TOP254-258

TOPSwitch®-HX Family

Improved *EcoSmart®*, Integrated Off-Line Switcher with Enhanced Feature Set and Extended Power Range

Product Highlights

Lower System Cost, High Design Flexibility

- Multi-mode operation maximizes efficiency at all loads
- No heatsink required up to 35 W with P package with universal input
  - Up to 48 W at 230 VAC
- Output overvoltage protection (OVP)
  - User programmable non latching shutdown or latching shutdown with AC reset
  - Allows both primary and secondary sensing
- Line under-voltage (UV) detection prevents turn-off glitches
- Line over-voltage (OV) shutdown extends line surge limit
- Enhanced accurate programmable current limit
- Dual slope line feed-forward for line ripple rejection
- 132 kHz frequency (Y package) reduces transformer and power supply size
- Half frequency option in Y package for video applications
- Tight I^2f parameter tolerance reduces system cost
  - Maximizes MOSFET and transformer power delivery
  - Minimizes overload power, reducing cost of transformer, primary clamp & secondary components
- Frequency jittering reduces EMI filter cost
- Improved auto-restart delivers <3% of maximum power in short circuit and open loop fault conditions
- Accurate hysteretic thermal shutdown function automatically recovers without requiring a reset
- Fully integrated soft-start for minimum start-up stress
- Pin-out simplifies heatsinking to the PCB (P package)
- Extended creepage between DRAIN and all other pins improves field reliability
- SOURCE pins are electrically quiet for low EMI

EcoSmart – Energy Efficient

- Specifically designed to enhance energy efficiency over entire load range
- No-load consumption <200 mW at 265 VAC
- Standby output power ≥0.5 W for 1 W input power at 265 VAC

Description

TOPSwitch-HX cost effectively incorporates a 700 V power MOSFET, high voltage switched current source, PWM control, oscillator, thermal shutdown circuit, fault protection and other control circuitry onto a monolithic device.

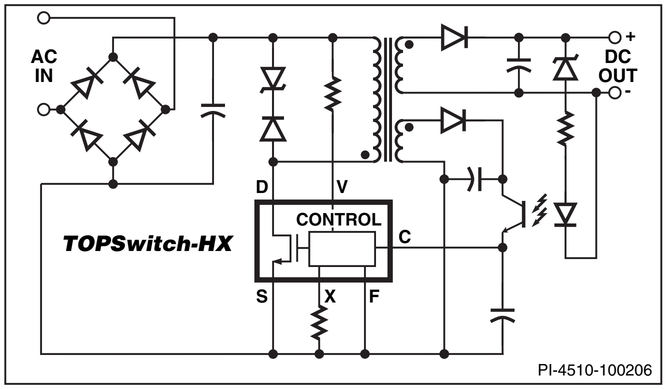

Figure 1. Typical Flyback Application.

OUTPUT POWER TABLE				
PRODUCT[4]	230 VAC ±15%[3]		85-265 VAC	
	Adapter[1]	Open Frame[2]	Adapter[1]	Open Frame[2]
TOP254PN	16 W	28 W	11 W	20 W
TOP254MN				
TOP254YN	30 W	62 W	20 W	43 W
TOP255PN	19 W	30 W	13 W	22 W
TOP255MN				
TOP255YN	40 W	81 W	26 W	57 W
TOP256PN	21 W	34 W	15 W	26 W
TOP256MN				
TOP256YN	60 W	119 W	40 W	66 W
TOP257PN	25 W	41 W	19 W	30 W
TOP257MN				
TOP257YN	85 W	157 W	55 W	119 W
TOP258PN	35 W	48 W	22 W	35 W
TOP258MN				
TOP258YN	105 W	195 W	70 W	148 W

Table 1. Output Power Table.

Notes:
1. Typical continuous power in a non-ventilated enclosed adapter measured at 50 °C ambient.
2. Maximum practical continuous power in an open frame design at 50 °C ambient.
3. 230 VAC or 100/115 VAC with doubler.
4. Packages: P: DIP-8C, Y: TO-220-&C.

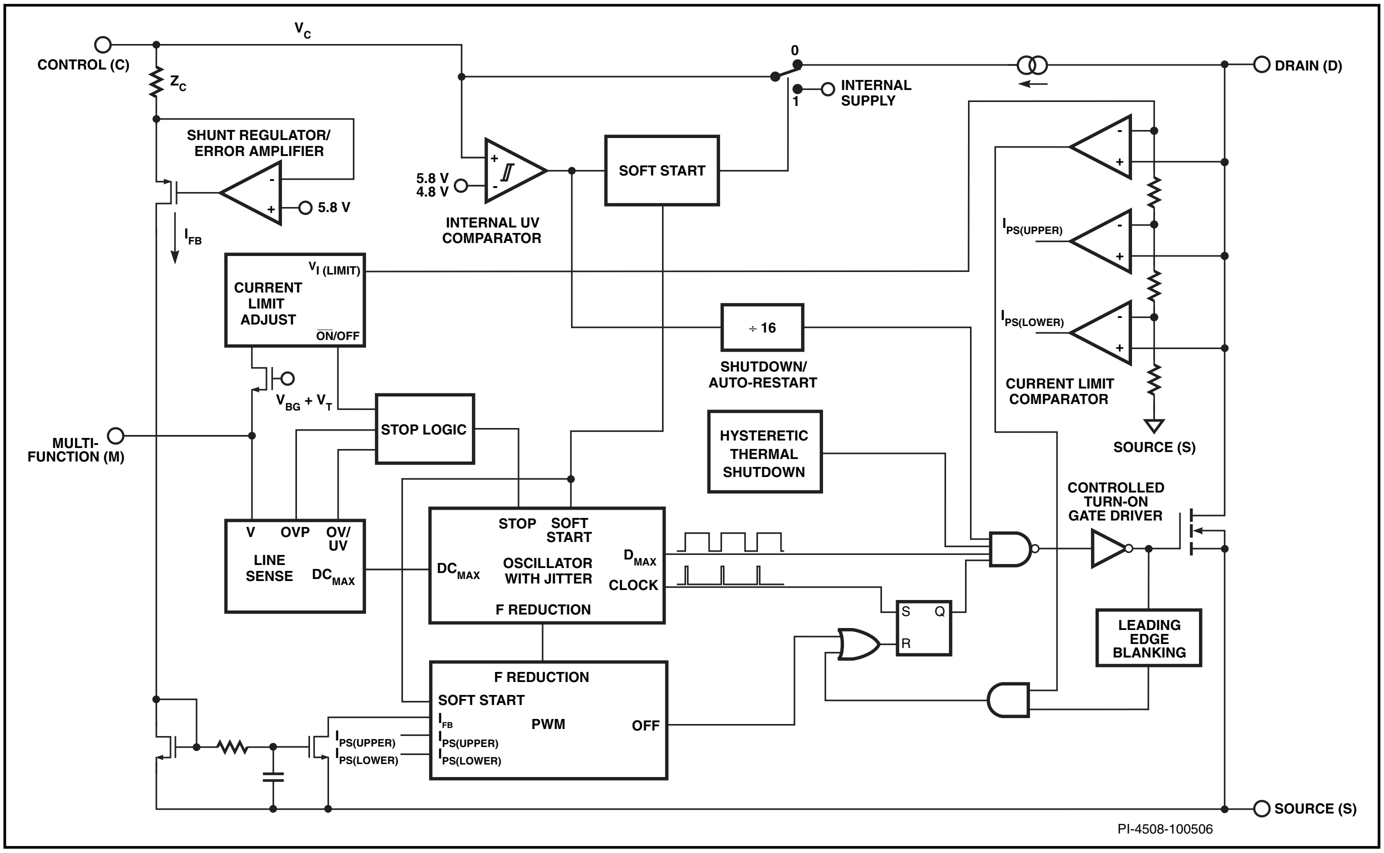

Figure 2a. Functional Block Diagram (P Package).

