



January 2007

# FAN7311B LCD Backlight Inverter Drive IC

## Features

- High-Efficiency Single-Stage Power Conversion
- Wide Input Voltage Range: 5V to 25.5V
- Backlight Lamp Ballast and Soft Dimming
- Reduced Number of Required External Components
- Precision Voltage Reference Trimmed to 2%
- ZVS Full-Bridge Topology
- Soft-Start Capability
- PWM Control at Fixed Frequency
- Analog and Burst Dimming Function
- Programmable Striking Frequency
- Open-Lamp Protection
- Open-Lamp Regulation
- 20-Pin SOIC

## Applications

- LCD TV
- LCD Monitor

## Description

The FAN7311B provides all the control functions for a series parallel resonant converter as well as a pulse width modulation (PWM) controller to develop a supply voltage. Typical operating frequency range is between 30kHz and 250kHz, depending on the cold cathode fluorescent lamp (CCFL) and the transformer's characteristics. The FAN7311B uses a new patent-pending phase-shift control.



## Ordering Information

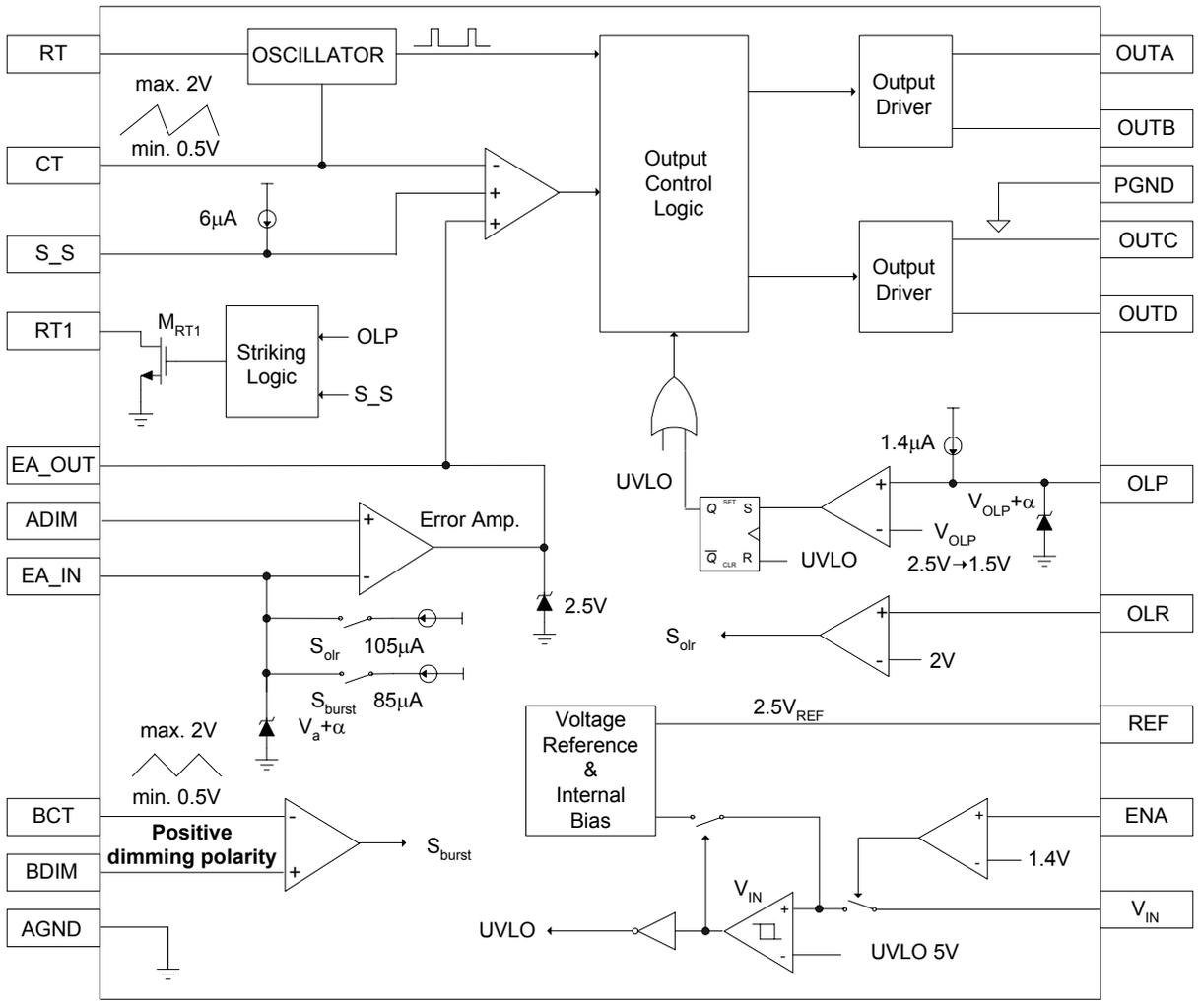
| Part Number | Package | Pb-Free | Operating Temperature Range | Packing Method |
|-------------|---------|---------|-----------------------------|----------------|
| FAN7311BM   | 20-SOIC | Yes     | -25°C to 85°C               | Rail           |
| FAN7311BMX  | 20-SOIC | Yes     |                             | Tape & Reel    |

