HF500-30

Fixed Frequency Flyback Regulator with Multi-Mode Control and Over-Power Line Compensation

The Future of Analog IC Technology

PRELIMINARY SPECIFICATIONS SUBJECT TO CHANGE

DESCRIPTION

The HF500-30 is a fixed-frequency, current-mode regulator with built-in slope compensation. It 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 to spread energy out in a conducted mode. During a light-load condition, the regulator freezes the peak current and reduces its switching frequency to $f_{OSC(min)}$ to offer excellent efficiency at light load. At very light load, the regulator enters burst mode to achieve low standby power consumption.

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

The HF500-30 features timer-based fault detection and over-power compensation to ensure that the overload is independent of the input voltage.

The HF500-30 is available in a PDIP8-7B package.

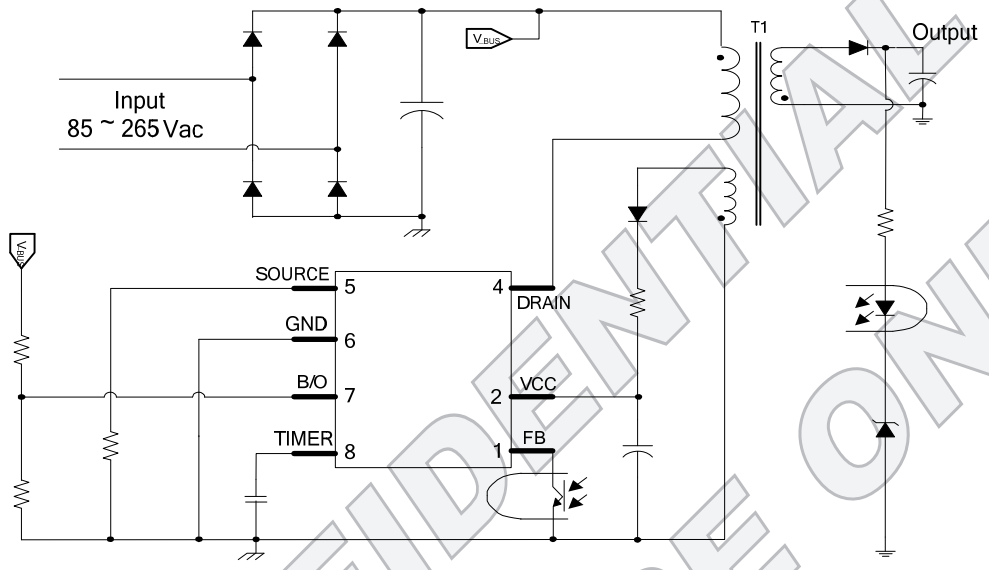
Features

- 700V/1.4Ω Integrated MOSFET
- Fixed-Frequency Current-Mode-Control Operation with Built-In Slope Compensation
- Frequency Foldback Down to $f_{OSC(min)}$ 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
- VCC Under-Voltage Lockout (UVLO) with Hysteresis
- Programmable Input B/O and 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

APPLICATIONS

- Power Supplies for Home Appliances
- Set-Top Boxes
- Standby and Auxiliary Power
- Adapters

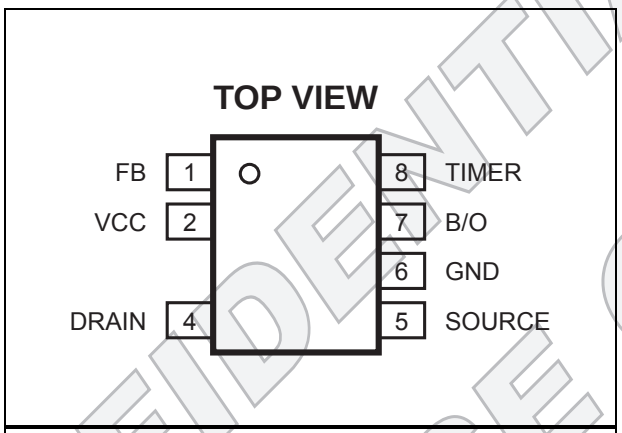
TYPICAL APPLICATION



ORDERING INFORMATION

Part Number*	Package	Top Marking

PACKAGE REFERENCE



PDIP8-7B

ABSOLUTE MAXIMUM RATINGS (1)