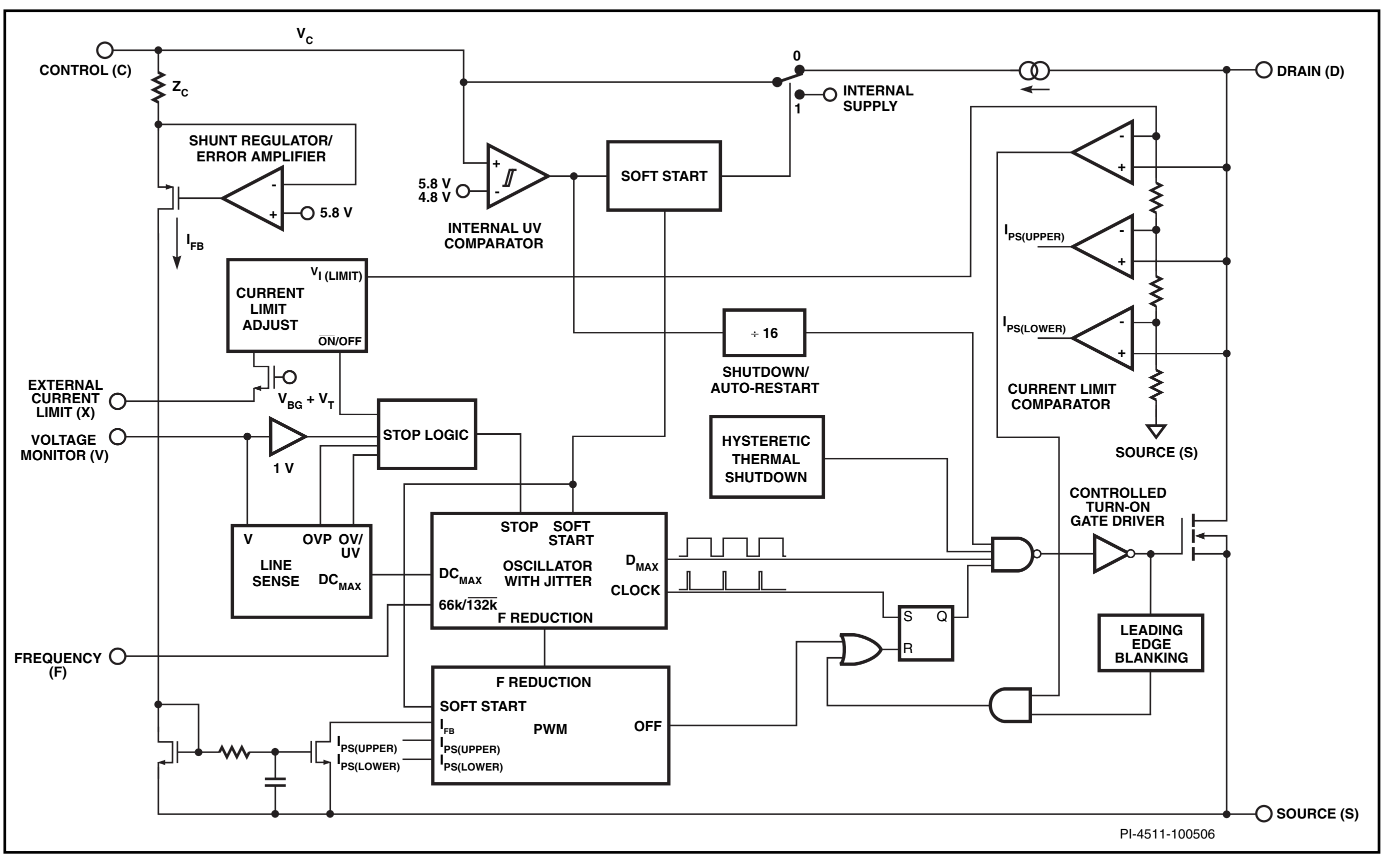

Figure 2b. Functional Block Diagram (Y Package).

This document contains information on a new product. Specifications and information herein are subject to change without notice.

Pin Functional Description

DRAIN (D) Pin:
High-voltage power MOSFET DRAIN pin. The internal start-up bias current is drawn from this pin through a switched high-voltage current source. Internal current limit sense point for drain current.

CONTROL (C) Pin:
Error amplifier and feedback current input pin for duty cycle control. Internal shunt regulator connection to provide internal bias current during normal operation. It is also used as the connection point for the supply bypass and auto-restart/compensation capacitor.

EXTERNAL CURRENT LIMIT (X) Pin (Y & M package only):
Input pin for external current limit adjustment and remote ON/OFF. A connection to SOURCE pin disables all functions on this pin.

MULTI-FUNCTION (M) Pin (P package only):
This pin combines the functions of the VOLTAGE MONITOR (V) and EXTERNAL CURRENT LIMIT (X) pins of the Y package into one pin. Input pin for OV, UV, line feed forward with DC_{MAX} reduction, output overvoltage protection (OVP), external current limit adjustment, remote ON/OFF and device reset. A connection to SOURCE pin disables all functions on this pin and makes *TOPSwitch-HX* operate in simple three terminal mode (like *TOPSwitch-II*).

VOLTAGE MONITOR (V) Pin (Y & M package only):
Input for OV, UV, line feed forward with DC_{MAX} reduction, output overvoltage protection (OVP), remote ON/OFF and device reset. A connection to the Source pin disables all functions on this pin.

FREQUENCY (F) Pin (Y package only):
Input pin for selecting switching frequency 132 kHz if connected to SOURCE pin and 66 kHz if connected to CONTROL pin. The switching frequency is internally set for fixed 66 kHz operation in the P package.

SOURCE (S) Pin:
Output MOSFET source connection for high voltage power return. Primary side control circuit common and reference point.

TOPSwitch-HX Family Functional Description

Like *TOPSwitch*, *TOPSwitch-HX* is an integrated switched mode power supply chip that converts a current at the control input to a duty cycle at the open drain output of a high voltage power MOSFET. During normal operation the duty cycle of the power MOSFET decreases linearly with increasing CONTROL pin current as shown in Figure 4.

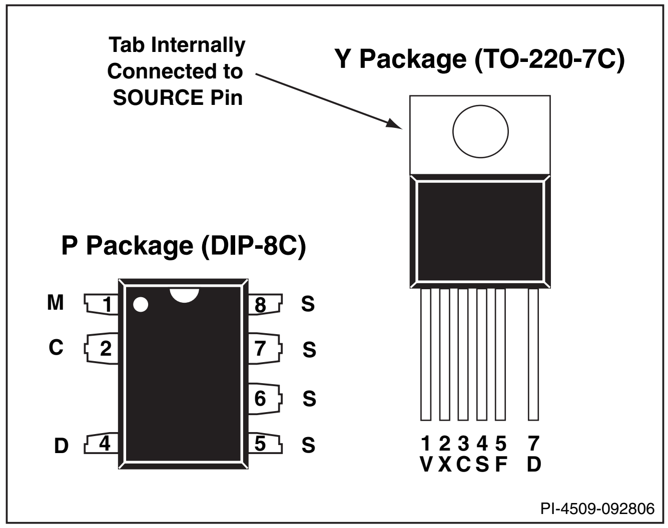

Figure 3. Pin Configuration (top view).

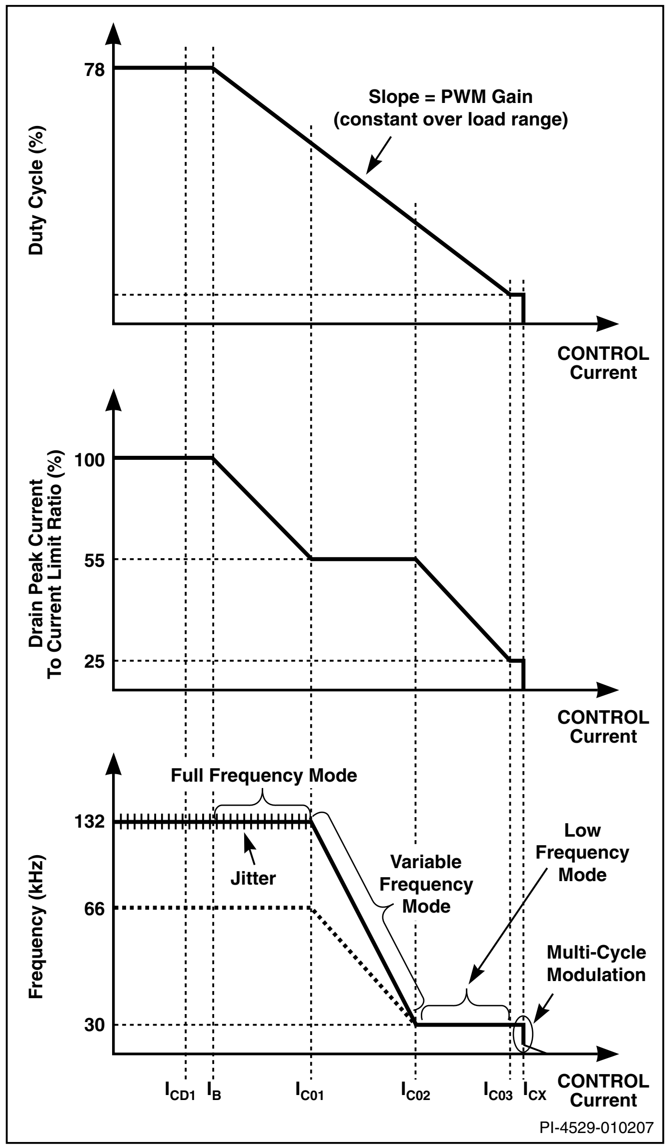

Figure 4. Control Pin Characteristic (Multi-Mode Operation).

In addition to the three terminal *TOPSwitch* features, such as the high voltage start-up, the cycle-by-cycle current limiting, loop compensation circuitry, auto-restart, thermal shutdown, the *TOPSwitch-HX* incorporates many additional functions that reduce system cost, increase power supply performance and design flexibility. A patented high voltage CMOS technology allows both the high-voltage power MOSFET and all the low voltage control circuitry to be cost effectively integrated onto a single monolithic chip.

