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## High-Input Voltage SMPS Start-up

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### Features

- Accepts inputs from 35 to 450V
- Output current limiting
- For PWM ICs with start-up threshold voltage of 13.9 - 18.0V
- Very low power consumption after start-up

### Applications

- Notebook and laptop computers
- Telecommunication power supplies
- Battery chargers
- Motor controllers

### Description

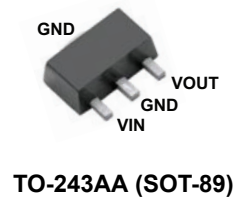
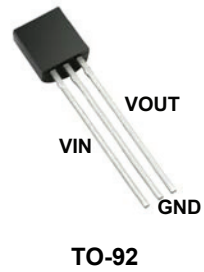
LR745 is a high input voltage SMPS start-up circuit. LR745 is ideally suited for use with industry standard low-voltage, Pulse-Width Modulation (PWM) ICs having start thresholds of 13.9 to 18.0V. It allows the PWM ICs to be operated from rectified 120 or 240VAC lines, and eliminates the use of power resistors often used for this purpose.

The internal circuitry of the LR745 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.

# LR745

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## Package Type



See [Table 2-1](#) for pin information

## 1.0 ELECTRICAL CHARACTERISTICS

### ABSOLUTE MAXIMUM RATINGS

Input Voltage ..... 450V  
 Output voltage..... 25V  
 Operating and storage temperature..... -55°C to +150°C

**Note:** Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions, above those indicated in the operational listings of this specification, is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

### 1.1 ELECTRICAL SPECIFICATIONS

**TABLE 1-1: ELECTRICAL CHARACTERISTICS<sup>1</sup>**

| Symbol      | Parameter                             | Min  | Typ   | Max  | Units         | Conditions                                                           |
|-------------|---------------------------------------|------|-------|------|---------------|----------------------------------------------------------------------|
| $V_{OUT}$   | Output voltage                        | 18.0 |       | 24   | V             | $I_{OUT} = 0$                                                        |
|             | $V_{OUT}$ over temperature            | 17.7 |       | 24.3 | V             | $I_{OUT} = 0$ , $T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$ |
| $I_{OUT}$   | Output current limiting               | 2.0  | 3.0   | 4.0  | mA            |                                                                      |
| $V_{IN}$    | Operating input voltage range         | 35   |       | 450  | V             |                                                                      |
| $I_{INQ}$   | Input quiescent current               |      |       | 500  | $\mu\text{A}$ | $V_{IN} = 400\text{V}$ , $I_{OUT} = 0$                               |
| $V_{OFF}$   | 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  | 7.0   | 7.7  | V             |                                                                      |
|             | $V_{RESET}$ over temperature          | 6.0  | 7.0   | 8.0  | V             | $T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$                 |
| $I_{OFF}$   | $V_{IN}$ off-state leakage current    |      |       | 75   | $\mu\text{A}$ | $V_{IN} = 400\text{V}$                                               |
| $V_{AUX}$   | External voltage applied to $V_{OUT}$ |      |       | 22   | V             |                                                                      |
| $I_{AUX}$   | Input current applied to $V_{OUT}$    |      |       | 500  | $\mu\text{A}$ | $V_{AUX} = 22\text{V}$                                               |

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

**TABLE 1-2: THERMAL CHARACTERISTICS**

| Package           | $\theta_{ja}$ |
|-------------------|---------------|
| TO-92             | 132°C/W       |
| TO-243AA (SOT-89) | 133°C/W       |

## 2.0 PIN DESCRIPTION

The locations of the pins are listed in [Package Type](#).

**TABLE 2-1: PIN DESCRIPTION**

| Function | Description                                                                                          |
|----------|------------------------------------------------------------------------------------------------------|
| VIN      | Regulator input. 8 - 450V.                                                                           |
| GND      | Ground return for all internal circuitry. This pin must be electrically connected to circuit common. |
| VOUT     | Regulator output.                                                                                    |

## 3.0 APPLICATION INFORMATION

Figure 3-1 shows a simplified typical configuration of a switch mode power supply, SMPS, using LR745 in the start-up circuit.

LR745's VOUT terminal is connected to the VCC line of a PWM IC. An auxiliary winding on the transformer generates a V<sub>AUX</sub> voltage to power the PWM IC after start-up. LR745 supplies power for the PWM IC only during start-up. After start-up, LR745 turns off and the auxiliary winding supplies power for the PWM IC. Figure 3-2 shows the typical current and voltage waveforms at various stages from power-up to operation powered by the auxiliary winding.