Drain breakdown voltage ..... -0.3V to 700V
V_{CC} to GND .....-0.3V to 30V
FB, TIMER, SOURCE, B/O to GND..-0.3V to 7V
Continuous power dissipation (T_A = +25°C) (2)
.....1.2W
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 (3)

Operating junction temp (T_J).... -40°C to +125°C
Operating VCC range .....12.5V to 24V

Thermal Resistance (4)

	θ_{JA}	θ_{JC}	
PDIP8-7B	105	45	°C/W

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 θ_{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)/θ_{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.

ELECTRICAL CHARACTERISTICS(5)

For typical value, VCC=16V, T_J = -40°C to 125°C, unless otherwise noted.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Start-Up Current Source (DRAIN)						
Supply current from DRAIN	I_{Drain_0}	V_{CC} = 0V, V_{Drain} = 120V/400V	1.4	3.6	6.2	mA
	I_{Drain_11}	V_{CC} = 11V, V_{Drain} = 120V/400V	1.4	5	7.9	
Leakage current from DRAIN	I_{LK}	V_{CC} = 10V, V_{Drain} = 400V		4.5	10.5	µA
Breakdown voltage	V_{BR}	T_J = 25°C	700			V
Internal MOSFET (DRAIN)						
On-state resistance	R_{DS_ON}	V_{CC} = 10.5V, I_D = 0.1A, T_J = 25°C		1.4		Ω
Supply Voltage Management (VCC)						
VCC level (increasing) where the internal regulator stops	VCC_{OFF}		11	12	13	V
VCC level (decreasing) where the IC shuts down and the internal regulator turns on	VCC_{UVLO}		6	7	8	V
VCC UVLO hysteresis	VCC_{OFF} – VCC_{UVLO}		4	4.8		V
VCC recharge level when protection occurs	VCC_{PRO}		4.7	5.3	5.9	V
VCC decreasing level where the latch-off phase ends	VCC_{LATCH}			2.5		V
Internal IC consumption	I_{CC}	V_{FB} = 3V, V_{CC} = 12V		0.9	1.2	mA
Internal IC consumption, latch-off phase	$I_{CCLATCH}$	V_{CC} = 12V, T_J = 25°C		700	900	µA
Voltage on VCC (upper limit) where the regulator latches off (OVP)	V_{OVP}		25	27	29	V
Blanking duration on the OVP comparator	T_{OVP}			60		ms
Oscillator						
Oscillator frequency	f_{OSC}	V_{FB} > 1.85V, T_J = 25°C	62	65	68	kHz
Frequency jittering amplitude in percentage of f_{OSC}	A_{jitter}	V_{FB} > 1.85V, T_J = 25°C	±5	±6.5	±8	%
Frequency jittering entry level	V_{FB_JITTER}				1.95	V
Frequency jittering modulation period	T_{jitter}	C_{TIMER} = 47nF		3.7		ms