Three terminals, FREQUENCY, VOLTAGE-MONITOR, and EXTERNAL CURRENT LIMIT (available in Y package), two terminals, VOLTAGE-MONITOR and STANDARD CURRENT LIMIT (available in M package) or one terminal MULTI-FUNCTION (available in P package) have been used to implement some of the new functions. These terminals can be connected to the SOURCE pin to operate the *TOPSwitch-HX* in a *TOPSwitch*-like three terminal mode. However, even in this three terminal mode, the *TOPSwitch-HX* offers many new transparent features that do not require any external components:

1. A fully integrated 17 ms soft-start significantly reduces or eliminates output overshoot in most applications by sweeping both current limit and frequency from low to high to limit the peak currents and voltages during start-up.
2. A maximum duty cycle (DC_{MAX}) of 78% allows smaller input storage capacitor, lower input voltage requirement and/or higher power capability.
3. Multi-mode operation optimizes and improves the power supply efficiency over the entire load range while maintaining good cross regulation in multi-output supplies.
4. Switching frequency of 132 kHz reduces the transformer size with no noticeable impact on EMI.
5. Frequency jittering reduces EMI in the full frequency mode at high load condition.
6. Hysteretic over-temperature shutdown ensures automatic recovery from thermal fault. Large hysteresis prevents circuit board overheating.
7. Packages with omitted pins and lead forming provide large drain creepage distance.
8. Reduction of the auto-restart duty cycle and frequency to improve the protection of the power supply and load during open loop fault, short circuit, or loss of regulation.
9. Tighter tolerances on I^2f power coefficient, current limit reduction, PWM gain and thermal shutdown threshold.

The VOLTAGE-MONITOR (V) pin is usually used for line sensing by connecting a resistor of 4 MΩ from this pin to the rectified DC high voltage bus to implement line overvoltage (OV), under-voltage (UV) and dual-slope line feed-forward with DC_{MAX} reduction. In this mode, the value of the resistor determines the OV/UV thresholds and the DC_{MAX} is reduced linearly with a dual slope to further improve the line ripple rejection. In addition, it also provides another threshold to implement the latched and hysteretic output overvoltage protection (OVP). The pin can also be used as a remote ON/OFF using the Iuv threshold.

The EXTERNAL CURRENT LIMIT (X) pin is usually used to reduce the current limit externally to a value close to the operating peak current, by connecting the pin to SOURCE through a resistor. This pin can also be used as a remote ON/OFF input.

For the P package the VOLTAGE-MONITOR and EXTERNAL CURRENT LIMIT pin functions are combined on one MULTI-FUNCTION (M) pin. However, some of the functions become mutually exclusive.

The FREQUENCY (F) pin in the Y package sets the switching frequency in the full frequency PWM mode to the default value of 132 kHz when connected to SOURCE pin. A half frequency option of 66 kHz can be chosen by connecting this pin to CONTROL pin instead. Leaving this pin open is not recommended. In the P package, the frequency is set internally at 66 kHz in the full frequency PWM mode.

CONTROL (C) Pin Operation

The CONTROL pin is a low impedance node that is capable of receiving a combined supply and feedback current. During normal operation, a shunt regulator is used to separate the feedback signal from the supply current. CONTROL pin voltage V_C is the supply voltage for the control circuitry including the MOSFET gate driver. An external bypass capacitor closely connected between the CONTROL and SOURCE pins is required to supply the instantaneous gate drive current. The total amount of capacitance connected to this pin also sets the auto-restart timing as well as control loop compensation.

When rectified DC high voltage is applied to the DRAIN pin during start-up, the MOSFET is initially off, and the CONTROL pin capacitor is charged through a switched high voltage current source connected internally between the DRAIN and CONTROL pins. When the CONTROL pin voltage V_C reaches approximately 5.8 V, the control circuitry is activated and the soft-start begins. The soft-start circuit gradually increases the Drain peak current and switching frequency from a low starting value to the maximum Drain peak current at the full frequency over approximately 17 ms. If no external feedback/supply current is fed into the CONTROL pin by the end of the soft-start, the high voltage current source is turned off and the CONTROL pin will start discharging in response to the supply current drawn by the control circuitry. If the power supply is designed properly, and no fault condition such as open loop or shorted output exists, the feedback loop will close, providing external CONTROL pin current, before the CONTROL pin voltage has had a chance to discharge to the lower threshold voltage of approximately 4.8 V (internal supply undervoltage lockout threshold). When the externally fed current charges the CONTROL pin to the shunt regulator voltage of 5.8 V, current in excess of the consumption of the chip is shunted to SOURCE through an NMOS current mirror as shown in Figure 2. The output current of that NMOS current mirror controls the duty cycle of the power MOSFET to provide closed loop regulation. The shunt regulator has a finite low output impedance Z_C that sets the gain of the error amplifier when used in a primary feedback configuration. The dynamic impedance Z_C of the CONTROL pin together with the external CONTROL pin capacitance sets the dominant pole for the control loop.

When a fault condition such as an open loop or shorted output prevents the flow of an external current into the CONTROL pin, the capacitor on the CONTROL pin discharges towards 4.8 V. At 4.8 V, auto-restart is activated which turns the output MOSFET off and puts the control circuitry in a low current standby mode. The high-voltage current source turns on and charges the external capacitance again. A hysteretic internal supply under-voltage comparator keeps V_C within a window of typically 4.8 V to 5.8 V by turning the high-voltage current source on and off as shown in Figure 6. The auto-restart circuit has a divide-by-sixteen counter, which prevents the output MOSFET from turning on again until sixteen discharge/charge cycles have elapsed. This is accomplished by enabling the output MOSFET only when the divide-by-sixteen counter reaches the full count (S15). The counter effectively limits *TOPSwitch-HX* power dissipation by reducing the auto-restart duty cycle to typically 2%. Auto-restart mode continues until output voltage regulation is again achieved through closure of the feedback loop.

Oscillator and Switching Frequency

The internal oscillator linearly charges and discharges an internal capacitance between two voltage levels to create a triangular waveform for the timing of the pulse width modulator. This oscillator sets the pulse width modulator/current limit latch at the beginning of each cycle.

The nominal full switching frequency of 132 kHz was chosen to minimize transformer size while keeping the fundamental EMI frequency below 150 kHz. The FREQUENCY pin (available only in Y package), when shorted to the CONTROL pin, lowers the full switching frequency to 66 kHz (half frequency), which may be preferable in some cases such as noise sensitive video applications or a high efficiency standby mode. Otherwise, the FREQUENCY pin should be connected to the SOURCE pin for the default 132 kHz. In the M and P packages, the full frequency PWM mode is set at 66 kHz, for higher efficiency and increased output power in all applications.

To further reduce the EMI level, the switching frequency in the full frequency PWM mode is jittered (frequency modulated) by approximately ±5 kHz at a 250 Hz (typical) rate as shown in Figure 5. The jitter is turned off gradually as the system is entering the variable frequency mode with a fixed peak Drain current or the low frequency mode with a fixed switching frequency.

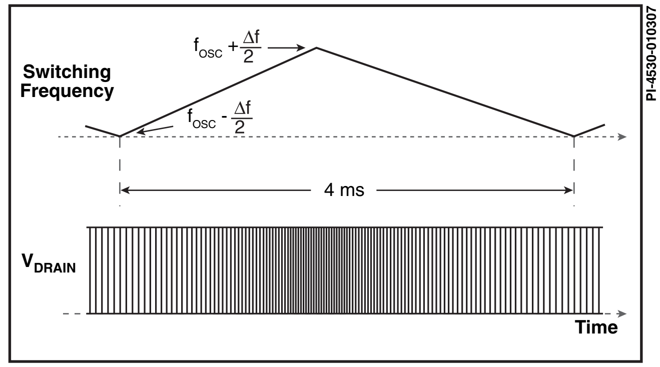

Figure 5. Switching Frequency Jitter (Idealized V_{DRAIN} Waveforms).

Pulse Width Modulator

The pulse width modulator implements multi-mode control by driving the output MOSFET with a duty cycle inversely proportional to the current into the CONTROL pin that is in excess of the internal supply current of the chip (see Figure 4). The feedback error signal, in the form of the excess current, is filtered by an RC network with a typical corner frequency of 7 kHz to reduce the effect of switching noise in the chip supply current generated by the MOSFET gate driver.

To optimize power supply efficiency, four different control modes are implemented. At maximum load, the modulator operates in full frequency PWM mode, as load decreases, the modulator automatically transitions, first to variable frequency PWM mode, then to low frequency PWM mode. At light load, the control operation switches from PWM control to multi-cycle-modulation control, and the modulator operates in multi-cycle-modulation mode. Although different modes operate differently, to make transitions between modes smooth, the simple relationship between duty cycle and excess CONTROL pin current shown in Figure 4 is maintained through all three PWM modes. Please see the following sections for the details of the operation of each mode and the transitions between modes.