### 3.1 Stage I

Once a voltage is applied on VIN, LR745 starts to charge the V<sub>CC</sub> capacitor, C<sub>1</sub>. The V<sub>CC</sub> voltage starts 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<sub>CC</sub> line. The V<sub>CC</sub> voltage will continue to increase until it reaches the PWM IC's start threshold voltage, typically 16V.

### 3.2 Stage II

Once V<sub>CC</sub> reaches 16V, the PWM IC is in its operating condition and will typically draw 20mA, depending on the operating frequency and size of the switching metal-oxide-semiconductor field-effect transistor (MOSFET). The output of LR745, V<sub>OUT</sub>, is internally current limited to 3.0mA. The remaining 17mA will be

supplied by C<sub>1</sub>, causing the V<sub>CC</sub> voltage decrease. When V<sub>CC</sub> decreases to 13.25V, LR745 will turn off its output, thereby reducing its input current from 3.0mA to 10s of microamperes. At this point, all 20mA will be supplied by C<sub>1</sub>. The PWM IC can now operate to a minimum V<sub>CC</sub> voltage, 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<sub>AUX</sub>. It is necessary to size the V<sub>CC</sub> storage capacitor, C<sub>1</sub>, such that V<sub>AUX</sub> increases to a voltage greater than 10V before V<sub>CC</sub> decreases to 10V. This allows V<sub>AUX</sub> to supply the required operating current for the PWM IC.

If for some reason the auxiliary voltage does not reach 10V, V<sub>CC</sub> will continue to decrease. Once V<sub>CC</sub> goes below 10V, the PWM IC will return to its start-up condition. The PWM IC will now only draw 0.5mA. V<sub>CC</sub> will continue to decrease but at a much slower rate. Once V<sub>CC</sub> decreases below 7.0V, LR745 will turn the output, V<sub>OUT</sub>, back on. V<sub>OUT</sub> will start charging C<sub>1</sub> as described in Stage I.

### 3.3 Stage III

At this stage, LR745 output is turned off and the PWM IC is operating from the V<sub>AUX</sub> supply. The auxiliary voltage, V<sub>AUX</sub>, can be designed to vary anywhere between the minimum operating V<sub>CC</sub> voltage of the PWM IC (10V) to the maximum auxiliary voltage rating of the LR745 (22V).

