

High Input Voltage SMPS Start-up Circuit

Ordering Information

Maximum Input Voltage	Order Number / Package	
	TO-92	TO-243AA*
450V	LR745N3	LR745N8

*Same as SOT-89. Product supplied on 2000 piece carrier tape reels.

Product marking for TO-243AA:
LR7*
where * = 2-week alpha date code

Features

- ☐ 25V to 450V operating input voltage range
- ☐ Compatible with industry standard PWM ICs. See application notes AN-H28 and AN-H29.
- ☐ Output current limiting
- ☐ For PWM ICs with start-up threshold voltage of 13.9V to 18.8V
- ☐ Very low power consumption after start-up

Applications

- ☐ Notebook and Laptop computers
- ☐ Telecommunication power supplies
- ☐ Battery chargers
- ☐ Motor controller

Absolute Maximum Ratings

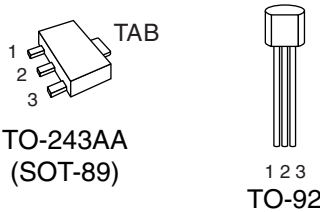
Input Voltage	450V
Output Voltage	25V
Operating and Storage Temperature	-55°C to 150°C
Soldering Temperature*	300°C

*Distance of 1.6mm from case for 10 seconds

General Description

The Supertex LR7 is a high input voltage SMPS start-up circuit. The LR7 is ideally suited for use with industry standard low voltage PWM ICs having start thresholds of 13.9V to 18.8V. It allows the PWM ICs to be operated from rectified 120V or 240VAC lines, and eliminates the use of power resistors often used for this purpose. The internal circuitry of the LR7 allows the PWM ICs to operate at a V_{CC} voltage below their start threshold voltage after start-up. The auxiliary voltage can be less than the start threshold voltage, which allows for improved efficiency. Current from the high voltage line is drawn only during the start-up period. After start-up, the internal high voltage line is disconnected from the IC thereby reducing the continuous power dissipation to a minimum.

Pin Configuration

		
	V_{IN}	GND
TO-92	1	2
TO-243AA	1	2, TAB
		V_{OUT}
		3

For detailed circuit and application information, please refer to application notes AN-H28 and AN-H29.

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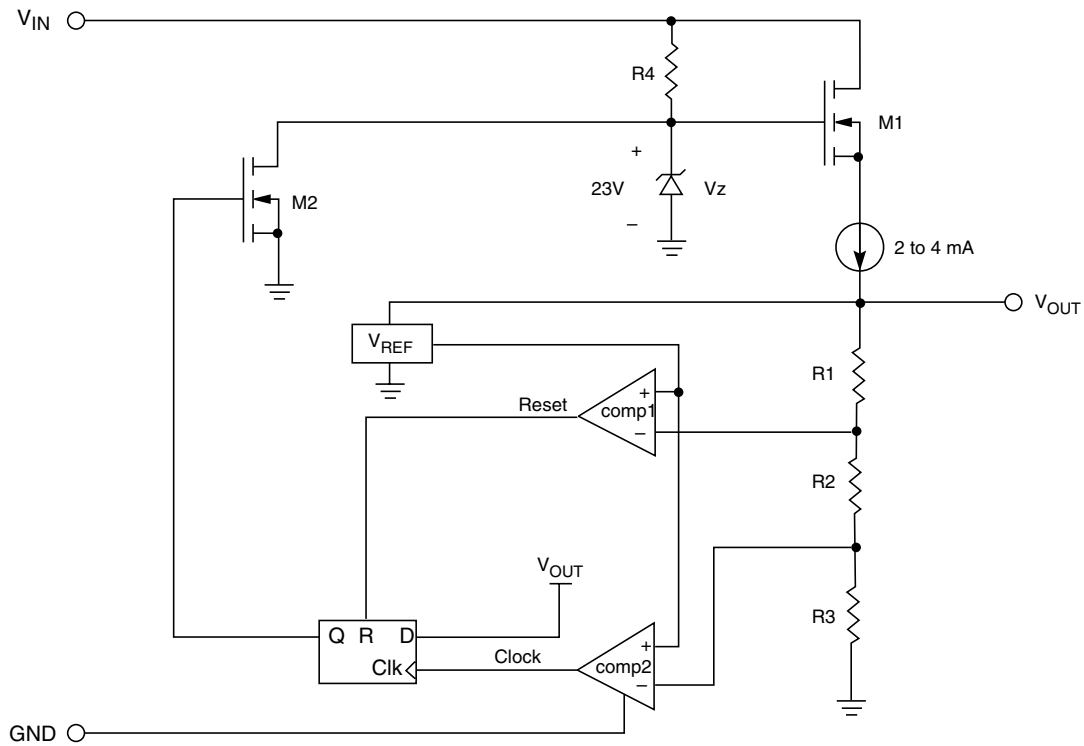
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Electrical Characteristics