Full Frequency PWM mode: The PWM modulator enters full frequency PWM mode when the CONTROL pin current (I_C) reaches I_B. In this mode, the average switching frequency is kept constant at f_{OSC} (66 kHz for P and M packages, pin selectable 132 kHz or 66 kHz for Y package). Duty cycle is reduced from DC_{MAX} through the reduction of the on-time when I_C is increased beyond I_B. This operation is identical to the PWM control of all other *TOPSwitch* families. *TOPSwitch-HX* only operates in this mode if the cycle-by-cycle peak drain current stays above $k_{PS(UPPER)}$*I_{LIMIT}(set), where $k_{PS(UPPER)}$ is 55% (typical) and I_{LIMIT}(set) is the current limit externally set via the X pin.

Variable Frequency PWM mode: When peak drain current is lowered to $k_{PS(UPPER)}$* I_{LIMIT}(set) as a result of power supply load reduction, the PWM modulator initiates the transition to variable frequency PWM mode, and gradually turns off frequency jitter. In this mode, peak drain current is held constant at $k_{PS(UPPER)}$* I_{LIMIT}(set) while switching frequency drops from the initial full frequency of f_{OSC} (132 kHz or 66 kHz) towards the minimum frequency of $f_{MCM(MIN)}$ (30 kHz typical). Duty cycle reduction is accomplished by extending the off-time.

Low Frequency PWM mode: When switching frequency reaches $f_{MCM(MIN)}$ (30 kHz typical), the PWM modulator starts to transition to low frequency mode. In this mode, switching frequency is held constant at $f_{MCM(MIN)}$ and duty cycle is reduced, similar to the full frequency PWM mode, through the reduction of the on-time. Peak drain current decreases from the initial value of $k_{PS(UPPER)}$*I_{LIMIT}(set) towards the minimum value of $k_{PS(LOWER)}$*I_{LIMIT}(set), where $k_{PS(LOWER)}$ is 25% (typical) and I_{LIMIT}(set) is the current limit externally set via the X pin.

Multi-Cycle-Modulation Mode: When peak drain current is lowered to $k_{PS(LOWER)}$*I_{LIMIT}(set), the modulator transitions to multi-cycle-modulation mode. In this mode, at each turn-on, the modulator enables output switching for a period of $T_{MCM(MIN)}$ at the switching frequency of $f_{MCM(MIN)}$ (4 or 5 consecutive pulses at 30 kHz) with the peak drain current of $k_{PS(LOWER)}$*I_{LIMIT}(set), and stays off until the CONTROL pin current falls below $I_{C(OFF)}$. This mode of operation, not only keeps peak drain current low, but also minimizes harmonic frequencies between 6 kHz and 30 kHz. By avoiding transformer resonant frequency this way, all potential transformer audible noises are greatly supressed.

Maximum Duty Cycle

The maximum duty cycle, DC_{MAX} is set at a default maximum value of 78% (typical). However, by connecting the VOLTAGE-MONITOR or MULTI-FUNCTION pin (depending on the package) to the rectified DC high voltage bus through a resistor with appropriate value (4 MΩ typical), the maximum duty cycle can be made to decrease from 78% to 40% (typical) when input line voltage increases from 80 V to 380 V, with dual gain slopes.

Error Amplifier

The shunt regulator can also perform the function of an error amplifier in primary side feedback applications. The shunt regulator voltage is accurately derived from a temperature-compensated bandgap reference. The CONTROL pin dynamic impedance Z_C sets the gain of the error amplifier. The CONTROL pin clamps external circuit signals to the V_C voltage level. The CONTROL pin current in excess of the supply current is separated by the shunt regulator and becomes the feedback current I_{fb} for the pulse width modulator.

On-Chip Current Limit with External Programmability

The cycle-by-cycle peak drain current limit circuit uses the output MOSFET ON-resistance as a sense resistor. A current limit comparator compares the output MOSFET on-state drain to source voltage, $V_{DS(ON)}$ with a threshold voltage. High drain current causes $V_{DS(ON)}$ to exceed the threshold voltage and turns the output MOSFET off until the start of the next clock cycle. The current limit comparator threshold voltage is temperature compensated to minimize the variation of the current limit due to temperature related changes in $R_{DS(ON)}$ of the output MOSFET. The default current limit of *TOPSwitch-HX* is preset internally. However, with a resistor connected between EXTERNAL CURRENT LIMIT (X) pin (Y and M packages) or MULTI-FUNCTION (M) pin (P package) and SOURCE pin, current limit can be programmed externally to a lower level between 30% and 100% of the default current limit. By setting current limit low, a larger *TOPSwitch-HX* than necessary for the power required can be used to take advantage of the lower $R_{DS(ON)}$ for higher efficiency/smaller heat sinking requirements. *TOPSwitch-HX* current limit reduction initial tolerance through the X pin (or M pin) has been improved significantly compare with previous *TOPSwitch-GX*. With a second resistor connected between the EXTERNAL CURRENT LIMIT (X) pin (Y and M packages) or MULTI-FUNCTION (M) pin (P package) and the rectified DC high voltage bus, the current limit is reduced with increasing line voltage, allowing a true power limiting operation against line variation to be implemented. When using an RCD clamp, this power limiting technique reduces maximum clamp voltage at high line. This allows for higher reflected voltage designs as well as reducing clamp dissipation.

The leading edge blanking circuit inhibits the current limit comparator for a short time after the output MOSFET is turned on. The leading edge blanking time has been set so that, if a power supply is designed properly, current spikes caused by primary-side capacitances and secondary-side rectifier reverse recovery time should not cause premature termination of the switching pulse.

The current limit is lower for a short period after the leading edge blanking time. This is due to dynamic characteristics of the MOSFET. During startup and fault conditions the controller prevents excessive drain currents by reducing the switching frequency.

Line Under-Voltage Detection (UV)

At power up, UV keeps *TOPSwitch-HX* off until the input line voltage reaches the under-voltage threshold. At power down, UV prevents auto-restart attempts after the output goes out of regulation. This eliminates power down glitches caused by slow discharge of the large input storage capacitor present in applications such as standby supplies. A single resistor connected from the VOLTAGE-MONITOR pin (Y and M packages) or MULTI-FUNCTION pin (P package) to the rectified DC high voltage bus sets UV threshold during power up. Once the power supply is successfully turned on, the UV threshold is lowered to 40% of the initial UV threshold to allow extended input voltage operating range (UV low threshold). If the UV low threshold is reached during operation without the power supply losing regulation, the device will turn off and stay off until UV (high threshold)

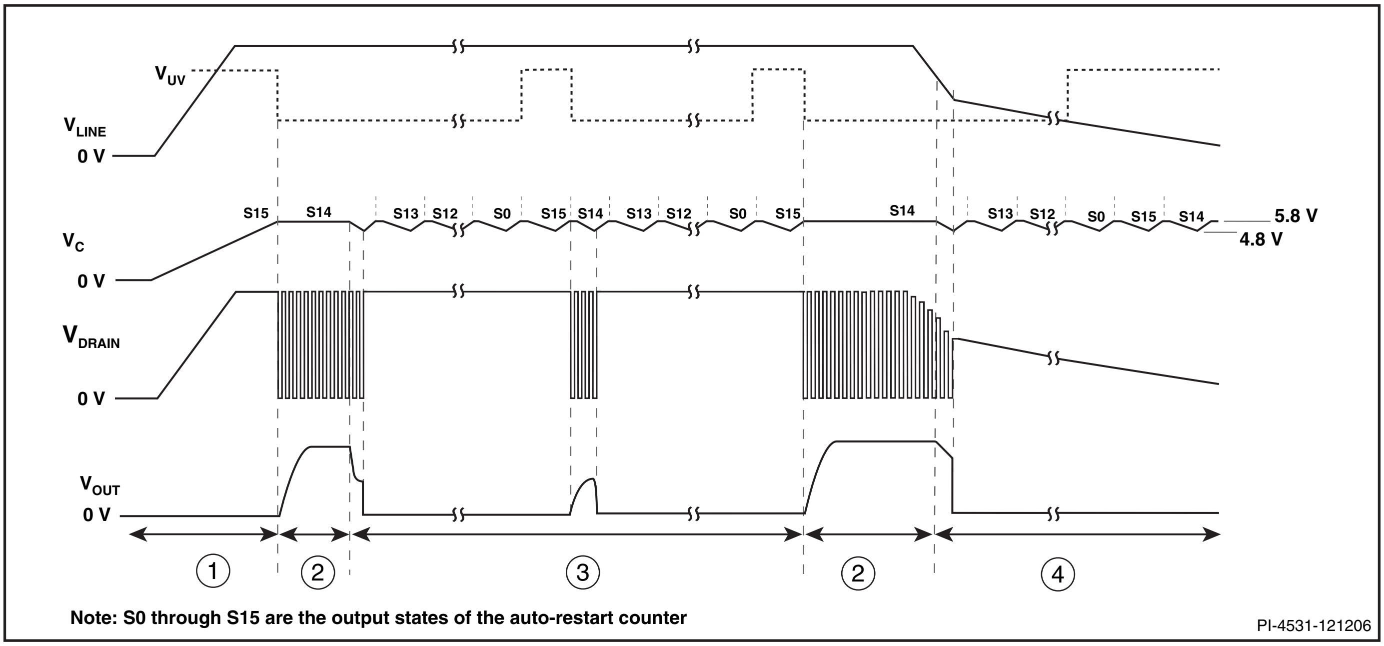

Figure 6. Typical Waveforms for (1) Power Up (2) Normal Operation (3) Auto-Restart (4) Power Down.

has been reached again. If the power supply loses regulation before reaching the UV low threshold, the device will enter auto-restart. At the end of each auto-restart cycle (S15), the UV comparator is enabled. If the UV high threshold is not exceeded the MOSFET will be disabled during the next cycle (see Figure 6). The UV feature can be disabled independent of the OV feature.