**Protected by U.S. Patent: 5,652,479; 7,158,390.**

FAN7311B LCD Backlight Inverter Drive IC



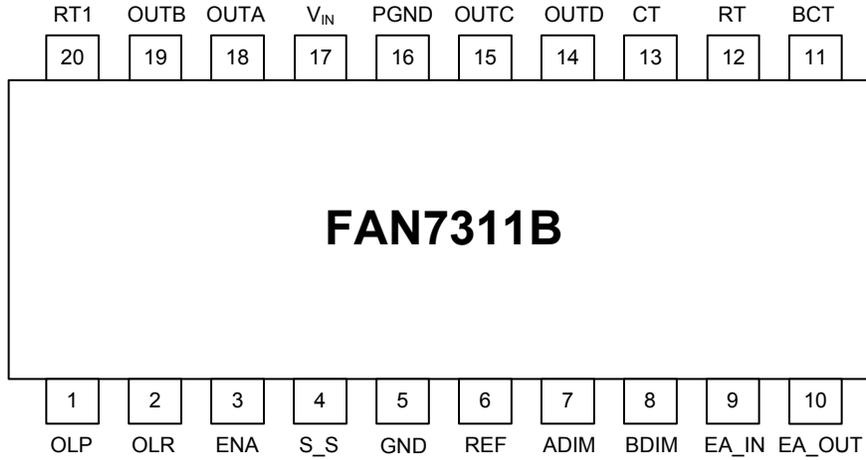
Internal Block Diagram



FAN7311B Rev.00

Figure 1. Functional Block Diagram of FAN7311B

## Pin Assignments



FAN7311B Rev. 00

Figure 2. Pin Configuration (Top View)

## Pin Definitions

| Pin # | Name   | Description            | Pin # | Name            | Description                    |
|-------|--------|------------------------|-------|-----------------|--------------------------------|
| 1     | OLP    | Open-Lamp Protection   | 11    | BCT             | Burst Dimming Timing Capacitor |
| 2     | OLR    | Open-Lamp Regulation   | 12    | RT              | Timing Resistor                |
| 3     | ENA    | Enable Input           | 13    | CT              | Timing Capacitor               |
| 4     | S_S    | Soft-Start             | 14    | OUTD            | NMOSFET Drive Output D         |
| 5     | GND    | Analog Ground          | 15    | OUTC            | PMOSFET Drive Output C         |
| 6     | REF    | 2.5V Reference Voltage | 16    | PGND            | Power Ground                   |
| 7     | ADIM   | Analog Dimming Input   | 17    | V <sub>IN</sub> | Supply Voltage                 |
| 8     | BDIM   | Burst Dimming Input    | 18    | OUTA            | PMOSFET Drive Output A         |
| 9     | EA_IN  | Error Amplifier Input  | 19    | OUTB            | NMOSFET Drive Output B         |
| 10    | EA_OUT | Error Amplifier Output | 20    | RT1             | Striking Frequency Resistor    |

## Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.

