \frac{2 \times P_{in}}{C_n} \times t
\]

(3)

At \( t_1 \), the DC bus voltage reaches its minimum value and the AC input starts to charge the input capacitor. So, \( t_1 \) can be calculated with Equation (4):

\[
V_{DC(t_1)} = V_{AC(t_1)}
\]

(4)

Then, \( V_{DC(min)} \) is calculated with \( t_1 \) and Equation (4). A larger input capacitor should be chosen if the estimated \( V_{DC(min)} \) is too low.

As a 900V offline regulator, the HF920A is ideal for very high voltage input applications, which means a very high bus voltage that is beyond the rated voltage of normal, high voltage electrolytic capacitors. Stack capacitors to meet the high bus voltage requirement (see Figure 6).

![Figure 6: Input Stack Capacitor Circuit](image)

The same type of capacitors should be chosen for \( C_1 \) and \( C_2 \) in order to balance the voltage on them. Each of them will endure half of the bus voltage, but due to the capacitance distribution (typically ±20% for electrolytic capacitors), the voltage on them will vary in mass production. In this case, \( R_1 \) to \( R_4 \) should be used as the voltage balancing resistors.

To get balanced voltage on \( C_1 \) and \( C_2 \), \( R_1 \) to \( R_4 \) should also have the same value. \( R_1 \) to \( R_4 \) should be in a 1206 package to meet the voltage rating requirement. Also, the \( R_1 \) to \( R_4 \) values should be large enough for energy saving. For example, if the total value of \( R_1 \) to \( R_4 \) is 20MΩ, it will consume about 18mW at a 600VDC bus voltage.

Voltage Stress on the Primary MOSFET

Usually, the maximum voltage stress on the primary MOSFET is designed to be less than 90% of its breakdown voltage for reliable operation.

The maximum voltage stress occurs when the primary MOSFET turns off. It can be calculated with Equation (5):

\[
V_{DS(max)} = V_{BUS(max)} + N(V_O + V_F) + V_{spike}
\]

(5)
Where, $V_F$ is the rectifier diode’s forward voltage, $V_O$ is the output voltage, $N$ is the primary to secondary turns ratio, and $V_{\text{spike}}$ is the voltage spike (due to the transformer’s primary leakage inductance).

According to Equation (5), voltage stress can be reduced either by choosing a small $N$ or $V_{\text{spike}}$. However, a small $N$ will lead to larger secondary stress, which means there is a tradeoff to make. A small $V_{\text{spike}}$ requires a strong snubber to suppress the voltage spike.

The input circuit should be designed to guarantee a proper $V_{\text{BUS(max)}}$. For example, using suppression components to protect it from surge.

**Primary-Side Inductor Design ($L_m$)**

Normally, the converter is designed to operate in CCM under low input voltage for universal input applications. With a built-in slope compensation function, the HF920A supports stable CCM control when the duty cycle exceeds 50%. Set the ratio ($K_P$) of the primary inductor ripple current amplitude vs. the peak current value to $0 < K_P \leq 1$. Where a smaller $K_P$ means deeper CCM, and $K_P = 1$ stands for BCM and DCM. Figure 7 shows the relevant waveforms. Larger primary inductance leads to a smaller $K_P$, which reduces RMS current but increases the transformer size. For most HF920A applications, an optimal $K_P$ value is between 0.8 and 1, considering their wide input range.

![Figure 7: Typical Primary Current Waveform](image)

**Figure 7: Typical Primary Current Waveform**

For CCM at a minimum input, the converter duty cycle is determined using Equation (6):

$$D = \frac{(V_O + V_F) \times N}{(V_O + V_F) \times N + V_{\text{DC(min)}}}$$  \hspace{1cm} (6)

Where:

$V_F$ is the secondary diode’s forward voltage, and

$N$ is the transformer turns ratio.

The MOSFET turn-on time is calculated with Equation (7):

$$T_{\text{ON}} = \frac{D}{f_s}$$ \hspace{1cm} (7)

Where, $f_s$ is the operating frequency.

