LNK302/304-306
LinkSwitch™-TN Family

Lowest Component Count, Energy-Efficient Off-Line Switcher IC

Product Highlights

Cost Effective Linear/Cap Dropper Replacement

- Lowest cost and component count buck converter solution
- Fully integrated auto-restart for short-circuit and open loop fault protection – saves external component costs
- LNK302 uses a simplified controller without auto-restart for very low system cost
- 66 kHz operation with accurate current limit – allows low cost off-the-shelf 1 mH inductor for up to 120 mA output current
- Tight tolerances and negligible temperature variation
- High breakdown voltage of 700 V provides excellent input surge withstand
- Frequency jittering dramatically reduces EMI (~10 dB)
    - Minimizes EMI filter cost
- High thermal shutdown temperature (+135 °C minimum)

Much Higher Performance Over Discrete Buck and Passive Solutions

- Supports buck, buck-boost and flyback topologies
- System level thermal overload, output short-circuit and open control loop protection
- Excellent line and load regulation even with typical configuration
- High bandwidth provides fast turn-on with no overshoot
- Current limit operation rejects line ripple
- Universal input voltage range (85 VAC to 265 VAC)
- Built-in current limit and hysteretic thermal protection
- Higher efficiency than passive solutions
- Higher power factor than capacitor-fed solutions
- Entirely manufacturable in SMD

EcoSmart™– Extremely Energy Efficient

- Consumes typically only 50/80 mW in self-powered buck topology at 115/230 VAC input with no-load (opto feedback)
- Consumes typically only 7/12 mW in flyback topology with external bias at 115/230 VAC input with no-load
- Meets California Energy Commission (CEC), Energy Star, and EU requirements

Applications

- Appliances and timers
- LED drivers and industrial controls

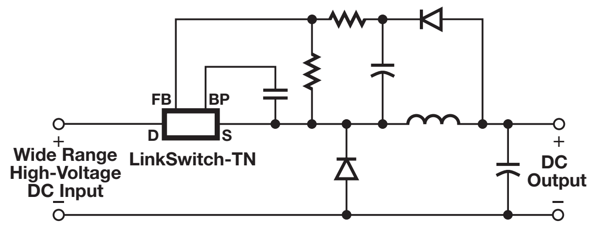

Figure 1. Typical Buck Converter Application (See Application Examples Section for Other Circuit Configurations).

Output Current Table[1]

Product[4]	230 VAC ±15%		85-265 VAC	
	MDCM[2]	**CCM[3]**	**MDCM[2]**	**CCM[3]**
LNK302P/G/D	63 mA	80 mA	63 mA	80 mA
LNK304P/G/D	120 mA	170 mA	120 mA	170 mA
LNK305P/G/D	175 mA	280 mA	175 mA	280 mA
LNK306P/G/D	225 mA	360 mA	225 mA	360 mA

Table 1. Output Current Table.

Notes:
1. Typical output current in a non-isolated buck converter. Output power capability depends on respective output voltage. See Key Applications Considerations Section for complete description of assumptions, including fully discontinuous conduction mode (DCM) operation.
2. Mostly discontinuous conduction mode.
3. Continuous conduction mode.
4. Packages: P: DIP-8B, G: SMD-8B, D: SO-8C.

Description

LinkSwitch-TN is specifically designed to replace all linear and capacitor-fed (cap dropper) non-isolated power supplies in the under 360 mA output current range at equal system cost while offering much higher performance and energy efficiency. LinkSwitch-TN devices integrate a 700 V power MOSFET, oscillator, simple On/Off control scheme, a high-voltage switched current source, frequency jittering, cycle-by-cycle current limit and thermal shutdown circuitry onto a monolithic IC. The start-up and operating power are derived directly from the voltage on the DRAIN pin, eliminating the need for a bias supply and associated circuitry in buck or flyback converters. The fully integrated auto-restart circuit in the LNK304-306 safely limits output power during fault conditions such as short-circuit or open loop, reducing component count and system-level load protection cost. A local supply provided by the IC allows use of a non-safety graded optocoupler acting as a level shifter to further enhance line and load regulation performance in buck and buck-boost converters, if required.