ELECTRICAL CHARACTERISTICS[5] *(continued)*

For typical value, VCC=16V, T_J = -40°C to 125°C, unless otherwise noted.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Protections (B/O)						
Brown-in threshold voltage on B/O	V_{B/O_IN}	$V_{B/O}$ increasing	0.95	1	1.05	V
Brownout threshold voltage on B/O	V_{B/O_OUT}	$V_{B/O}$ decreasing	0.85	0.9	0.95	V
Brown-in/out hysteresis	$\Delta V_{B/O}$		0.065	0.1	0.14	V
Timer duration for line cycle dropout	$T_{B/O}$	C_{TIMER} = 47nF	34	55		ms
Input OVP threshold on B/O	$OVP_{B/O}$		4.2	4.5	4.8	V
Input OVP delay time	$T_{OVPB/O}$			90		µs
Voltage on B/O to disable B/O and input OVP function	V_{DIS}		5.4	6	6.6	V
Clamp voltage on B/O	V_{B/O_Cla}		7			V
Input impedance	$R_{B/O}$		1.2			MΩ
Current Sense (SOURCE)						
Current limit point	V_{ILIM}		0.93	1	1.07	V
Short-circuit protection point	V_{SCP}		1.3	1.5	1.7	V
Current limitation during frequency foldback	V_{FOLD}	V_{FB} = 1.85V	0.63	0.68	0.73	V
Current limitation when entering burst	V_{IBURL}	V_{FB} = 0.7V		0.1		V
Current limitation when exiting burst	V_{IBURH}	V_{FB} = 0.8V		0.13		V
Leading-edge blanking for V_{ILIM}	T_{LEB1}			350		ns
Leading-edge blanking for V_{SCP}	T_{LEB2}			270		ns
Slope of the compensation ramp	S_{RAMP}		18	25	31	mV/µs
Feedback (FB)						
Internal pull-up resistor	R_{FB}	T_J = 25°C	12	13.5	15	kΩ
Internal pull-up voltage	V_{DD}			4.3		V
V_{FB} to internal current-set point division ratio	K_{FB1}	V_{FB} = 2V	2.5	2.8	3.1	
V_{FB} to current-set point division ratio	K_{FB2}	V_{FB} = 3V	2.8	3.1	3.4	
FB level (decreasing) where the regulator enters burst mode	V_{BURL}		0.63	0.7	0.77	V
FB level (increasing) where the regulator exits burst mode	V_{BURH}		0.72	0.8	0.88	V

ELECTRICAL CHARACTERISTICS(5) *(continued)*

For typical value, VCC=16V, T_J = -40°C to 125°C, unless otherwise noted.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Over-Load Protection (FB)						
FB level where the regulator enters OLP after a dedicated time	V_{OLP}			3.7		V
Time duration before OLP when FB reaches the protection point	T_{OLP}	C_{TIMER} = 47nF	32			ms
Over-Power Compensation (B/O)						
Compensation voltage	V_{OPC}	$V_{B/O}$ = 1.1V, V_{FB}=2.5V, T_J = 25°C		0		mV
		$V_{B/O}$ = 1.3V, V_{FB}=2.5V, T_J = 25°C		19		
		$V_{B/O}$ = 2.9V, V_{FB}=2.5V, T_J = 25°C	153	200	247	
		$V_{B/O}$ = 3.5V, V_{FB}=2.5V, T_J = 25°C	205	270	335	
		$V_{B/O}$ > V_{DIS}, T_J = 25°C		0		
FB voltage (lower limit) when compensation is removed	$V_{OPC(OFF)}$		0.55			V
FB voltage (upper limit) when compensation is fully applied	$V_{OPC(ON)}$				2.5	V
Frequency Foldback						
FB voltage (lower threshold) when frequency foldback starts	$V_{FB(FOLD)}$			1.8		V
Minimum switching frequency	$f_{OSC(min)}$	T_J = 25°C	20.5	25	30	kHz
FB voltage (lower threshold) when frequency foldback ends	$V_{FB(FOLDE)}$			1		V
Latch-Off Input (Integration in TIMER)						
Lower threshold when the regulator is latched	$V_{TIMER(LATCH)}$		0.7	1	1.2	V
Blanking duration on latch detection	T_{LATCH}			42		µs
Thermal Shutdown						
Thermal shutdown threshold	T_{TSD}			150		°C#
Thermal shutdown hysteresis	$T_{TSD(HYS)}$			25		°C#