Line Overvoltage Shutdown (OV)

The same resistor used for UV also sets an overvoltage threshold, which, once exceeded, will force *TOPSwitch-HX* to stop switching instantaneously (after completion of the current switching cycle). If this condition lasts for at least 100 µs, the *TOPSwitch-HX* output will be forced into off state. Unlike with *TOPSwitch-GX*, however, when the line voltage is back to normal with a small amount of hysteresis provided on the OV threshold to prevent noise triggering, the state machine sets to S13 and forces *TOPSwitch-HX* to go through the entire auto-restart sequence before attempting to switch again. The ratio of OV and UV thresholds is preset at 4.5 as can be seen in Figure 7. When the MOSFET is off, the rectified DC high voltage surge capability is increased to the voltage rating of the MOSFET (700 V), due to the absence of the reflected voltage and leakage spikes on the drain. The OV feature can be disabled independent of the UV feature.

Hysteretic or Latching Output Overvoltage Protection (OVP)

The detection of the hysteretic or latching output overvoltage protection (OVP) is through the trigger of the line overvoltage threshold. The V-pin voltage will drop by 0.5 V, and the controller measures the external attached impedance right after this voltage drops. If I_V exceeds $I_{OV(LS)}$ (336 µA typical) longer than 100 µs, *TOPSwitch-HX* will latch into a permanent off state for the latching OVP. It only can be reset if V_V goes below 1 V or V_C goes below the power-up-reset threshold ($V_{C(RESET)}$) and then back to normal.

If I_V does not exceed $I_{OV(LS)}$ or exceeds no longer than 100 µs, *TOPSwitch-HX* will initiate the line overvoltage and the hysteretic OVP. Their behavior will be identical to the line overvoltage shutdown (OV) that had been described in detail in the previous section.

Line Feed-Forward with DC_{MAX} Reduction

The same resistor used for UV and OV also implements line voltage feed-forward, which minimizes output line ripple and reduces power supply output sensitivity to line transients. Note that for the same CONTROL pin current, higher line voltage results in smaller operating duty cycle. As an added feature, the maximum duty cycle DC_{MAX} is also reduced from 78% (typical) at a voltage slightly higher than the UV threshold to 30% (typical) at the OV threshold. DC_{MAX} of 36% at high line was chosen to ensure that the power capability of the *TOPSwitch-HX* is not restricted by this feature under normal operation. *TOPSwitch-HX* provides a better fit to the ideal feed-forward by using two reduction slopes: -1% per µA for all bus voltage less than 190 V and -0.25% per µA for all bus voltage more than 190 V. This dual slope line feed-forward improves the line ripple rejection significantly compare with the *TOPSwitch-GX*.

Remote ON/OFF

TOPSwitch-HX can be turned on or off by controlling the current into the VOLTAGE-MONITOR pin or out from the EXTERNAL CURRENT LIMIT pin (Y and M packages) and into or out from the MULTI-FUNCTION pin (P package, see Figure 7). In addition, the VOLTAGE-MONITOR pin has a 1 V threshold comparator connected at its input. This voltage threshold can also be used to perform remote ON/OFF control.

When a signal is received at the VOLTAGE-MONITOR pin or the EXTERNAL CURRENT LIMIT pin (Y and M packages) or the MULTI-FUNCTION pin (P package) to disable the output through any of the pin functions such as OV, UV and remote ON/OFF, *TOPSwitch-HX* always completes its current switching cycle before the output is forced off.

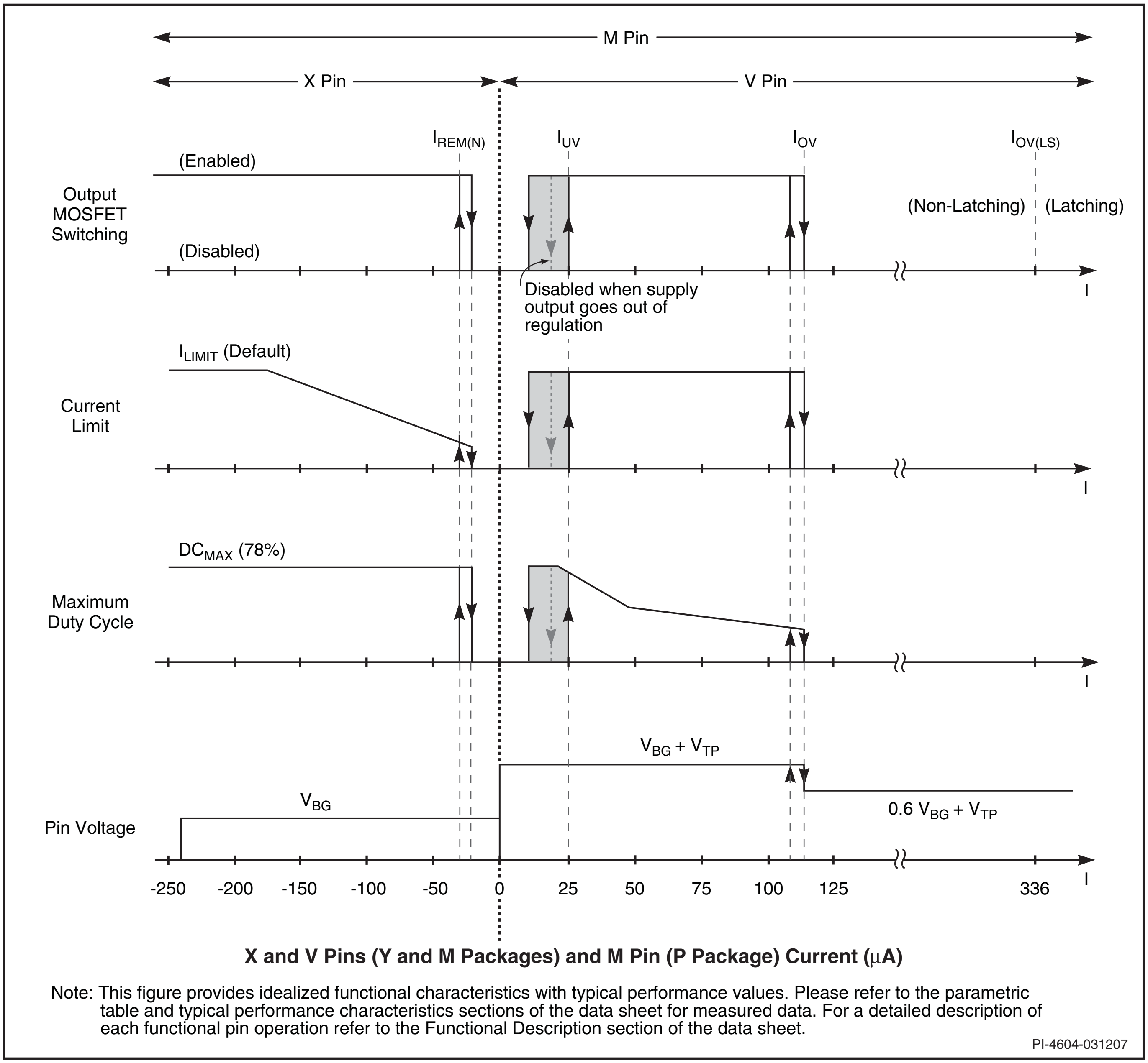

Figure 7. MULTI-FUNCTION (P package), VOLTAGE MONITOR and EXTERNAL CURRENT LIMIT (Y and M packages) Pin

As seen above, the remote ON/OFF feature can also be used as a standby or power switch to turn off the *TOPSwitch-HX* and keep it in a very low power consumption state for indefinitely long periods. If the *TOPSwitch-HX* is held in remote off state for long enough time to allow the CONTROL pin to discharge to the internal supply undervoltage threshold of 4.8 V (approximately 32 ms for a 47 μF CONTROL pin capacitance), the CONTROL pin goes into the hysteretic mode of regulation. In this mode, the CONTROL pin goes through alternate charge and discharge cycles between 4.8 V and 5.8 V (see CONTROL pin operation section above) and runs entirely off the high voltage DC input, but with very low power consumption (160 mW typical at 230 VAC with M or X pins open). When the TOPSwitch-HX is remotely turned on after entering this mode, it will initiate a normal start-up sequence with soft-start the next time the CONTROL pin reaches 5.8 V. In the worst case, the delay from remote on to start-up can be equal to the full discharge/charge cycle time of the CONTROL pin, which is approximately 125 ms for a 47 μF CONTROL pin capacitor. This reduced consumption remote off mode can eliminate expensive and unreliable in-line mechanical switches. It also allows for microprocessor controlled turn-on and turn-off sequences that may be required in certain applications such as inkjet and laser printers.