Test conditions unless otherwise specified: $T_A = 25^\circ\text{C}$; $V_{IN} = 450\text{V}$

Symbol	Parameter	Min	Typ	Max	Unit	Conditions
V_{OUT}	Output Voltage	18.8		24	V	$I_{OUT} = 0$
	V_{OUT} over Temperature	18.5		24.3	V	$I_{OUT} = 0$, $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$
I_{OUT}	Output Current Limiting	2	3	4	mA	
V_{IN}	Operating Input Voltage Range	25		450	V	
I_{INQ}	Input Quiescent Current			500	μA	$V_{IN} = 400\text{V}$, $I_{OUT} = 0$
V_{OFF}	Output Turn OFF Voltage	12.6	13.25	13.9	V	
	V_{OFF} Over Temperature	12.3	13.25	14.2	V	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$
V_{RESET}	Output Reset Voltage	6.3	7	7.7	V	
	V_{RESET} Over Temperature	6	7	8	V	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$
I_{OFF}	V_{IN} Off-State Leakage Current			75	μA	$V_{IN} = 400\text{V}$
V_{AUX}	External Voltage Applied to V_{OUT}			22	V	
I_{AUX}	Input Current to V_{OUT}			500	μA	$V_{AUX} = 22\text{V}$

Block Diagram



Block Diagram Detailed Description

The Supertex LR7 is a high voltage switch mode power supply start-up circuit, which has 3 terminals: V_{IN} , GND, and V_{OUT} . An input voltage range of 25VDC to 450VDC can be applied directly at the input V_{IN} pin. The output voltage, V_{OUT} , is monitored by the 2 comparators, comp1 and comp2. An internal reference, V_{REF} , and resistor divider R1, R2, and R3 set the nominal V_{OUT} trip points of 7.0V for comp1 and 13.25V for comp2.

When a voltage is applied on V_{IN} , V_{OUT} will start to ramp up from 0V. When V_{OUT} is less than 7.0V, the output of comp1 will be at a logic high state keeping the D flip flop in a reset state. The output of the D flip flop, Q, will be at logic low keeping transistor M2 off. The data input for the D flip flop, D, is internally connected to a logic high. As V_{OUT} becomes greater than 7.0V, comp1 will change to a logic low state. V_{OUT} will continue to increase, and the constant current source of typically 3mA output will charge an external storage capacitor. As V_{OUT} reaches above 13.25V, the output of comp2, will then switch from a logic high to a logic low state. The D flip flop's output does not change state since its clock input is designed to trigger only on a rising edge, logic low to logic high transition. When there is no load connected to the output, the output voltage will continue to increase until it reaches 21.5V which is the zener voltage minus the threshold voltage of transistor M1. The zener voltage is typically 23V and the threshold voltage of M1 is typically 1.5V. The zener diode is biased by resistor R4.

V_{OUT} will start to decrease when it is connected to an external load greater than the internal constant current source, which is the case when the PWM IC starts up. When V_{OUT} falls below 13.25V, the output of comp2 will switch from a logic low to a logic high. The output of comp2 will clock in a logic 1 into the D flip flop causing the D flip flop's output, Q, to switch from a logic low to a logic high. Transistor M2 will then be turned on pulling the gate of transistor M1 to ground thereby turning transistor M1 off. Transistor M1 will remain off as long as V_{OUT} is greater than 7.0V. Once V_{OUT} decreases below 7.0V, comp1 will reset the D flip flop, thereby turning transistor M2 off and transistor M1 back on.

Typical Application

Figure 1 shows a simplified typical configuration of a switch mode power supply, SMPS, using the Supertex LR7 in the start-up circuit.

The LR7's V_{OUT} terminal is connected to the V_{CC} line of a PWM IC, Unitrode part #UC3844. An auxiliary winding on the transformer is used to generate a V_{CC} voltage to power the PWM IC after start-up. The LR7 is used to supply power for the PWM IC only during start-up. After start-up, the LR7 turns off and the auxiliary winding is used to supply power for the PWM IC. Figure 2 shows the typical current and voltage waveforms at various stages from power up to operation powered by the auxiliary winding.