FIGURE 3-1: SIMPLIFIED SMPS USING LR745

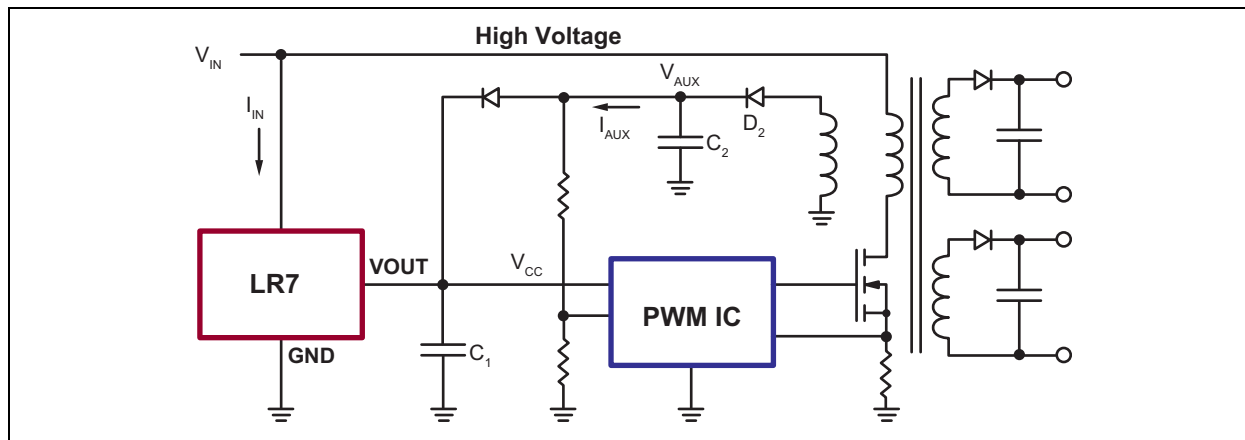
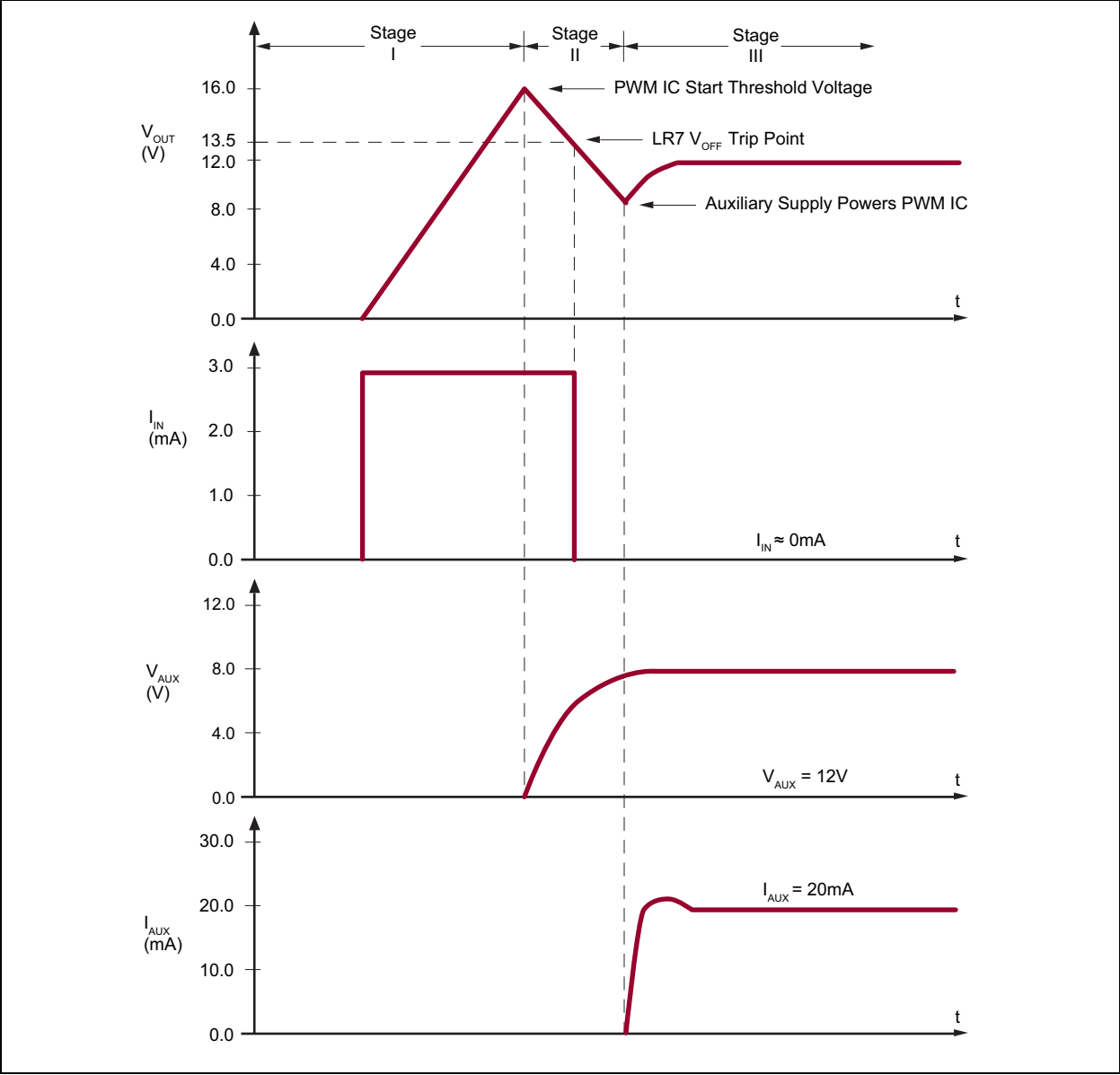
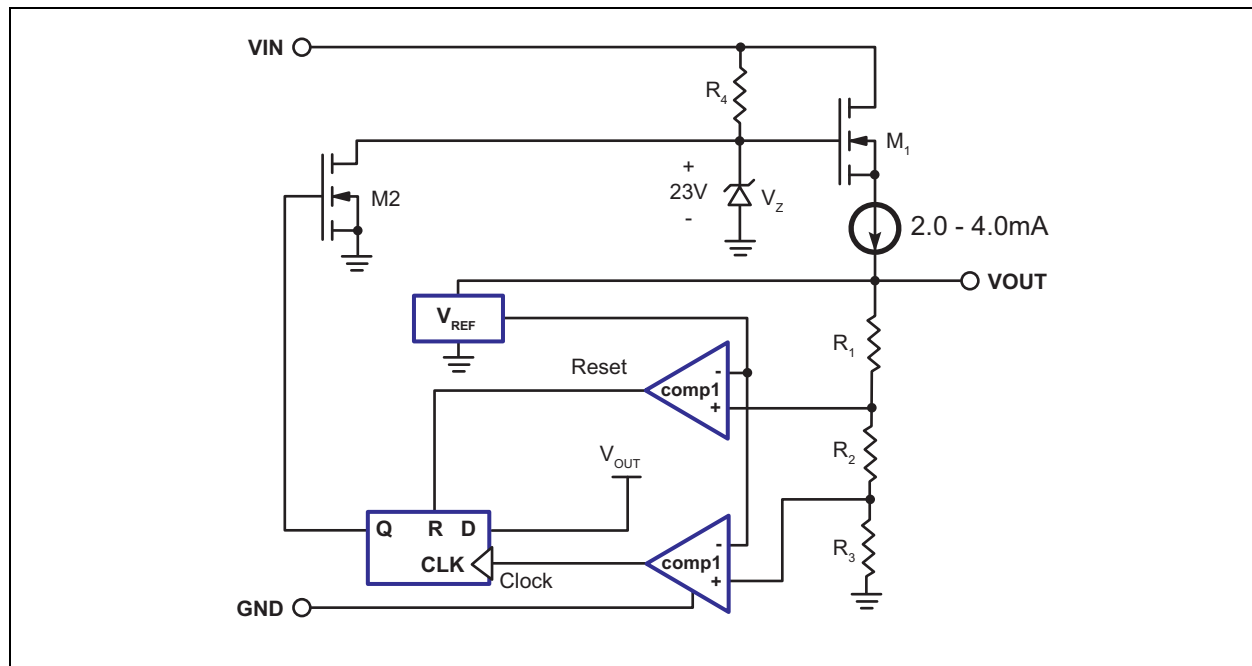