PIN FUNCTIONS

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

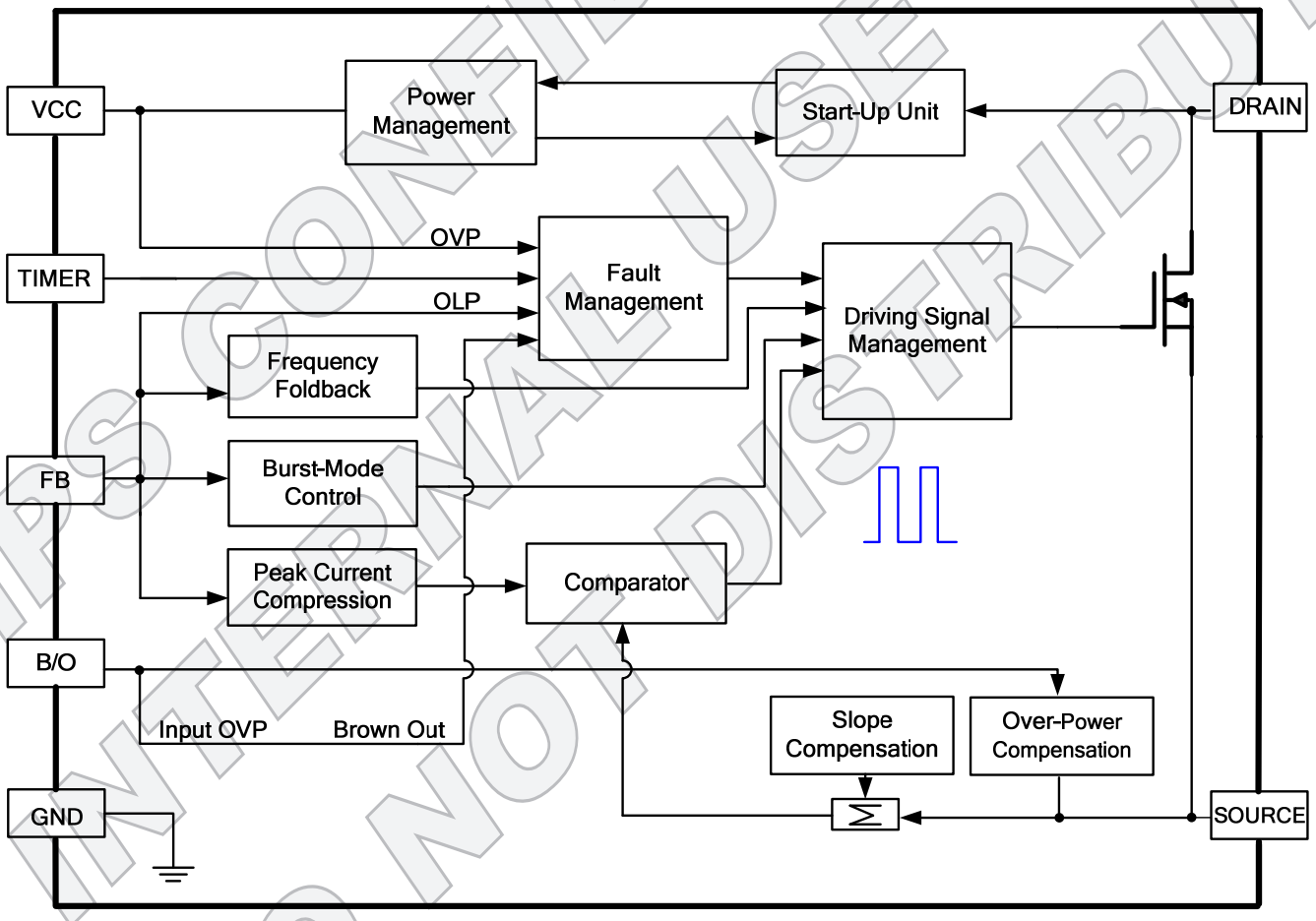


Figure 1: Functional Block Diagram

OPERATION

The HF500-30 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 HF500-30 uses frequency jittering to improve EMI performance.

Fixed Frequency with Jittering

Frequency jittering reduces EMI by spreading out the energy. Figure 2 shows the frequency jitter circuit.

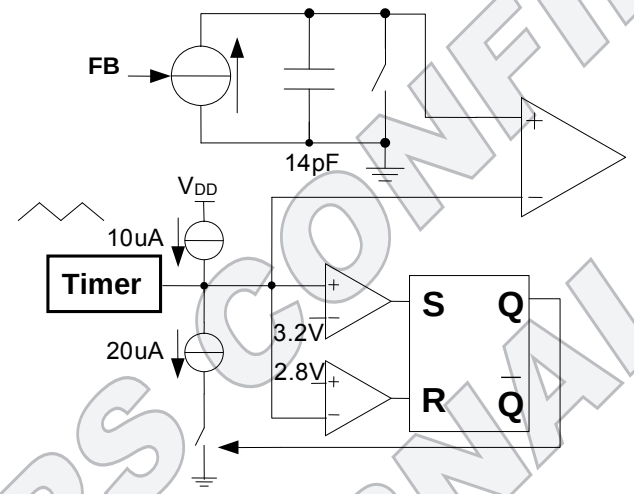


Figure 2: Frequency Jitter Circuit

An internal capacitor is charged with a controlled current source, which is fixed when FB > 2V, and its voltage is compared with the TIMER voltage. The TIMER voltage 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):