Soft-Start

The 17 ms soft-start sweeps the peak Drain current and switching requency linearly from minimum to maximum value by operating through the low frequency PWM mode and the variable frequency mode before entering the full frequency mode. In addition to start-up, soft-start is also activated at each restart attempt during auto-restart and when restarting after being in hysteretic regulation of CONTROL pin voltage (V_C), due to remote OFF or thermal shutdown conditions. This effectively minimizes current and voltage stresses on the output MOSFET, the clamp circuit and the output rectifier during start-up. This feature also helps minimize output overshoot and prevents saturation of the transformer during start-up.

Shutdown/Auto-Restart

To minimize *TOPSwitch-HX* power dissipation under fault conditions, the shutdown/auto-restart circuit turns the power supply on and off at an auto-restart duty cycle of typically 2% if an out of regulation condition persists. Loss of regulation interrupts the external current into the CONTROL pin. V_C regulation changes from shunt mode to the hysteretic auto-restart mode as described in CONTROL pin operation section. When the fault condition is removed, the power supply output becomes regulated, V_C regulation returns to shunt mode, and normal operation of the power supply resumes.

Hysteretic Over-Temperature Protection

Temperature protection is provided by a precision analog circuit that turns the output MOSFET off when the junction temperature exceeds the thermal shutdown temperature (142 °C typical). When the junction temperature cools to below the hysteretic temperature, normal operation resumes providing automatic recovery. A large hysteresis of 75 °C (typical) is provided to prevent overheating of the PC board due to a continuous fault condition. V_C is regulated in hysteretic mode and a 4.8 V to 5.8 V (typical) triangular waveform is present on the CONTROL pin while in thermal shutdown.

Bandgap Reference

All critical *TOPSwitch-HX* internal voltages are derived from a temperature-compensated bandgap reference. This voltage reference is used to generate all other internal current references, which are trimmed to accurately set the switching frequency, MOSFET gate drive current, current limit, and the line OV/UV/OVP thresholds. *TOPSwitch-HX* has improved circuitry to maintain all of the above critical parameters within very tight absolute and temperature tolerances.

High-Voltage Bias Current Source

This high-voltage current source biases *TOPSwitch-HX* from the DRAIN pin and charges the CONTROL pin external capacitance during start-up or hysteretic operation. Hysteretic operation occurs during auto-restart, remote OFF and over-temperature shutdown. In this mode of operation, the current source is switched on and off with an effective duty cycle of approximately 35%. This duty cycle is determined by the ratio of CONTROL pin charge (I_C) and discharge currents (I_{CD1} and I_{CD2}). This current source is turned off during normal operation when the output MOSFET is switching. The effect of the current source switching will be seen on the DRAIN voltage waveform as small disturbances and is normal.

ABSOLUTE MAXIMUM RATINGS(2)

DRAIN Peak Voltage: .... -0.3 V to 700 V
DRAIN Peak Current: TOP254...TBD
TOP255...TBD
TOP256...TBD
TOP257...TBD
TOP258...TBD
CONTROL Voltage.. -0.3 V to 9 V
CONTROL Current.. 100 mA
VOLTAGE MONITOR Pin Voltage ....TBD
CURRENT LIMIT Pin Voltage ....TBD
MULTI-FUNCTION Pin Voltage......................................TBD
FREQUENCY Pin Voltage..TBD
Storage Temperature ....TBD
Operating Junction Temperature.....................-40 °C to 150 °C
Lead Temperature[1] .... 260 °C

Notes:

1. 1/16 inch from case for 5 seconds.
2. Maximum ratings specified may be applied one at a time, without causing permanent damage to the product. Exposure to Absolute Maximum Rating conditions for extended periods of time may affect product reliability.

THERMAL IMPEDANCE

Thermal Impedance: Y Package:
(θ_{JA})... 80 °C/W(1)
(θ_{JC}) .... 2 °C/W(2)
M Package:
(θ_{JA})... °C/W(4)
(θ_{JC})... °C/W(5)
P Package:
(θ_{JA})......................70 °C/W(3); 60 °C/W(4)
(θ_{JC})...11 °C/W(5)

Notes:

1. Free standing with no heatsink.
2. Measured at the back surface of tab.
3. Soldered to 0.36 sq. in. (232 mm^2), 2 oz. (610 g/m^2) copper clad.
4. Soldered to 1 sq. in. (645 mm^2), 2 oz. (610 g/m^2) copper clad.
5. Measured on the SOURCE pin close to plastic interface.

Parameter	Symbol	Conditions SOURCE = 0 V; T_J = -40 to 125 °C (Unless Otherwise Specified)		Min	Typ	Max	Units
CONTROL FUNCTIONS							
Switching Frequency in Full Frequency Mode (average)	f_{OSC}	T_J = 25 °C	FREQUENCY Pin Connected to SOURCE	119	132	145	kHz
			FREQUENCY Pin Connected to CONTROL M/P Package	59.5	66	72.5	
Frequency Jitter Deviation	Δf		132 kHz Operation		±5		kHz
			66 kHz Operation		±2.5		
Frequency Jitter Modulation Rate	f_M				250		Hz
Maximum Duty Cycle	DC_{MAX}	$I_C = I_{CD1}$	$I_V \leq I_{V(DC)}$ or $I_M \leq I_{M(DC)}$ or V_V = 0 V, V_M = 0 V	75	78	83	%
			I_V = 95 µA	30			
Soft-Start Time	t_{SOFT}	T_J = 25 °C			17		ms
PWM Gain	DC_{reg}	T_J = 25 °C		-28	-23	-18	%/mA
PWM Gain Temperature Drift					-0.01		%/mA/ °C
External Bias Current	I_B		TOP254-257	TBD	1.7	TBD	mA
			TOP258	TBD	1.8	TBD	

PRELIMINARY

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Parameter	Symbol	Conditions SOURCE = 0 V; T_J = -40 to 125 °C (Unless Otherwise Specified)		Min	Typ	Max	Units
CONTROL FUNCTIONS (cont.)							
CONTROL Current at 0% Duty Cycle	$I_{C(OFF)}$	T_J = 25 °C	TOP254-257		4.4	TBD	mA
			TOP258		5.0	TBD	
Dynamic Impedance	Z_C	I_C = 4 mA; T_J = 25 °C		10	15	22	Ω
Dynamic Impedance Temperature Drift					0.18		%/°C
CONTROL Pin Internal Filter Pole					7		kHz
Upper Peak Current to Set Current Limit Ratio	$k_{PS(UPPER)}$	T_J = 25 °C		TBD	55	TBD	%
Lower Peak Current to Set Current Limit Ratio	$k_{PS(LOWER)}$	T_J = 25 °C			25		%
Multi-Cycle-Modulation Switching Frequency	$f_{MCM(MIN)}$	T_J = 25 °C		TBD	30	TBD	kHz
Minimum *Multi-Cycle-Modulation* On Period	$T_{MCM(MIN)}$	T_J = 25 °C			135		µs
SHUTDOWN/AUTO-RESTART							
Control Pin Charging Current	$I_{C(CH)}$	T_J = 25 °C	V_C = 0 V	TBD	-3.5	TBD	mA
			V_C = 5 V	TBD	-1.8	TBD	
Charging Current Temperature Drift					0.5		%/°C
Auto-Restart Upper Threshold Voltage	$V_{C(AR)U}$				5.8		V
Auto-Restart Lower Threshold Voltage	$V_{C(AR)L}$			4.5	4.8	5.1	V
Auto-Restart Hysteresis Voltage	$V_{C(AR)hyst}$			0.8	1.0		V
Auto-Restart Duty Cycle	$DC_{(AR)}$				2	TBD	%
Auto-Restart Frequency	$f_{(AR)}$				0.5		Hz