FIGURE 3-2: START-UP WAVEFORMS



### 3.4 Block Diagram

FIGURE 3-3: BLOCK DIAGRAM



LR745 is a high voltage, switch-mode power supply start-up circuit which has 3 terminals: VIN, GND, and VOUT. An input voltage range of 35 - 450V DC can be applied directly at the input VIN pin. The output voltage, VOUT, is monitored by the 2 comparators: comp1 and comp2. An internal reference, VREF, and resistor divider R1, R2, and R3 set the nominal VOUT trip points of 7.0V for comp1 and 13.25V for comp2.

When a voltage is applied on VIN, VOUT will start to ramp up from 0V. When VOUT 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 VOUT becomes greater than 7.0V, comp1 will change to a logic low state. VOUT will continue to increase, and the constant current source, typically 3.0mA output, will charge an external storage capacitor. As VOUT 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.

VOUT 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 VOUT 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 VOUT is greater than 7.0V. Once VOUT decreases below 7.0V, comp1 will reset the D flip-flop, thereby turning transistor M2 off and transistor M1 back on.

## 4.0 DESIGN CONSIDERATIONS

To ensure the best design using LR745, evaluate the value of  $C_1$  and the SMPS requirements.

### 4.1 Calculating the value for $C_1$

Sizing the  $V_{CC}$  capacitor,  $C_1$ , is an important factor. Making  $C_1$  too large will cause the SMPS to power up too slowly. However, if too small,  $C_1$  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  $C_1$  can be approximated by the following equation:

$$C_1 = \frac{\left[\frac{1}{f}\right] \cdot N \cdot I}{V_{START} - V_{MIN}}$$

Definitions:

- $f$  = 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  $C_1$  is calculated as follows:

$$C_1 = \frac{\left[\frac{1}{100\text{kHz}}\right] \cdot 100 \cdot 20\text{mA}}{16\text{V} - 10\text{V}}$$