$$f_s = \frac{1 \cdot 10^6}{5.28 \cdot V_{TIMER} / V + 0.2} Hz \quad (1)$$

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

$$T_{jitter} = 8 \cdot C_{TIMER} / nF \cdot 10^{-5} s \quad (2)$$

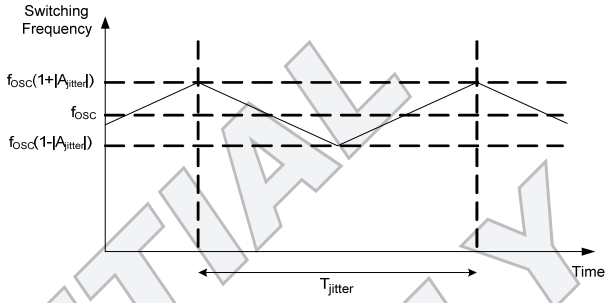


Figure 3: Frequency Jittering

Frequency Foldback

To achieve high efficiency during all load conditions, the HF500-30 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.

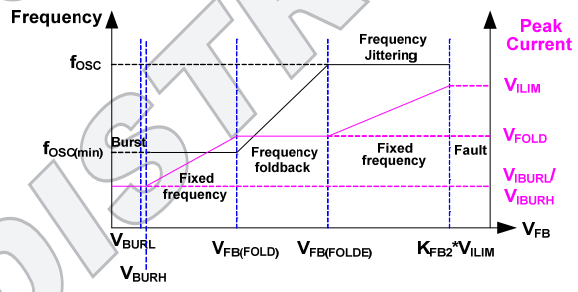


Figure 4: Frequency and Peak Current vs. FB

Current-Mode Operation with Slope Compensation

The primary peak current is controlled by the FB voltage. When the peak current reaches the level determined by FB, the MOSFET turns off. Also, the regulator operates 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 the voltage on VCC reaches VCC_{OFF}. If the voltage on VCC falls below VCC_{UVLO}, the switching pulse stops, and the current source turns on again. The auxiliary winding takes over the power supply for the IC when the output voltage rises normally to the set voltage. The lower threshold of VCC UVLO is pulled down from VCC_{UVLO} to VCC_{PRO} when a fault condition occurs, such as OLP, SCP, brownout, OVP, OTP, etc (see Figure 5).

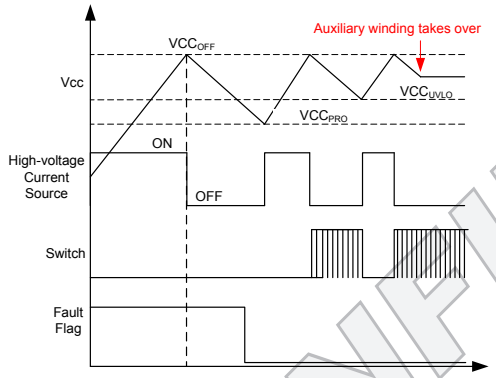


Figure 5: VCC Power Supply Process

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 at 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.

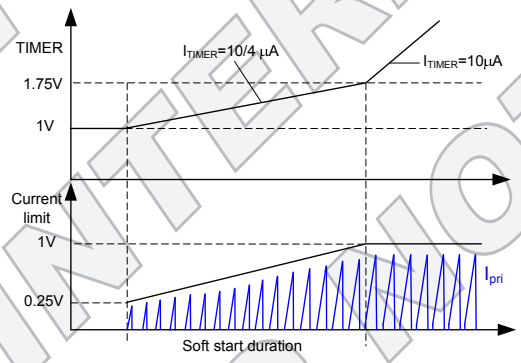


Figure 6: Soft Start

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):

$$T_{Soft-start} = 0.3 \cdot C_{TIMER} / nF \cdot 10^{-3} s \quad (3)$$

Burst Operation

The HF500-30 uses burst-mode operation to minimize the power dissipation in no-load or light-load conditions. As the load decreases, the FB voltage decreases. The IC stops the switching cycle when the FB voltage drops below the lower threshold (V_{BURL}); the FB increases again once the output voltage drops. Switching resumes once the FB voltage exceeds the threshold (V_{BURH}). The FB voltage 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