For typical values,  $T_A=25^{\circ}\text{C}$  and  $V_{IN}=12\text{V}$ . For min. and max. values,  $T_A$  is the operating ambient temperature range with  $-25^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$  and  $5\text{V} \leq V_{IN} \leq 25.5\text{V}$ , unless otherwise specified.

| Symbol              | Parameter  | Value      | Unit                        |
|---------------------|--|------------|-----------------------------|
| $V_{IN}$            | Supply Voltage                                     | 5 to 25.5  | V                           |
| $T_A$               | Operating Temperature Range                        | -25 to 85  | $^{\circ}\text{C}$          |
| $T_J$               | Junction Temperature                               | 150        | $^{\circ}\text{C}$          |
| $T_{STG}$           | Storage Temperature Range                          | -65 to 150 | $^{\circ}\text{C}$          |
| $\theta_{JA}^{(1)}$ | Thermal Resistance Junction-to-Ambient (still air) | 70         | $^{\circ}\text{C}/\text{W}$ |
| $P_D$               | Power Dissipation                                  | 1.8        | W                           |

### Notes:

1. Thermal resistance test board size: 76.2 \* 114.3 \* 1.6mm (1S0P). JEDEC standard: JESD51-2, JESD51-3.

## Electrical Characteristics

For typical values,  $T_A=25^\circ\text{C}$  and  $V_{IN}=12\text{V}$ . For min. and max. values,  $T_A$  is the operating ambient temperature range with  $-25^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$  and  $5\text{V} \leq V_{IN} \leq 25.5\text{V}$ , unless otherwise specified. Specifications from  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  are guaranteed by design based on final characterization results.