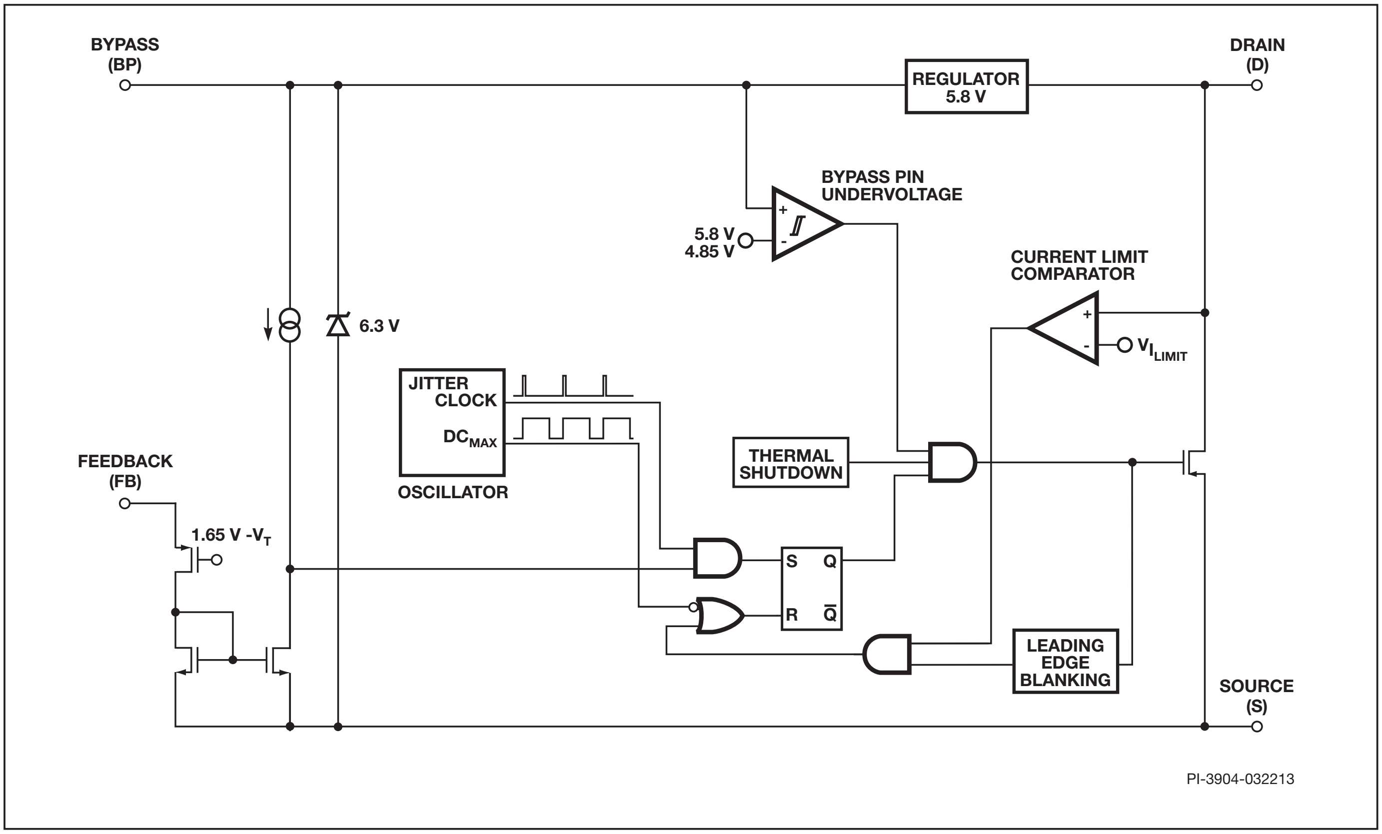

Figure 2a. Functional Block Diagram (LNK302).