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 V_{OPC} can be calculated using Equation (4):

$$V_{OPC} = 0.094 \cdot (V_{B/O} - 1.1V) \quad (4)$$

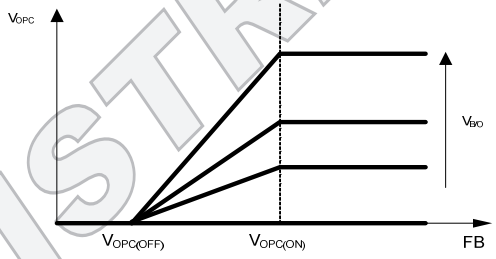


Figure 7: Compensation Current vs. FB and B/O Voltage

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 then reduced, and the FB voltage is pulled high (see Figure 8).

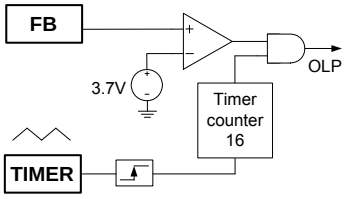


Figure 8: Overload Protection Block

FB rising higher than V_{OLP} is considered 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 reaches completion after it has counted to 16, it enters OLP. This timer duration does not trigger the OLP function when the power supply is starting up or during a load transition phase. Figure 9 shows the OLP function.

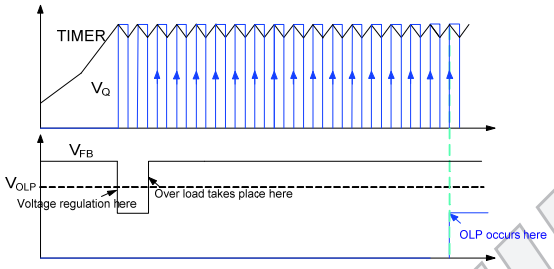


Figure 9: Overload Protection Function

Input Brownout and Input OVP

The input brownout and input OVP can be realized by B/O. If the B/O voltage is higher than V_{B/O_IN} during the input voltage rising period, the IC begins operating. If the B/O voltage is lower than V_{B/O_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 the input OVP. If the voltage on B/O is higher than V_{DIS}, it disables the input brownout and input OVP functions. To simplify the external circuit, connect B/O to VCC through a resistor if the input brownout, over-power compensation, and the input OVP functions are not desired.

Short-Circuit Protection (SCP)

The HF500-30 features a short-circuit protection that senses the SOURCE voltage and stops switching if V_{SOURCE} reaches V_{SCP} after a reduced leading-edge blanking time (T_{LEB2}). Once the fault disappears, the power supply resumes operation.

Thermal Shutdown

The HF500-30 uses thermal shutdown to turn off the switching cycle when the inner temperature exceeds T_{OTP}. As soon as 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 VCC_{UVLO} to VCC_{PRO}.

VCC Over-Voltage Protection (OVP)

The HF500-30 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 VCC_{LATCH} (e.g. the user unplugs the power supply from the main input and plugs it back in). Usually, this situation occurs when the optocoupler fails, resulting in the loss of the output voltage regulation.

TIMER Protection

The HF500-30 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. Figure 10 shows the LEB waveform.