Stage I

Once a voltage is applied on V_{IN} , the LR7 will start to charge the V_{CC} capacitor, C1. The V_{CC} voltage will start to increase at a rate limited by the internal current limiter of 3.0mA. The PWM IC is in its start-up condition and will typically draw 0.5mA from the V_{CC} line. The V_{CC} voltage will continue to increase until it reaches the PWM IC's start threshold voltage of typically 16V.

Stage II

Once V_{CC} reaches 16V, the PWM IC is in its operating condition and will draw typically 20mA depending on the operating frequency and size of the switching MOSFET. The output of LR7, V_{OUT} , is internally current limited to 3.0mA. The remaining 17mA will be supplied by C1 causing the V_{CC} voltage decrease. When V_{CC} decreases to 13.25V, the LR7 will turn off its output thereby reducing its input current from 3.0mA to 10's of microamperes. At this point, all 20mA will be supplied by C1. The PWM IC can now operate to a minimum V_{CC} voltage of typically 10V.

Once the switching MOSFET starts operating, the energy in the primary winding is transferred to the secondary outputs and the auxiliary winding, thereby building up V_{AUX} . It is necessary to size the V_{CC} storage capacitor, C1, such that V_{AUX} increases to a voltage greater than 10V before V_{CC} decreases to 10V. This allows V_{AUX} to supply the required operating current for the PWM IC.

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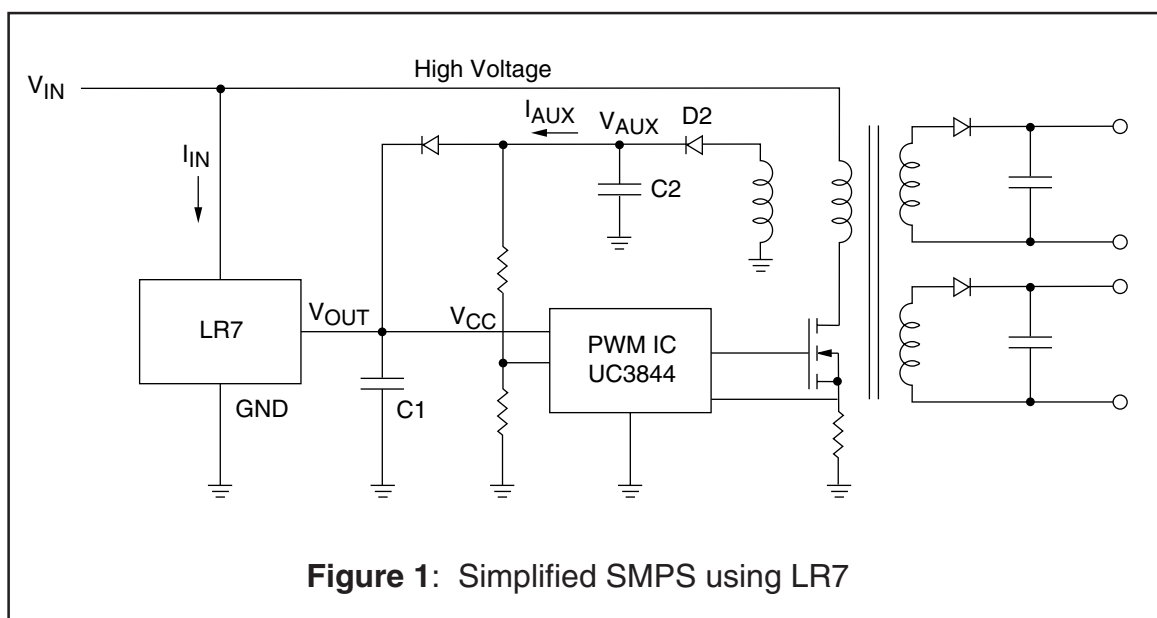