The input average current, ripple current, peak current, and valley current of the primary side are calculated using Equation (8), Equation (9), Equation (10) and Equation (11):

$$I_{\text{AV}} = \frac{P_n}{V_{\text{DC(min)}}}$$ \hspace{1cm} (8)

$$I_{\text{ripple}} = K_P \times I_{\text{peak}}$$ \hspace{1cm} (9)

$$I_{\text{peak}} = \frac{I_{\text{AV}}}{(1 - K_P) \times D}$$ \hspace{1cm} (10)

$$I_{\text{valley}} = (1 - K_P) \times I_{\text{peak}}$$ \hspace{1cm} (11)

Estimate $L_m$ using Equation (12):

$$L_m = \frac{V_{\text{DC(min)}} \times T_{\text{ON}}}{I_{\text{ripple}}}$$ \hspace{1cm} (12)

**Current-Sense Resistor**

![Figure 8: Peak Current Control Waveform with Slope Compensation](image)

Figure 8 shows the peak current control waveform with slope compensation. When the sum of the sense resistor voltage and the slope compensation voltage reaches the peak current limit ($V_{\text{CS}}$), the HF920A turns off the internal MOSFET. The $V_{\text{CS}}$ equals the maximum current set point ($V_{\text{CSL}}$) under full load, considering the margin; use $0.95 \times V_{\text{CSL}}$ for designing. The voltage on the sense resistor is given using Equation (13):

$$V_{\text{sense}} = 0.95 \times V_{\text{CSL}} - S_{\text{Ramp}} \times T_{\text{ON}}$$ \hspace{1cm} (13)
Where, SRAMP is the slope compensation ramp. It is in proportion to \( f_s \). Typically, \( SRAMP = 21 \text{ mV/\mu s} \) when \( RFSET = 200 \text{ k\Omega} \).

The value of the sense resistor is calculated using Equation (14):

\[
R_{\text{sense}} = \frac{V_{\text{sense}}}{I_{\text{peak}}} \tag{14}
\]

Choose a current sense resistor with an appropriate power rating. Its power loss can be calculated using Equation (15):

\[
P_{\text{sense}} = \left[\frac{(I_{\text{peak}} + I_{\text{valley}})}{2}\right]^2 + \frac{1}{12}\left[(I_{\text{peak}} - I_{\text{valley}})^2\right] \times D \times R_{\text{sense}} \tag{15}
\]

**Input Over-Voltage Protection on PRO**

A typical input over-voltage protection circuitry of the HF920A is shown in Figure 9.

The input over-voltage protection point can be calculated using Equation (16):

\[
V_{\text{INOP}} = V_{\text{PRO}} \times \frac{R_5 + R_6 + R_7 + R_8}{R_8} \tag{16}
\]

\[\text{Figure 9: Input Over-Voltage Protection Setup}\]

For resistors R5 to R7, 1206 packages should be used to meet the voltage rating requirement. The total value should be larger than 10MΩ for energy saving purposes.

Switching noise may couple to these large resistors and disturb the PRO protection. It is recommended to connect a bypass ceramic capacitor (around 1nF) to PRO. It should be placed as close to the IC as possible.

**Thermal Performance Optimization**

The HF920A is dedicated to high input voltage applications. However, the high input voltage can cause greater switching loss on the MOSFET, which can lead to poor thermal performance. Measures should be taken to reduce switching loss when designing these applications:

1. First, try to use a lower switching frequency, if possible.
2. Then use a small turns ratio-N to minimize the reflected voltage on the primary winding. Thus reducing the \( V_{DS} \).
3. Finally, reduce the turn on loss, because the turn on loss composes a large part of the switching loss.

Turn on loss is the product of the turn on current spike and \( V_{DS} \). Reducing the turn on loss can be achieved by reducing \( V_{DS} \) or the turn on current spike.

Another way of reducing the \( V_{DS} \) when the MOSFET is on, is to set the HF920A so it works under deep DCM. In deep DCM, the \( V_{DS} \) oscillation is fully damped so there is no chance of turning on at the high peak value.

The turn on current spike is caused by a parasitic capacitor and output diode reverse recovery.

DCM operation helps to avoid the output diode’s reverse recovery. The transformer structure should be designed to achieve minimum parasitic capacitance of each winding and between the primary and secondary windings.
PCB Layout Guidelines
Efficient PCB layout is critical to achieve reliable operation, good EMI performance, and good thermal performance. For best results, refer to Figure 10 and follow the guidelines below:

1) Minimize the power stage switching stage loop area. This includes the input loop (C8–C6–T1–U2–R21/R22–C8), the auxiliary winding loop (T1–D6–R16–C11–T1), the output loop (T1–D6–C9–T1, T1–D1–C1–T1 and T1–D2–C3–T1), and the RCD loop (T1–D5–R5/R7/C4–T1).