Parameter	Symbol	Conditions SOURCE = 0 V; T_J = -40 to 125 °C (Unless Otherwise Specified)		Min	Typ	Max	Units
MULTI-FUNCTION (M), VOLTAGE MONITOR (V) AND EXTERNAL CURRENT LIMIT (X) INPUTS							
Line Undervoltage Threshold Current and Hysteresis (M or V Pin)	I_{UV}	T_J = 25 °C	Threshold	TBD	25	TBD	μA
			Hysteresis		15		μA
Line Overvoltage Threshold Current and Hysteresis (M or V Pin)	I_{OV}	T_J = 25 °C	Threshold	105	112	120	μA
			Hysteresis		4		μA
Output Overvoltage Latching Shutdown Threshold Current	$I_{OV(LS)}$	T_J = 25 °C		TBD	336	TBD	μA
V or M Pin Reset Voltage	$V_{V(TH)}$ or $V_{M(TH)}$	T_J = 25 °C		TBD	1.0	1.6	V
Remote ON/OFF Negative Threshold Current and Hysteresis (M or X Pin)	$I_{REM\ (N)}$	T_J = 25 °C	Threshold	-35	-27	-20	μA
			Hysteresis		5		
V or M Pin Short Circuit Current	$I_{V(SC)}$ or $I_{M(SC)}$	V_V, V_M = V_C		TBD	400	TBD	μA
X or M Pin Short Circuit Current	$I_{X(SC)}$ or $I_{M(SC)}$	V_X, V_M = 0 V	Normal Mode	-300	-240	-180	μA
			Auto-Restart Mode	-110	-90	-70	
V or M Pin Voltage (Positive Current)	V_V or V_M		I_V or I_M = I_{UV}	TBD	2.80	TBD	V
			I_V or I_M = I_{OV}	TBD	3.00	TBD	
V or M Pin Voltage Hysteresis (Positive Current)	$V_{V(hyst)}$ or $V_{M(hyst)}$		I_V or I_M = I_{OV}	TBD	0.50		V
X Pin Voltage (Negative Current)	V_X		I_X = -50 μA	TBD	1.33	TBD	V
			I_X = -150 μA	TBD	1.24	TBD	
M Pin Voltage (Negative Current)	V_M		I_M = -50 μA	TBD	1.30	TBD	V
			I_M = -150 μA	TBD	1.19	TBD	
Maximum Duty Cycle Reduction Onset Threshold Current	$I_{V(DC)}$ or $I_{M(DC)}$	$I_C \geq I_B$, T_J = 25 °C		TBD	22	TBD	μA

Parameter	Symbol	Conditions SOURCE = 0 V; T_J = -40 to 125 °C (Unless Otherwise Specified)		Min	Typ	Max	Units
MULTI-FUNCTION (M), VOLTAGE MONITOR (V) AND EXTERNAL CURRENT LIMIT (X) INPUTS (cont.)							
Maximum Duty Cycle Reduction Slope		T_J = 25 °C	$I_{V(DC)} < I_V$ <48 µA or $I_{M(DC)} < I_M$ <48 µA		-1.0		%/µA
			I_V, I_M ≥48 µA		-0.25		
Remote OFF DRAIN Supply Current	$I_{D(RMT)}$	V_{DRAIN} = 150 V	X, V or M Pin Floating		0.6	TBD	mA
			V or M Pin Shorted to CONTROL		1.0	TBD	
Remote ON Delay	$t_{R(ON)}$	From Remote ON to Drain Turn-On			2.5		µs
Remote OFF Setup Time	$t_{R(OFF)}$	Minimum Time Before Drain Turn-On to Disable Cycle			2.5		µs
FREQUENCY INPUT							
FREQUENCY Pin Threshold Voltage	V_F				2.9		V
FREQUENCY Pin Input Current	I_F	$V_F = V_C$		10	40	100	µA
CIRCUIT PROTECTION							
Self Protection Current Limit	I_{LIMIT}	TOP254PN T_J = 25 °C	di/dt = 105 mA/µs	TBD	1.00	TBD	A
		TOP254MN T_J = 25 °C					
		TOP254YN T_J = 25 °C	di/dt = 270 mA/µs	TBD	1.30	TBD	
		TOP255PN T_J = 25 °C	di/dt = 120 mA/µs	TBD	1.15	TBD	
		TOP255MN T_J = 25 °C					
		TOP255YN T_J = 25 °C	di/dt = 350 mA/µs	TBD	1.70	TBD	
		TOP256PN T_J = 25 °C	di/dt = 140 mA/µs	TBD	1.35	TBD	
		TOP256MN T_J = 25 °C					
		TOP256YN T_J = 25 °C	di/dt = 530 mA/µs	TBD	2.55	TBD	
		TOP257PN T_J = 25 °C	di/dt = 155 mA/µs	TBD	1.5	TBD	
		TOP257MN T_J = 25 °C					

Parameter	Symbol	Conditions SOURCE = 0 V; T_J = -40 to 125 °C (Unless Otherwise Specified)		Min	Typ	Max	Units
CIRCUIT PROTECTION (cont.)							
Self Protection Current Limit	I_{LIMIT}	TOP257YN T_J = 25 °C	di/dt = 705 mA/µs	TBD	3.40	TBD	A
		TOP258PN T_J = 25 °C	di/dt = 170 mA/µs	TBD	1.65	TBD	
		TOP258MN T_J = 25 °C					
		TOP258YN T_J = 25 °C	di/dt = 890 mA/µs	TBD	4.30	TBD	
Initial Current Limit	I_{INIT}			TBD			A
Power Coefficient	P_{COEFF}	$I_{X/M} \leq$ -110 µA, T_J = 25 °C	$I^2f_{(132)}=I_{LIMIT(TYP)}{}^2 \times f_{OSC(132)}$	TBD	$I^2f_{(132)}$	TBD	A^2kHz
			$I^2f_{(66)}=I_{LIMIT(TYP)}{}^2 \times f_{OSC(66)}$	TBD	$I^2f_{(66)}$	TBD	
Leading Edge Blanking Time	t_{LEB}	T_J = 25 °C			220		ns
Current Limit Delay	$t_{IL(D)}$				100		ns
Thermal Shut-down Temperature				TBD	142	TBD	°C
Thermal Shut-down Hysteresis					75		°C
Power-Up Reset Threshold Voltage	$V_{C(RESET)}$			1.75	3.0	4.25	V
OUTPUT							
ON-State Resistance	$R_{DS(ON)}$	TOP254 I_D = 150 mA	T_J = 25 °C		5.2	TBD	Ω
			T_J = 100 °C		TBD	TBD	
		TOP255 I_D = 250 mA	T_J = 25 °C		3.9	TBD	
			T_J = 100 °C		TBD	TBD	
		TOP256 I_D = 300 mA	T_J = 25 °C		2.6	TBD	
			T_J = 100 °C		TBD	TBD	
		TOP257 I_D = 400 mA	T_J = 25 °C		1.95	TBD	
			T_J = 100 °C		TBD	TBD	
		TOP258 I_D = 500 mA	T_J = 25 °C		1.56	TBD	
			T_J = 100 °C		TBD	TBD	
DRAIN Supply Voltage			T_J = TBD °C	18			V
				36			

PRELIMINARY

Parameter	Symbol	Conditions SOURCE = 0 V; T_J = -40 to 125 °C (Unless Otherwise Specified)		Min	Typ	Max	Units
OUTPUT (cont.)							
OFF-State Drain Leakage Current	I_{DSS}	V_V, V_M = Floating, I_C = 4 mA, V_{DS} = 560 V, T_J = 125 °C				470	µA
Breakdown Voltage	BV_{DSS}	V_V, V_M = Floating, I_C = 4 mA, T_J = 25 °C		700			V
Rise Time	t_R	Measured in a Typical Flyback Converter Application			100		ns
Fall Time	t_F				50		ns
SUPPLY VOLTAGE CHARACTERISTICS							
Shunt Regulator Voltage	$V_{C(SHUNT)}$	I_C = 4 mA		5.60	5.85	6.10	V
Shunt Regulator Temperature Drift					±50		ppm/°C
Control Supply/ Discharge Current	I_{CD1}	Output MOSFET Enabled V_X, V_V, V_M, = 0 V	TOP254-257	TBD	1.4	TBD	mA
			TOP258	TBD	1.6	TBD	
	I_{CD2}	Output MOSFET Disabled V_X, V_V, V_M = 0 V		TBD	0.6	TBD	

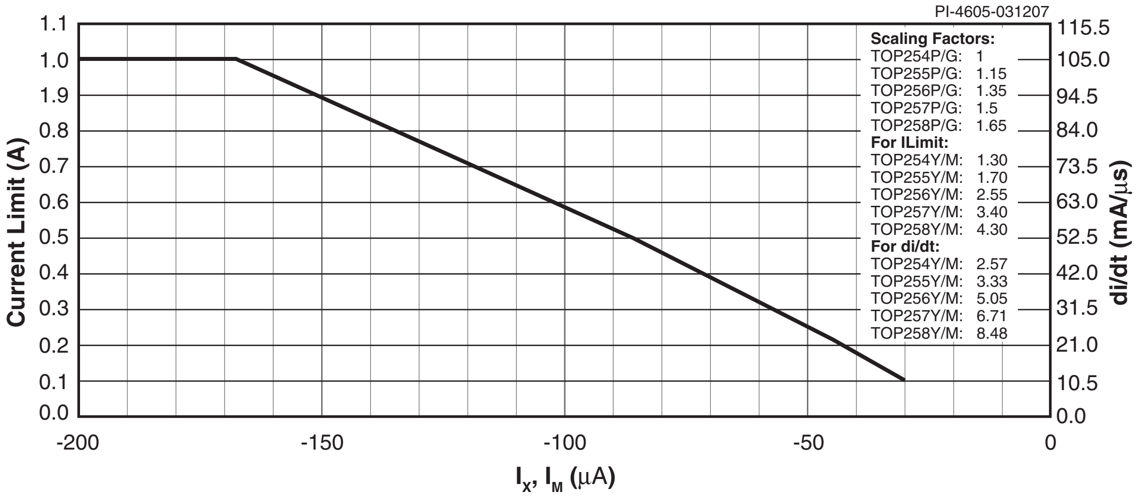


Figure 8a. Current Limit vs. X or M Pin Current.