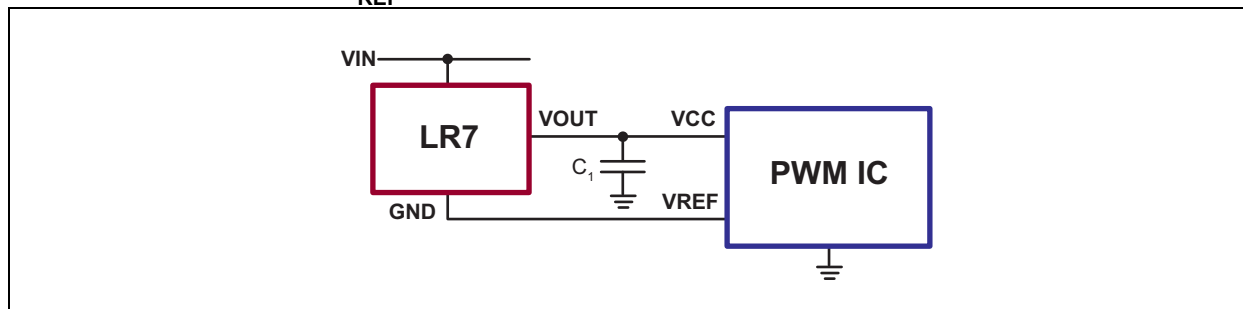
$$C_1 = 3.3\mu\text{F}$$

## 4.2 SMPS with wide minimum to maximum load

An important point is that the LR745'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 a 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 4-1](#) is recommended.

In [Figure 4-1](#), the  $V_{REF}$  pin of the UC3844 is used to bias the ground pin of the LR745. 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 LR745 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 LR745 will see an effective  $V_{OUT}$  voltage of 11V (16V minus 5.0V) because the ground of the LR745 is now at 5.0V. The LR745 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 5.0V during start is a common feature in most PWM ICs.

**FIGURE 4-1: USING  $V_{REF}$  FOR GROUND VOLTAGE**

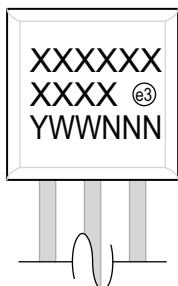




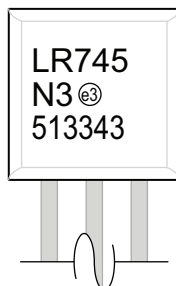
## 5.0 PACKAGING INFORMATION

### 5.1 Package Marking Information

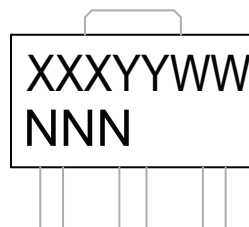
3-lead TO-92



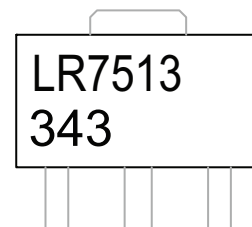
Example



3-lead TO-243AA \*  
(SOT-89)



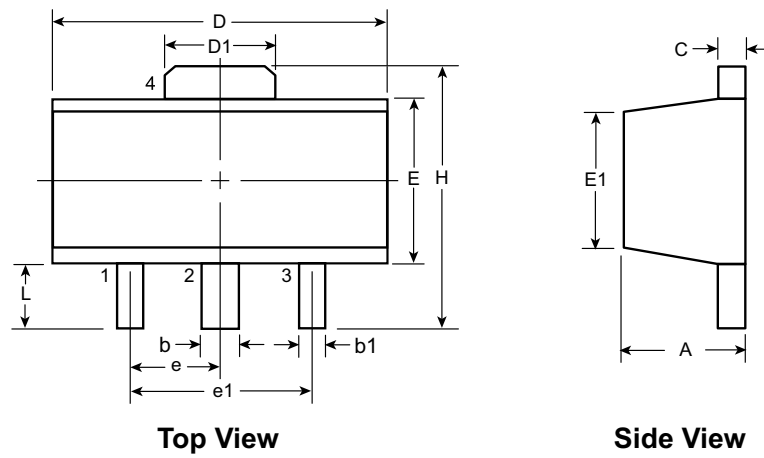
Example



|                |        |                                                                                                                  |
|----------------|--------|------------------------------------------------------------------------------------------------------------------|
| <b>Legend:</b> | XX...X | Product Code or Customer-specific information                                                                    |
|                | Y      | Year code (last digit of calendar year)                                                                          |
|                | YY     | Year code (last 2 digits of calendar year)                                                                       |
|                | WW     | Week code (week of January 1 is week '01')                                                                       |
|                | NNN    | Alphanumeric traceability code                                                                                   |
|                | (e3)   | Pb-free JEDEC® designator for Matte Tin (Sn)                                                                     |
|                | *      | This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package. |

**Note:** In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for product code or customer-specific information. Package may or not include the corporate logo.