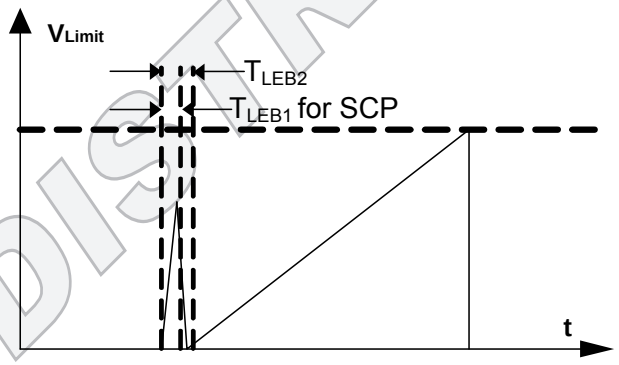
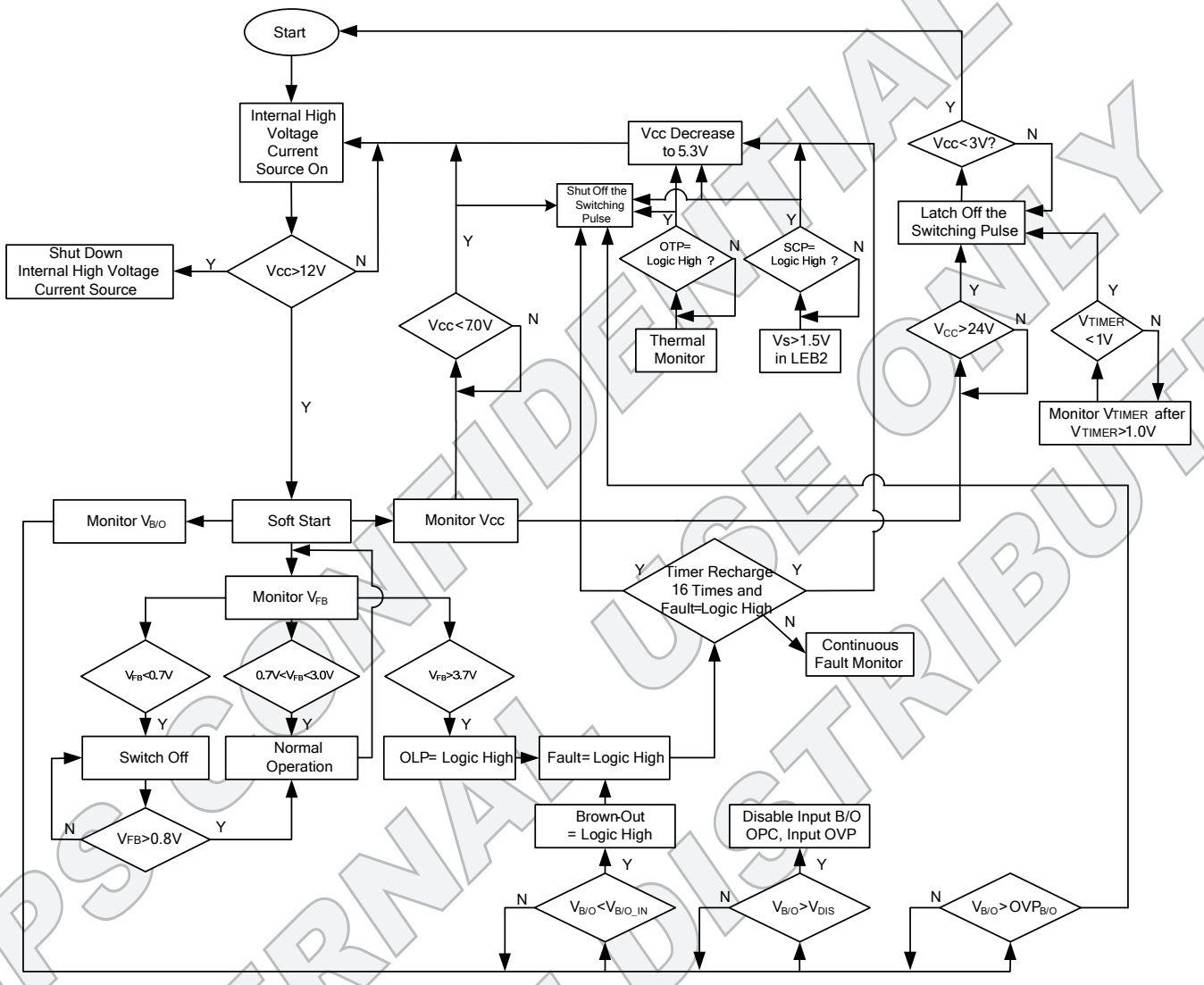