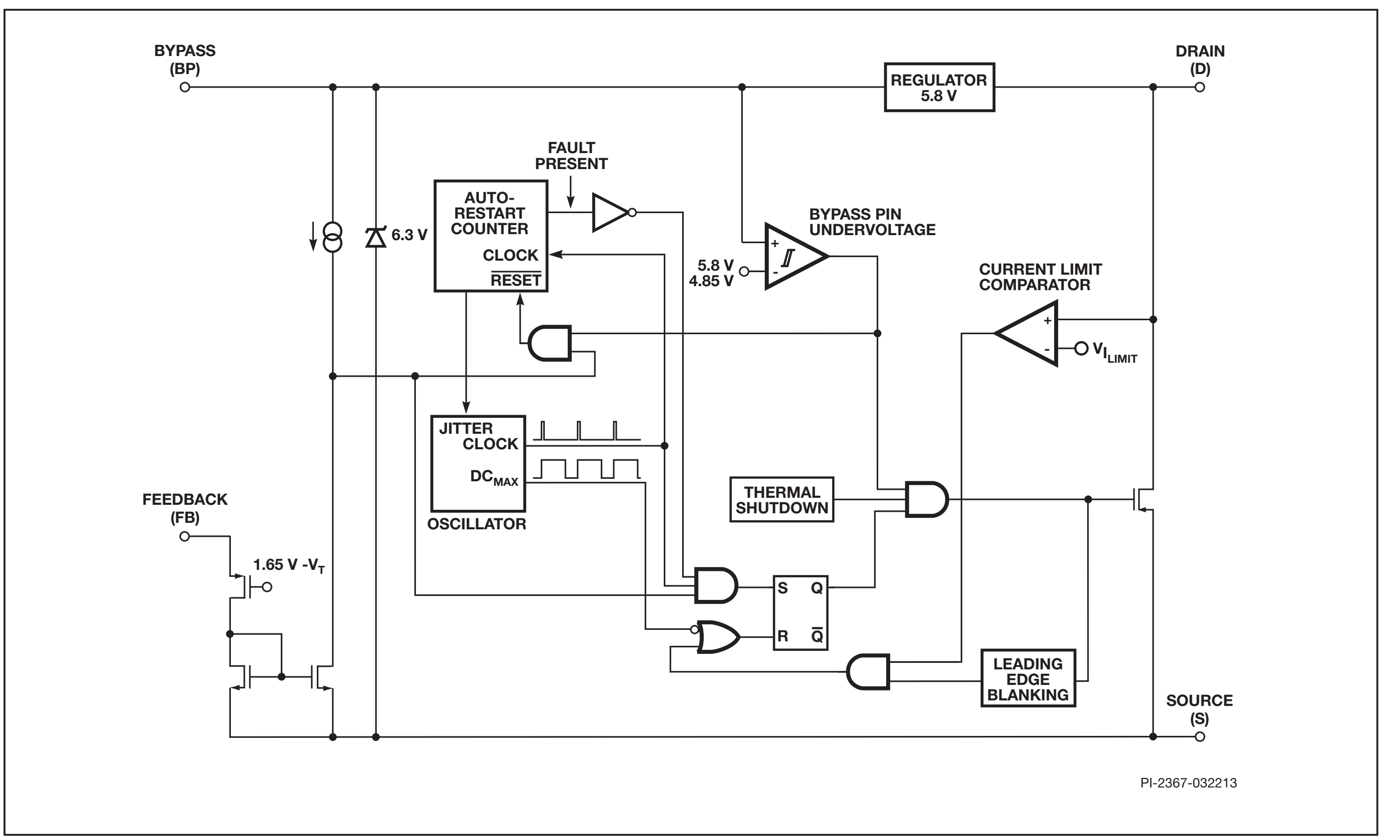

Figure 2b. Functional Block Diagram (LNK304-306).