Figure 1: Simplified SMPS using LR7

LR7 Start-up Waveforms

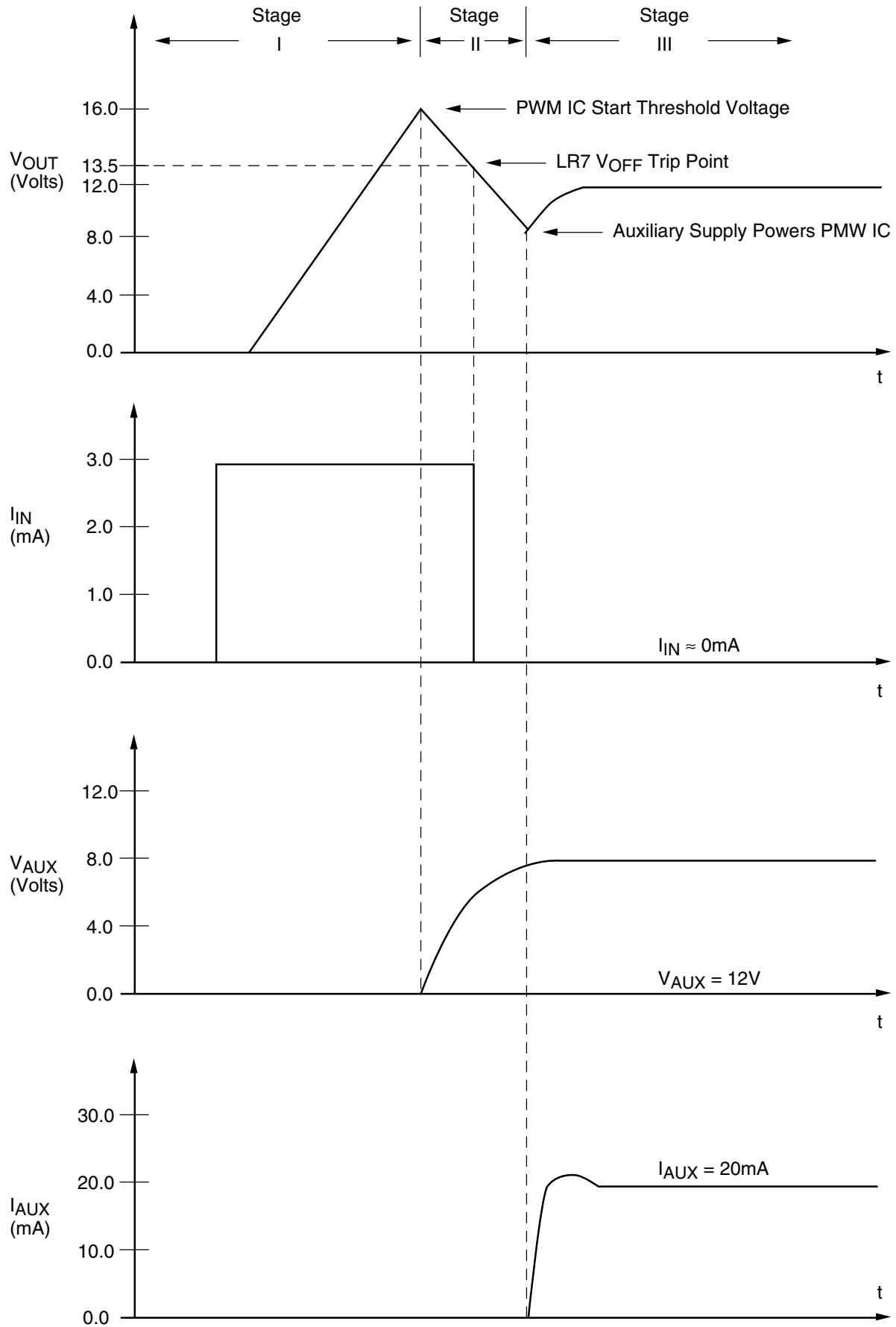


Figure 2

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If for some reason the auxiliary voltage does not reach 10V, V_{CC} will continue to decrease. Once V_{CC} goes below 10V, the PWM IC will return to its start-up condition. The PWM IC will now only draw 0.5mA. V_{CC} will continue to decrease but at a much slower rate. Once V_{CC} decrease below 7.0V, the LR7 will turn the output, V_{OUT} , back on. V_{OUT} will start charging C1 as described in Stage I.

Stage III

At this stage the LR7's output is turned off and the PWM IC is operating from the V_{AUX} supply. The auxiliary voltage, V_{AUX} , can be designed to vary anywhere between the minimum operating V_{CC} voltage of the PWM IC (10V) to the maximum auxiliary voltage rating of the LR7 (22V).