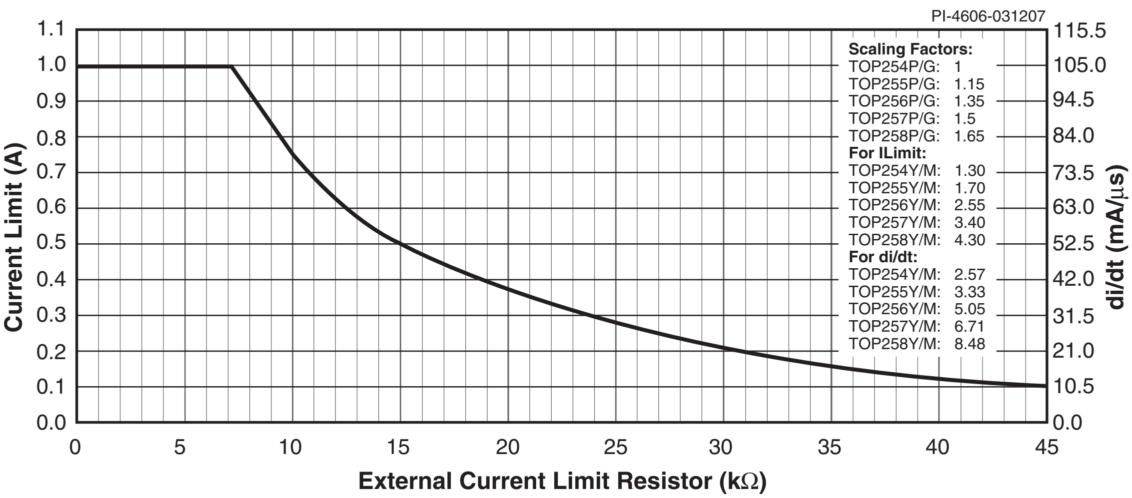
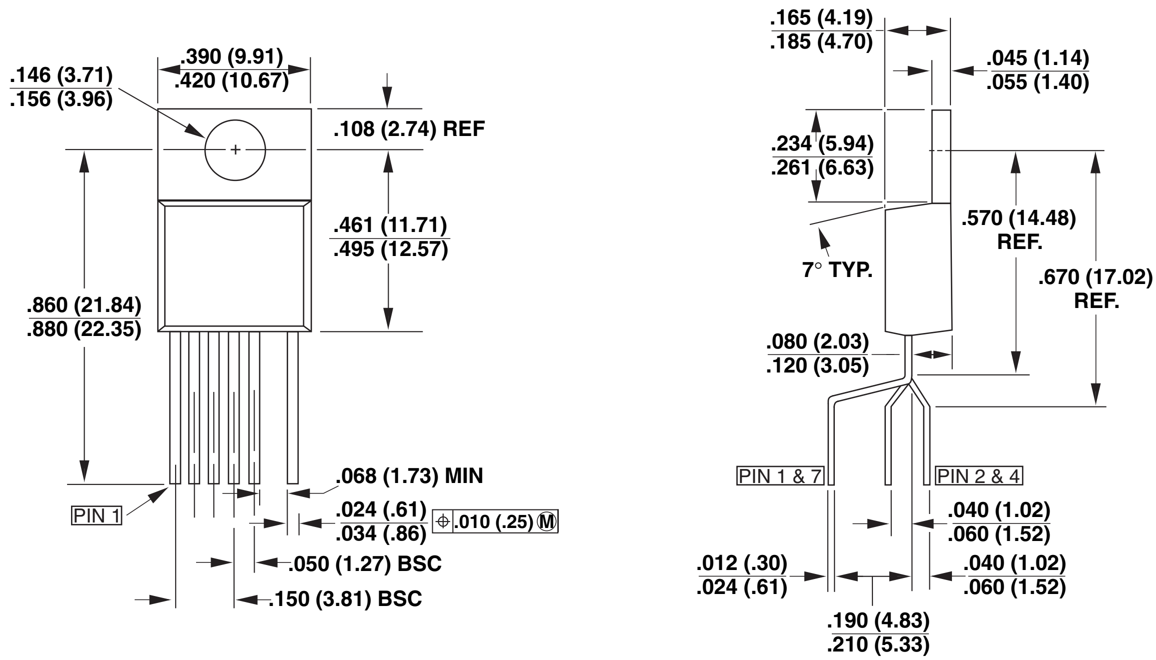
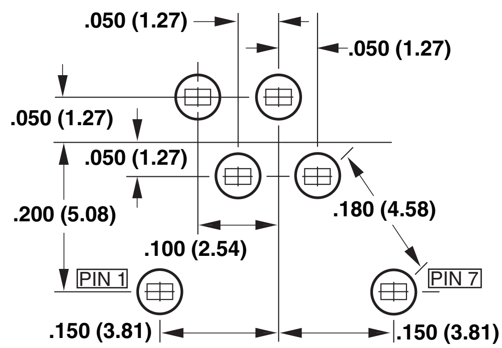


Figure 8b. Current Limit vs. External Current Limit Resistance.

TO-220-7C





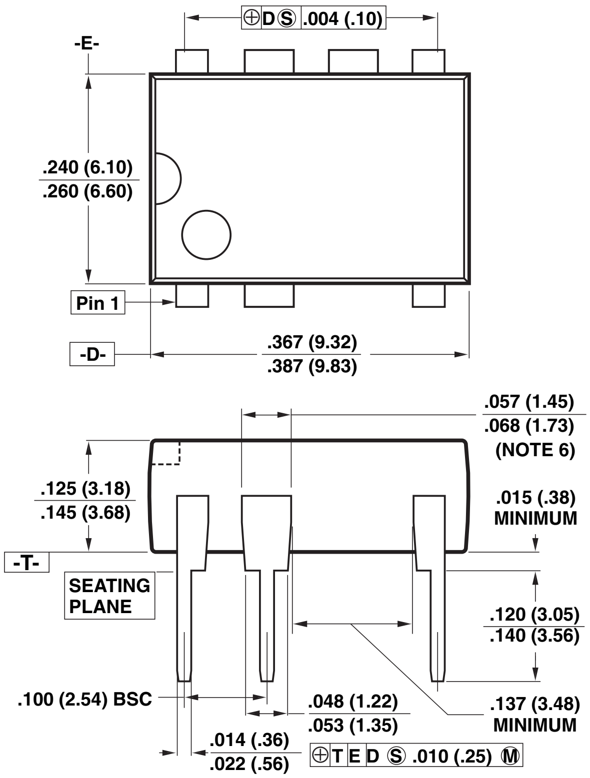
Y07C

MOUNTING HOLE PATTERN

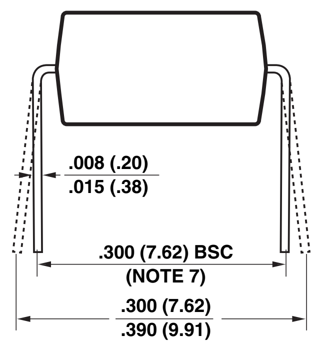
Notes:
1. Controlling dimensions are inches. Millimeter dimensions are shown in parentheses.
2. Pin numbers start with Pin 1, and continue from left to right when viewed from the front.
3. Dimensions do not include mold flash or other protrusions. Mold flash or protrusions shall not exceed .006 (.15mm) on any side.
4. Minimum metal to metal spacing at the package body for omitted pin locations is .068 in. (1.73 mm).
5. Position of terminals to be measured at a location .25 (6.35) below the package body.
6. All terminals are solder plated.

PI-2644-122004

DIP-8C



Notes:
1. Package dimensions conform to JEDEC specification MS-001-AB (Issue B 7/85) for standard dual-in-line (DIP) package with .300 inch row spacing.
2. Controlling dimensions are inches. Millimeter sizes are shown in parentheses.
3. Dimensions shown do not include mold flash or other protrusions. Mold flash or protrusions shall not exceed .006 (.15) on any side.
4. Pin locations start with Pin 1, and continue counter-clockwise to Pin 8 when viewed from the top. The notch and/or dimple are aids in locating Pin 1. Pin 3 is omitted.
5. Minimum metal to metal spacing at the package body for the omitted lead location is .137 inch (3.48 mm).
6. Lead width measured at package body.
7. Lead spacing measured with the leads constrained to be perpendicular to plane T.



P08C

PI-3933-100504

M Package

PRELIMINARY

Rev. A 03/07

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PART ORDERING INFORMATION

TOP 254 P N - TL

***TOPSwitch* Product Family**	
HX Series Number	
Package Identifier	
P	Plastic DIP-8C
M	Plastic DIP-10C
Y	Plastic TO-220-7C
Lead Finish	
N	Pure Matte Tin (Pb-Free) (P and Y Packages)
Tape & Reel and Other Options	
Blank	Standard Configurations

Revision	Notes	Date
A	-	1/07

For the latest updates, visit our website: *www.powerint.com*

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