Pin Functional Description

DRAIN (D) Pin:
Power MOSFET drain connection. Provides internal operating current for both start-up and steady-state operation.

BYPASS (BP) Pin:
Connection point for a 0.1 μF external bypass capacitor for the internally generated 5.8 V supply.

FEEDBACK (FB) Pin:
During normal operation, switching of the power MOSFET is controlled by this pin. MOSFET switching is terminated when a current greater than 49 μA is delivered into this pin.

SOURCE (S) Pin:
This pin is the power MOSFET source connection. It is also the ground reference for the BYPASS and FEEDBACK pins.

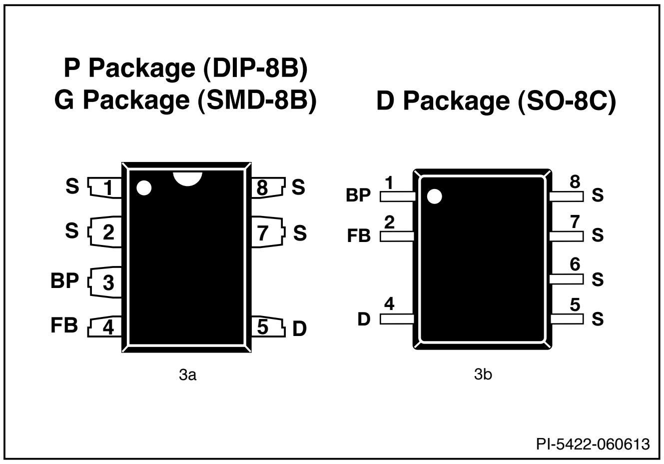

Figure 3. Pin Configuration.

LinkSwitch-TN Functional Description

LinkSwitch-TN combines a high-voltage power MOSFET switch with a power supply controller in one device. Unlike conventional PWM (pulse width modulator) controllers, LinkSwitch-TN uses a simple ON/OFF control to regulate the output voltage. The LinkSwitch-TN controller consists of an oscillator, feedback (sense and logic) circuit, 5.8 V regulator, BYPASS pin undervoltage circuit, over-temperature protection, frequency jittering, current limit circuit, leading edge blanking and a 700 V power MOSFET. The LinkSwitch-TN incorporates additional circuitry for auto-restart.

Oscillator

The typical oscillator frequency is internally set to an average of 66 kHz. Two signals are generated from the oscillator: the maximum duty cycle signal (DC_{MAX}) and the clock signal that indicates the beginning of each cycle.

The LinkSwitch-TN oscillator incorporates circuitry that introduces a small amount of frequency jitter, typically 4 kHz peak-to-peak, to minimize EMI emission. The modulation rate of the frequency jitter is set to 1 kHz to optimize EMI reduction for both average and quasi-peak emissions. The frequency jitter should be measured with the oscilloscope triggered at the falling edge of the DRAIN waveform. The waveform in Figure 4 illustrates the frequency jitter of the LinkSwitch-TN.

Feedback Input Circuit

The feedback input circuit at the FEEDBACK pin consists of a low impedance source follower output set at 1.65 V. When the current delivered into this pin exceeds 49 μA, a low logic level (disable) is generated at the output of the feedback circuit. This output is sampled at the beginning of each cycle on the rising edge of the clock signal. If high, the power MOSFET is turned on for that cycle (enabled), otherwise the power MOSFET remains off (disabled). Since the sampling is done only at the beginning of each cycle, subsequent changes in the FEEDBACK pin voltage or current during the remainder of the cycle are ignored.