Design Considerations

I. Calculating the value for C1

Sizing the V_{CC} capacitor, C1, is an important factor. Making C1 too large will cause the SMPS to power up too slowly. However, if too small, C1 will not allow the SMPS to power up due to insufficient charge in the capacitor to power the IC and MOSFET until the auxiliary supply is available. The value of C1 can be approximately by the following equation:

$$C1 = \frac{\left(\frac{1}{f}\right) \times (N) \times (I)}{(V_{START} - V_{MIN})}$$

where, f = switching frequency
 N = number of clock cycles required to charge V_{AUX} to V_{MIN} value
 I = PWM operating current
 V_{START} = PWM IC start threshold rating
 V_{MIN} = PWM IC minimum V_{CC} operating voltage

Consider for example, a PWM IC with a switching frequency of 100KHz, operating current of 20mA, start threshold of 16V, and a minimum operating voltage of 10V. If 100 clock cycles are required to charge the auxiliary voltage to 10V, the minimum value of C1 is calculated as follows:

$$C1 = \frac{\left(\frac{1}{100\text{KHZ}}\right) \times (100) \times (20\text{mA})}{(16\text{V} - 10\text{V})}$$

$$C1 = 3.3\mu\text{F}$$

II. SMPS with wide minimum to maximum load

An important point is that the LR7's output voltage, V_{OUT} , must discharge to below the nominal V_{OFF} trip point of 13.25V in order for its output to turn off. If the SMPS requires a wide minimum to maximum output load variation, it will be difficult to guarantee that V_{CC} will fall below 13.25V under minimum load conditions. Consider an SMPS that is required to power small as well as large loads and is also required to power up quickly. Such as SMPS may power up too fast with a small load, not allowing the V_{CC} voltage to fall below 13.25V. For such conditions, the circuit in Figure 3 is recommended.

In Figure 3, the V_{REF} pin of the UC3844 is used to bias the ground pin of the LR7. The V_{REF} pin on the UC3844 is a 5.0V reference, which stays at 0V until the V_{CC} voltage reaches the start threshold voltage. Once V_{CC} reaches the start threshold voltage, V_{REF} will switch digitally from 0V to 5.0V. During start-up, the LR7 will be on and V_{CC} will start to increase up to 16V. Once V_{CC} reaches 16V, the UC3844 will start to operate and V_{REF} will increase from 0V to 5.0V. The LR7 will see an effective V_{OUT} voltage of 11V (16V minus 5.0V) because the ground of the LR7 is now at 5.0V. The LR7 will immediately turn off its output V_{OUT} without having to wait for the V_{CC} voltage to decrease. The V_{REF} switching from 0 to 5V during start is a common feature in most PWM ICs.

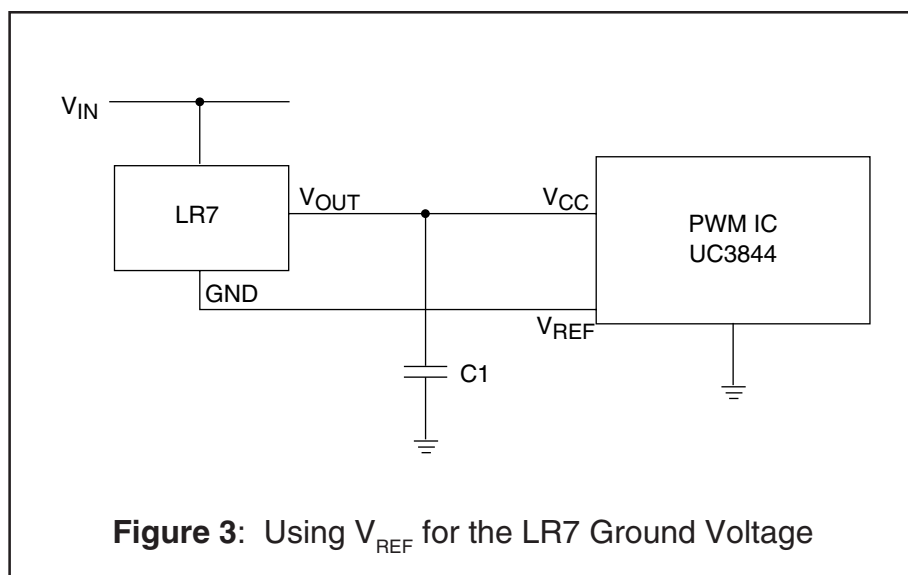


Figure 3: Using V_{REF} for the LR7 Ground Voltage