## 3-Lead TO-243AA (SOT-89) Package Outline (N8)



Note: For the most current package drawings, see the Microchip Packaging Specification at [www.microchip.com/packaging](http://www.microchip.com/packaging).

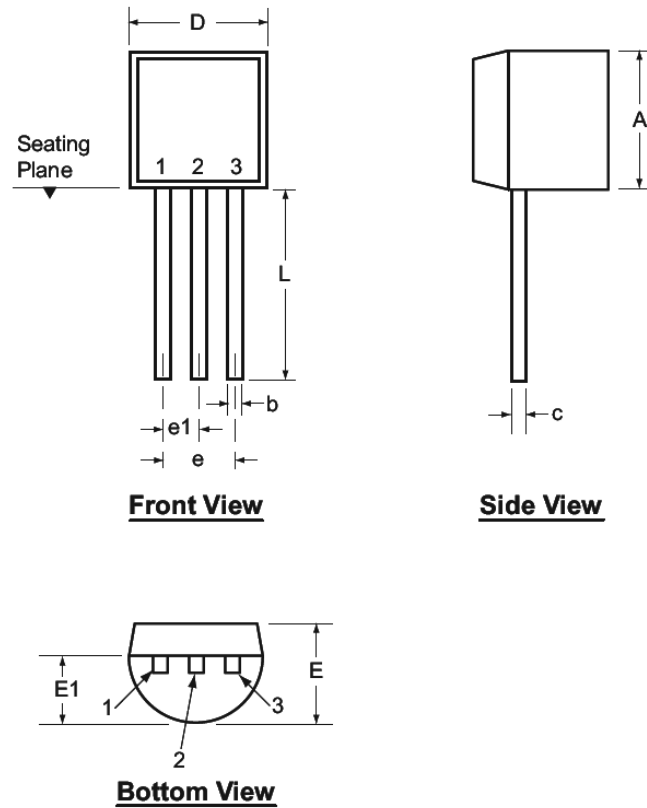
| Symbol             |     | A    | b    | b1   | C    | D    | D1   | E    | E1                | e           | e1          | H    | L                 |
|--------------------|-----|------|------|------|------|------|------|------|-------------------|-------------|-------------|------|-------------------|
| Dimensions<br>(mm) | MIN | 1.40 | 0.44 | 0.36 | 0.35 | 4.40 | 1.62 | 2.29 | 2.00 <sup>†</sup> | 1.50<br>BSC | 3.00<br>BSC | 3.94 | 0.73 <sup>†</sup> |
|                    | NOM | -    | -    | -    | -    | -    | -    | -    | -                 |             |             | -    | -                 |
|                    | MAX | 1.60 | 0.56 | 0.48 | 0.44 | 4.60 | 1.83 | 2.60 | 2.29              |             |             | 4.25 | 1.20              |

JEDEC Registration TO-243, Variation AA, Issue C, July 1986.

<sup>†</sup> This dimension differs from the JEDEC drawing

Drawings not to scale.

## 3-Lead TO-92 Package Outline (L/LL/N3)



Note: For the most current package drawings, see the Microchip Packaging Specification at [www.microchip.com/packaging](http://www.microchip.com/packaging).

| Symbol                 |     | A    | b                 | c                 | D    | E    | E1   | e    | e1   | L     |
|------------------------|-----|------|-------------------|-------------------|------|------|------|------|------|-------|
| Dimensions<br>(inches) | MIN | .170 | .014 <sup>†</sup> | .014 <sup>†</sup> | .175 | .125 | .080 | .095 | .045 | .500  |
|                        | NOM | -    | -                 | -                 | -    | -    | -    | -    | -    | -     |
|                        | MAX | .210 | .022 <sup>†</sup> | .022 <sup>†</sup> | .205 | .165 | .105 | .105 | .055 | .610* |

JEDEC Registration TO-92.

\* This dimension is not specified in the JEDEC drawing.

† This dimension differs from the JEDEC drawing.

Drawings not to scale.