Figure 10: Leading-Edge Blanking

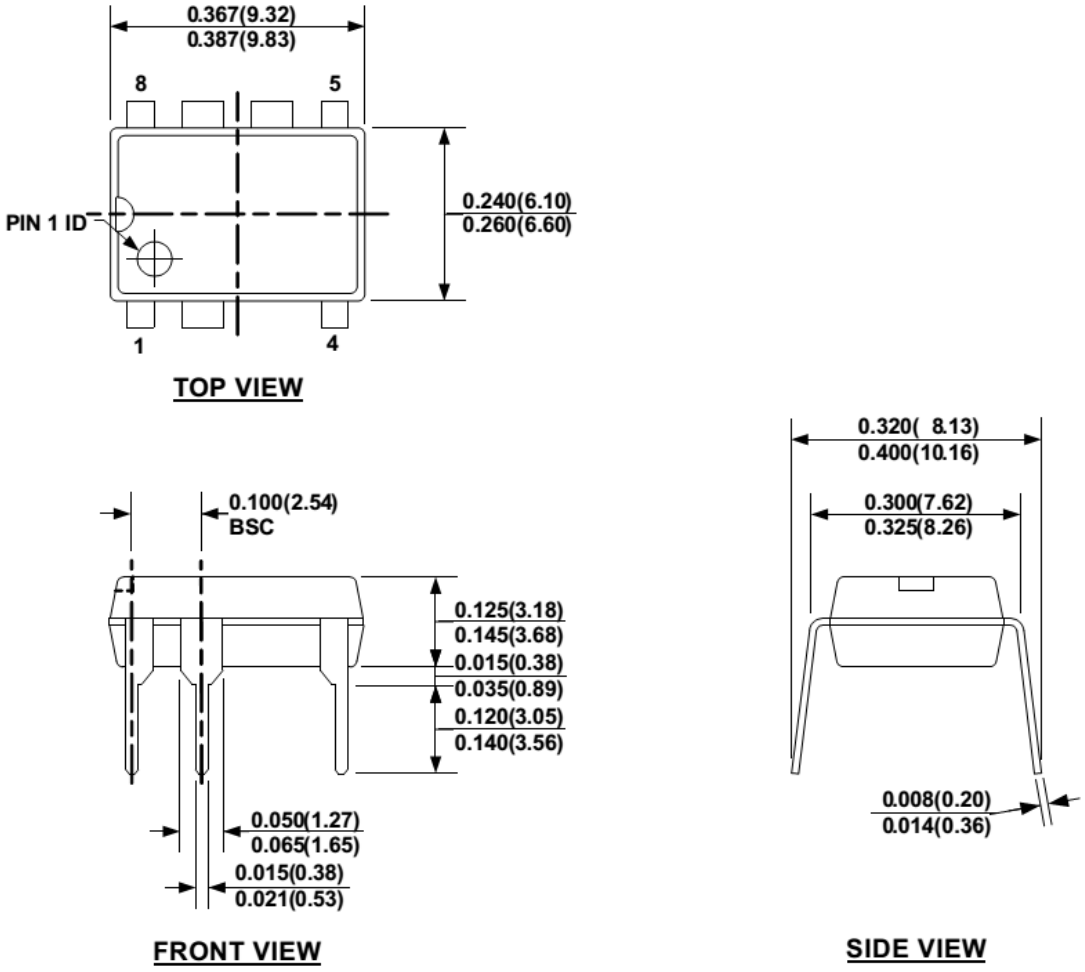
FLOW CHART



UVLO, brown-out, OTP & OLP are auto restart; OVP on VCC, and latch-off on TIMER are latch mode.
To release from the latch condition, unplug from the main input.

PACKAGE INFORMATION

PDIP8-7B



NOTE:

1) CONTROL DIMENSION IS IN INCHES DIMENSION IN BRACKET IS IN MILLIMETERS
2) PACKAGE LENGTH AND WIDTH DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
3) JEDEC REFERENCE IS MS-001.
4) DRAWING IS NOT TO SCALE