2) Ensure the power loop ground doesn’t pass through the control circuit ground. If a heat sink is used, connect it to the primary GND plane to improve EMI and thermal dissipation.

3) Place the control circuit capacitors (for FB, PRO, and VCC) close to the IC to decouple the switching noise.

4) Enlarge the GND pad near the IC for good thermal dissipation.

5) Keep the EMI filter far away from the switching point.

6) Ensure enough clearance distance to meet the insulation requirement.

Design Example
Table 2 is a design example using the application guidelines for the given specifications.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Table 2: Design Example</strong></td>
<td></td>
</tr>
<tr>
<td><strong>VIN</strong></td>
<td>85 to 420VAC</td>
</tr>
<tr>
<td><strong>VOUT1</strong></td>
<td>13.5V</td>
</tr>
<tr>
<td><strong>IOUT1</strong></td>
<td>0.3A</td>
</tr>
<tr>
<td><strong>VOUT2</strong></td>
<td>8V</td>
</tr>
<tr>
<td><strong>IOUT2</strong></td>
<td>0.05A</td>
</tr>
<tr>
<td><strong>VOUT3</strong></td>
<td>8V</td>
</tr>
<tr>
<td><strong>IOUT3</strong></td>
<td>0.05A</td>
</tr>
<tr>
<td><strong>fS</strong></td>
<td>50kHz</td>
</tr>
</tbody>
</table>

The detailed application schematic is shown in Figure 11. The typical performance and circuit waveforms are shown in the Typical Performance Characteristics section. For more details, please refer to the related evaluation board datasheets.
Figure 11: Typical Application Schematic

Figure 12: Transformer Structure
<table>
<thead>
<tr>
<th>Tape (T)</th>
<th>Winding</th>
<th>Terminal Start → End</th>
<th>Wire Size (Φ)</th>
<th>Turns (T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N1</td>
<td>1 → NC</td>
<td>0.15mm*2</td>
<td>22</td>
</tr>
<tr>
<td>1</td>
<td>N2</td>
<td>2 → 1</td>
<td>0.15mm*1</td>
<td>170</td>
</tr>
<tr>
<td>1</td>
<td>N3</td>
<td>4 → 3</td>
<td>0.1mm*1</td>
<td>26</td>
</tr>
<tr>
<td>1</td>
<td>N6</td>
<td>5 → 6</td>
<td>0.3mm TIW *1</td>
<td>26</td>
</tr>
<tr>
<td>1</td>
<td>N4</td>
<td>10 → 9</td>
<td>0.16mm TIW *1</td>
<td>16</td>
</tr>
<tr>
<td>1</td>
<td>N5</td>
<td>A → B</td>
<td>0.16mm TIW *1</td>
<td>16</td>
</tr>
</tbody>
</table>
FLOW CHART

Start

Internal High-Voltage Current Source On

Auxiliary Winding Supply to the IC

Y

VCC > VCC

N

Y

Soft Start

Monitor VCC

Monitor VFB

VFB < VRL<br>

Switch Off

Fixed Switching Frequency Operation

N

VFB > VRL<br>

VRL < VFB < VLP

VFB > VLP

N

N

N

VCC < VCL<br>

Shut Down the Switching Pulse

TSD = Logic High?

Pin PRO Monitor

PRO = Logic Low?

Pin PRO Monitor

Y

YES

VCC < VCR

Shut Down the Switching Pulse

Y

YES

8192 Counter and OLP = Logic High?

OLP = Logic High

UVLO, TSD, OVP and OLP are Auto Restart
EVOLUTION OF THE SIGNALS IN PRESENCE OF FAULTS
PACKAGE INFORMATION

SOIC8-7A

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.
PACKAGE INFORMATION (continued)

SOIC14-11

TOP VIEW

RECOMMENDED LAND PATTERN

FRONT VIEW

SIDE VIEW

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.
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5) DRAWING CONFORMS TO JEDEC MS-012, VARIATION AB.
6) DRAWING IS NOT TO SCALE.

DETAIL "A"

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