## APPENDIX A: REVISION HISTORY

### Revision A (April 2015)

- Update file to new format

## PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

| <u>PART NO.</u> |                 | XX                                                    | - | X          | - | X |
|-----------------|-----------------|-------------------------------------------------------|---|------------|---|---|
| Device          | Package Options | Environmental                                         |   | Media Type |   |   |
| Device:         | LR745           | = High-Input, Voltage SMPS, Start-up/Linear Regulator |   |            |   |   |
| Package:        | N3              | = TO-92 (fixed voltage)                               |   |            |   |   |
|                 | N8              | = TO-243AA (SOT-89) (fixed voltage)                   |   |            |   |   |
| Environmental   | G               | = Lead (Pb)-free/ROHS-compliant package               |   |            |   |   |
| Media Type:     | (blank)         | = 1000/Bag for N3 packages                            |   |            |   |   |
|                 |                 | = 2000/Reel for N8 packages                           |   |            |   |   |
|                 | P003            | = 2000/Reel for N3 package                            |   |            |   |   |
|                 | P013            | = 2000/Ammo Pack for N3 package                       |   |            |   |   |

### Examples:

- a) LR745N3-G TO-92 package, 1000/bag
- b) LR745N3-G-P003: TO-92 package, 2000/reel.
- c) LR745N3-G-P013: TO-92 package, 2000/ammo pack.
- d) LR745N8-G TO-243AA package, 2000/reel

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Fax: 86-21-5407-5066

#### China - Shenyang

Tel: 86-24-2334-2829

Fax: 86-24-2334-2393

#### China - Shenzhen

Tel: 86-755-8864-2200

Fax: 86-755-8203-1760

#### China - Wuhan

Tel: 86-27-5980-5300

Fax: 86-27-5980-5118

#### China - Xian

Tel: 86-29-8833-7252

Fax: 86-29-8833-7256

### ASIA/PACIFIC

#### China - Xiamen

Tel: 86-592-2388138

Fax: 86-592-2388130

#### China - Zhuhai

Tel: 86-756-3210040

Fax: 86-756-3210049

#### India - Bangalore

Tel: 91-80-3090-4444

Fax: 91-80-3090-4123

#### India - New Delhi

Tel: 91-11-4160-8631

Fax: 91-11-4160-8632

#### India - Pune

Tel: 91-20-3019-1500

#### Japan - Osaka

Tel: 81-6-6152-7160

Fax: 81-6-6152-9310

#### Japan - Tokyo

Tel: 81-3-6880-3770

Fax: 81-3-6880-3771

#### Korea - Daegu

Tel: 82-53-744-4301

Fax: 82-53-744-4302

#### Korea - Seoul

Tel: 82-2-554-7200

Fax: 82-2-558-5932 or

82-2-558-5934

#### Malaysia - Kuala Lumpur

Tel: 60-3-6201-9857

Fax: 60-3-6201-9859

#### Malaysia - Penang

Tel: 60-4-227-8870

Fax: 60-4-227-4068

#### Philippines - Manila

Tel: 63-2-634-9065

Fax: 63-2-634-9069

#### Singapore

Tel: 65-6334-8870

Fax: 65-6334-8850

#### Taiwan - Hsin Chu

Tel: 886-3-5778-366

Fax: 886-3-5770-955

#### Taiwan - Kaohsiung

Tel: 886-7-213-7828

#### Taiwan - Taipei

Tel: 886-2-2508-8600

Fax: 886-2-2508-0102

#### Thailand - Bangkok

Tel: 66-2-694-1351

Fax: 66-2-694-1350

### EUROPE

#### Austria - Wels

Tel: 43-7242-2244-39

Fax: 43-7242-2244-393

#### Denmark - Copenhagen

Tel: 45-4450-2828

Fax: 45-4485-2829

#### France - Paris

Tel: 33-1-69-53-63-20

Fax: 33-1-69-30-90-79

#### Germany - Dusseldorf

Tel: 49-2129-3766400

#### Germany - Munich

Tel: 49-89-627-144-0

Fax: 49-89-627-144-44

#### Germany - Pforzheim

Tel: 49-7231-424750

#### Italy - Milan

Tel: 39-0331-742611

Fax: 39-0331-466781

#### Italy - Venice

Tel: 39-049-7625286

#### Netherlands - Drunen

Tel: 31-416-690399

Fax: 31-416-690340

#### Poland - Warsaw

Tel: 48-22-3325737

#### Spain - Madrid

Tel: 34-91-708-08-90

Fax: 34-91-708-08-91

#### Sweden - Stockholm

Tel: 46-8-5090-4654

#### UK - Wokingham

Tel: 44-118-921-5800

Fax: 44-118-921-5820

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