| Symbol   | Parameter                                  | Test Condition  | Min.      | Typ.      | Max.      | Unit          |
|--|--|---|-----------|-----------|-----------|---------------|
| <b>REFERENCE SECTION (Recommend X7R Capacitor)</b> |  |   |           |           |           |               |
| $\Delta V_{ref}$                                   | Line Regulation                            | $5 \leq V_{IN} \leq 25.5\text{V}$                           |           | 2         | 25        | mV            |
| V25  | 2.5V Regulation Voltage                    |   | 2.45      | 2.50      | 2.55      | V             |
| <b>OSCILLATOR SECTION (MAIN)</b>                   |  |   |           |           |           |               |
| $f_{osc}$  | Oscillation Frequency                      | $T_A = 25^\circ\text{C}$ , CT = 270pF,<br>RT = 18k $\Omega$ | 110.4     | 115.0     | 119.6     | kHz           |
|  |  | CT = 270pF, RT = 18k $\Omega$                               | 108       | 115       | 122       |               |
| $V_{cth}$  | CT High Voltage                            |   |           | 2.0       |           | V             |
| $V_{ctl}$  | CT Low Voltage                             |   |           | 0.5       |           | V             |
| <b>OSCILLATOR SECTION (BURST)</b>                  |  |   |           |           |           |               |
| $f_{oscb}$   | Oscillation Frequency                      | $T_A = 25^\circ\text{C}$ , CTB = 10nF,<br>RT=18k $\Omega$   | 209.25    | 225.00    | 240.75    | Hz            |
|  |  | CTB = 10nF, RT=18k $\Omega$                                 | 206.25    | 225.00    | 241.75    |               |
| $V_{bcth}$   | BCT High Voltage                           |   |           | 2         |           | V             |
| $V_{bctl}$   | BCT Low Voltage                            |   |           | 0.5       |           | V             |
| <b>ERROR AMP SECTION</b>                           |  |   |           |           |           |               |
| $A_v$  | Open Loop Gain <sup>(2)</sup>              |   |           | 80        |           | dB            |
| $G_{BW}$   | Unit Gain Bandwidth <sup>(2)</sup>         |   |           | 1.5       |           | MHz           |
| $V_{eh}$   | Feedback Output High Voltage               | EA_IN = 0V  | 2.00      | 2.27      | 2.54      | V             |
| $I_{sin}$  | Output Sink Current                        | EA_OUT = 1.5V   |           |           | -1        | mA            |
| $I_{sur}$  | Output Source Current                      | EA_OUT = 1.5V   | 1         |           |           | mA            |
| $I_{olr}$  | EA_IN Driving Current on OLR               |   | 75        | 105       | 135       | $\mu\text{A}$ |
| $I_{burst}$  | EA_IN Driving Current on Burst Dimming     |   | 61        | 85        | 109       | $\mu\text{A}$ |
| $V_{fbh}$  | Feedback High Voltage on Burst Dimming     | R(EA_IN) = 60k $\Omega$                                     | $V_a+0.1$ | $V_a+0.4$ | $V_a+0.7$ | V             |
| <b>SOFT-START SECTION</b>                          |  |   |           |           |           |               |
| $I_{SS}$   | Soft-Start Current                         | S_S=1V  | 4         | 6         | 8         | $\mu\text{A}$ |
| $V_{ssh}$  | Soft-Start Clamping Voltage <sup>(2)</sup> |   |           | 4         |           | V             |
| <b>PROTECTION SECTION</b>                          |  |   |           |           |           |               |
| $V_{olp0}$   | Open-Lamp Protection Voltage 0             | Start at open lamp  | 2.2       | 2.5       | 2.8       | V             |
| $V_{olp1}$   | Open-Lamp Protection Voltage 1             | Normal -> open lamp   | 1.3       | 1.5       | 1.7       | V             |
| $V_{olr}$  | Open-Lamp Regulation Voltage               |   | 1.75      | 2.00      | 2.25      | V             |
| $I_{olp}$  | Open-Lamp Protection Charging Current      |   | 0.7       | 1.4       | 2.1       | $\mu\text{A}$ |
| <b>UNDER-VOLTAGE LOCKOUT SECTION</b>               |  |   |           |           |           |               |
| $V_{th}$   | Start Threshold Voltage                    |   |           |           | 5         | V             |
| $I_{st}$   | Start-up Current                           | $V_{IN} = V_{th}-0.2$                                       |           | 130       | 180       | $\mu\text{A}$ |
| $I_{op}$   | Operating Supply Current                   | $V_{IN} = 12\text{V}$                                       |           | 1.5       | 4.0       | mA            |
| $I_{sb}$   | Stand-by Current                           | $V_{IN} = 12\text{V}$                                       |           | 200       | 370       | $\mu\text{A}$ |

### Note:

2. These parameters, although guaranteed, are not 100% tested in production.

**Electrical Characteristics** (Continued)

For typical values,  $T_A=25^\circ\text{C}$  and  $V_{IN}=12\text{V}$ . For min. and max. values,  $T_A$  is the operating ambient temperature range with  $-25^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$  and  $5\text{V} \leq V_{IN} \leq 25.5\text{V}$ , unless otherwise specified. Specifications from  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  are guaranteed by design based on final characterization results.