5.8 V Regulator and 6.3 V Shunt Voltage Clamp

The 5.8 V regulator charges the bypass capacitor connected to the BYPASS pin to 5.8 V by drawing a current from the voltage on the DRAIN, whenever the MOSFET is off. The BYPASS pin is the internal supply voltage node for the LinkSwitch-TN. When the MOSFET is on, the LinkSwitch-TN runs off of the energy stored in the bypass capacitor. Extremely low power consumption of the internal circuitry allows the LinkSwitch-TN to operate continuously from the current drawn from the DRAIN pin. A bypass capacitor value of 0.1 μF is sufficient for both high frequency decoupling and energy storage.

In addition, there is a 6.3 V shunt regulator clamping the BYPASS pin at 6.3 V when current is provided to the BYPASS pin through an external resistor. This facilitates powering of LinkSwitch-TN externally through a bias winding to decrease the no-load consumption to about 50 mW.

BYPASS Pin Undervoltage

The BYPASS pin undervoltage circuitry disables the power MOSFET when the BYPASS pin voltage drops below 4.85 V. Once the BYPASS pin voltage drops below 4.85 V, it must rise back to 5.8 V to enable (turn-on) the power MOSFET.

Over-Temperature Protection

The thermal shutdown circuitry senses the die temperature. The threshold is set at 142 °C typical with a 75 °C hysteresis. When the die temperature rises above this threshold (142 °C) the power MOSFET is disabled and remains disabled until the die temperature falls by 75 °C, at which point it is re-enabled.

Current Limit

The current limit circuit senses the current in the power MOSFET. When this current exceeds the internal threshold (I_{LIMIT}), the power MOSFET is turned off for the remainder of that cycle. The leading edge blanking circuit inhibits the current limit comparator for a short time (t_{LEB}) after the power MOSFET is turned on. This leading edge blanking time has been set so that current spikes caused by capacitance and rectifier reverse recovery time will not cause premature termination of the switching pulse.

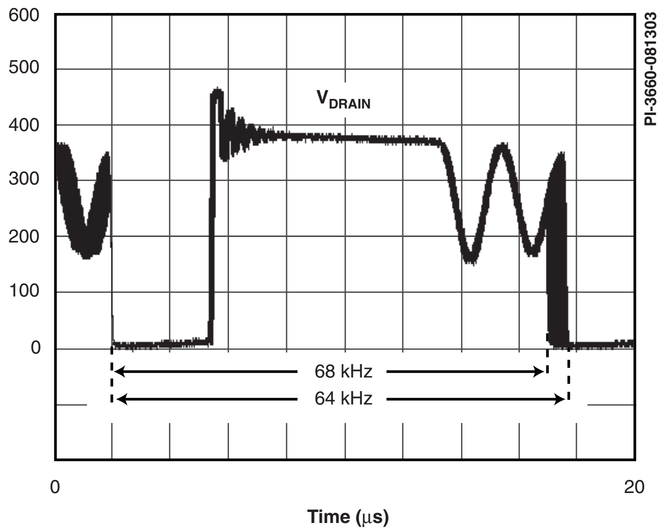

Figure 4. Frequency Jitter.

Auto-Restart (LNK304-306 Only)
In the event of a fault condition such as output overload, output short, or an open-loop condition, LinkSwitch-TN enters into auto-restart operation. An internal counter clocked by the oscillator gets reset every time the FEEDBACK pin is pulled high. If the FEEDBACK pin is not pulled high for 50 ms, the power MOSFET switching is disabled for 800 ms. The auto-restart alternately enables and disables the switching of the power MOSFET until the fault condition is removed.

Applications Example

A 1.44 W Universal Input Buck Converter
The circuit shown in Figure 5 is a typical implementation of a 12 V, 120 mA non-isolated power supply used in appliance control such as rice cookers, dishwashers or other white goods. This circuit may also be applicable to other applications such as night-lights, LED drivers, electricity meters, and residential heating controllers, where a non-isolated supply is acceptable.

The input stage comprises fusible resistor RF1, diodes D3 and D4, capacitors C4 and C5, and inductor L2. Resistor RF1 is a flame proof, fusible, wire wound resistor. It accomplishes several functions: a) Inrush current limitation to safe levels for rectifiers D3 and D4; b) Differential mode noise attenuation; c) Input fuse should any other component fail short-circuit (component fails safely open-circuit without emitting smoke, fire or incandescent material).

The power processing stage is formed by the LinkSwitch-TN, freewheeling diode D1, output choke L1, and the output capacitor C2. The LNK304 was selected such that the power supply operates in the mostly discontinuous-mode (MDCM). Diode D1 is an ultrafast diode with a reverse recovery time (t_{RR}) of approximately 75 ns, acceptable for MDCM operation. For continuous conduction mode (CCM) designs, a diode with a t_{rr} of ≤35 ns is recommended. Inductor L1 is a standard off-the-shelf inductor with appropriate RMS current rating (and acceptable temperature rise). Capacitor C2 is the output filter capacitor; its primary function is to limit the output voltage ripple. The output voltage ripple is a stronger function of the ESR of the output capacitor than the value of the capacitor itself.

To a first order, the forward voltage drops of D1 and D2 are identical. Therefore, the voltage across C3 tracks the output voltage. The voltage developed across C3 is sensed and regulated via the resistor divider R1 and R3 connected to U1's FEEDBACK pin. The values of R1 and R3 are selected such that, at the desired output voltage, the voltage at the FEEDBACK pin is 1.65 V.

Regulation is maintained by skipping switching cycles. As the output voltage rises, the current into the FEEDBACK pin will rise. If this exceeds I_{FB} then subsequent cycles will be skipped until the current reduces below I_{FB}. Thus, as the output load is reduced, more cycles will be skipped and if the load increases, fewer cycles are skipped. To provide overload protection if no cycles are skipped during a 50 ms period, LinkSwitch-TN will enter auto-restart (LNK304-306), limiting the average output power to approximately 6% of the maximum overload power. Due to tracking errors between the output voltage and the voltage across C3 at light load or no-load, a small pre-load may be required (R4). For the design in Figure 5, if regulation to zero load is required, then this value should be reduced to 2.4 kΩ.

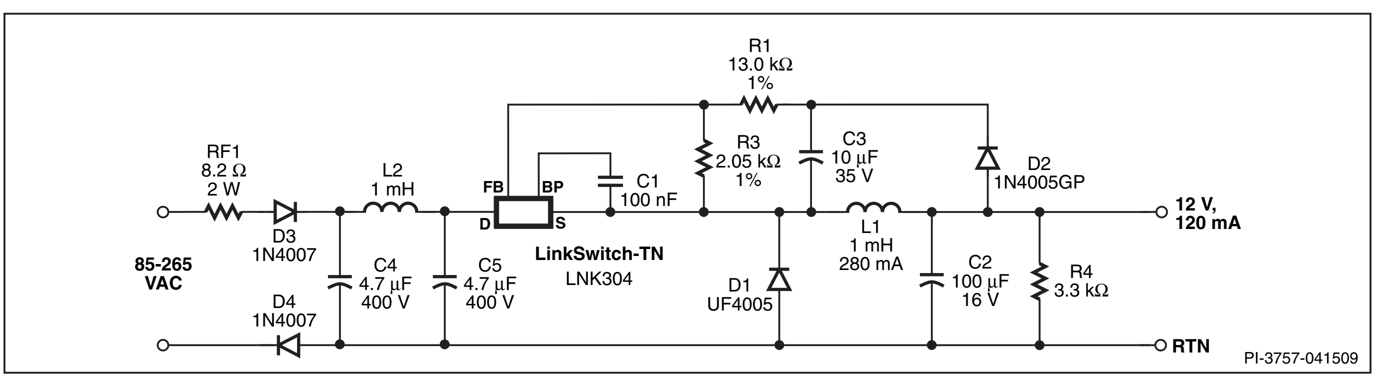

Figure 5. Universal Input, 12 V, 120 mA Constant Voltage Power Supply Using LinkSwitch-TN.