| Symbol                   | Parameter   | Test Condition                        | Min.          | Typ.         | Max.         | Unit |
|--------------------------|---|---------------------------------------|---------------|--------------|--------------|------|
| <b>ON/OFF SECTION</b>    |   |                                       |               |              |              |      |
| $V_{on}$                 | On State Input Voltage                                |                                       | 2             |              | 5            | V    |
| $V_{off}$                | Off Stage Input Voltage                               |                                       |               |              | 0.7          | V    |
| <b>OUTPUT SECTION</b>    |   |                                       |               |              |              |      |
| $V_{pdhv}$               | PMOS Gate High Voltage                                | $V_{IN} = 12\text{V}$                 |               | $V_{IN}$     |              | V    |
| $V_{phlv}$               | PMOS Gate Low Voltage                                 | $V_{IN} = 12\text{V}$                 | $V_{IN}-10.5$ | $V_{IN}-8.5$ | $V_{IN}-6.5$ | V    |
| $V_{ndhv}$               | NMOS Gate Drive Voltage                               | $V_{IN} = 12\text{V}$                 | 6.5           | 8.5          | 10.5         | V    |
| $V_{ndhv}$               | NMOS Gate Drive Voltage                               | $V_{IN} = 12\text{V}$                 |               | 0            |              | V    |
| $V_{puv}$                | PMOS Gate Voltage with UVLO Activated                 | $V_{IN} = V_{th}-0.2$                 | $V_{IN}-0.3$  |              |              | V    |
| $V_{nuv}$                | NMOS Gate Voltage with UVLO Activated                 | $V_{IN} = V_{th}-0.2$                 |               |              | 0.3          | V    |
| $t_r$                    | Rising Time <sup>(3)</sup>                            | $V_{IN} = 12\text{V}, C_L=2\text{nF}$ |               | 200          | 500          | ns   |
| $t_f$                    | Falling Time <sup>(3)</sup>                           | $V_{IN} = 12\text{V}, C_L=2\text{nF}$ |               | 200          | 500          | ns   |
| <b>MAX./MIN. OVERLAP</b> |   |                                       |               |              |              |      |
|                          | Min. Overlap Between Diagonal Switches <sup>(3)</sup> | $f_{osc} = 100\text{kHz}$             |               | 0            |              | %    |
|                          | Max. Overlap Between Diagonal Switches <sup>(3)</sup> | $f_{osc} = 100\text{kHz}$             |               | 100          |              | %    |
| <b>DELAY TIME</b>        |   |                                       |               |              |              |      |
|                          | PDR_A/NDR_B <sup>(3)</sup>                            | RT = 18k $\Omega$                     |               | 450          |              | ns   |
|                          | PDR_C/NDR_D <sup>(3)</sup>                            | RT = 18k $\Omega$                     |               | 450          |              | ns   |

**Note:**

3. These parameters, although guaranteed, are not 100% tested in production.

## Function Description

**UVLO:** The under-voltage lockout circuit guarantees stable operation of the IC's control circuit by stopping and starting it as a function of the  $V_{IN}$  value. The UVLO circuit turns on the control circuit when  $V_{IN}$  exceeds 5V. When  $V_{IN}$  is lower than 5V, the IC's standby current is less than 200 $\mu$ A.

**ENA:** Applying voltage higher than 2V to the ENA pin enables operation of the IC. Applying voltage lower than 0.7V to the ENA pin disables operation of the inverter.

**Soft-Start:** The soft-start function requires that the S\_S pin is connected through a capacitor to GND. A soft-start circuit ensures a gradual increase in the input and output power. The capacitor connected to the S\_S pin determines the rate at which the duty ratio rises. It is charged by a 6 $\mu$ A current source.

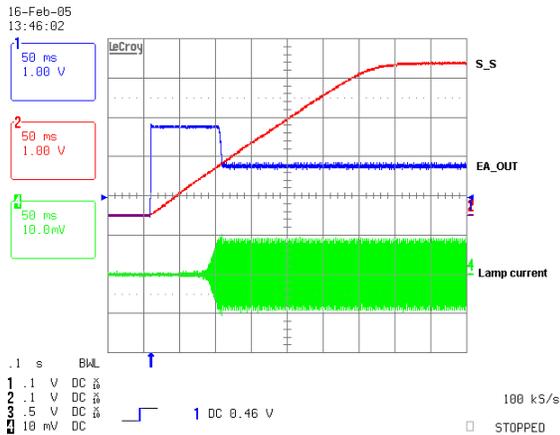


Figure 3. Soft-Start During Initial Operation

**Main Oscillator:** The timing capacitors (CTs) are charged by the reference current source, which is formed by the timing resistor (RT). The timing resistor's voltage is regulated at 1.25V. The sawtooth waveform charges up to 2V. Once this voltage is reached, the capacitors begin discharging down to 0.5V. Next, the timing capacitors start charging again and a new switching cycle begins. The main frequency can be programmed by adjusting the RT and CT values. The main frequency can be calculated as shown below.

$$f_{op} = \frac{19}{32 \cdot RT \cdot CT} \quad (1)$$

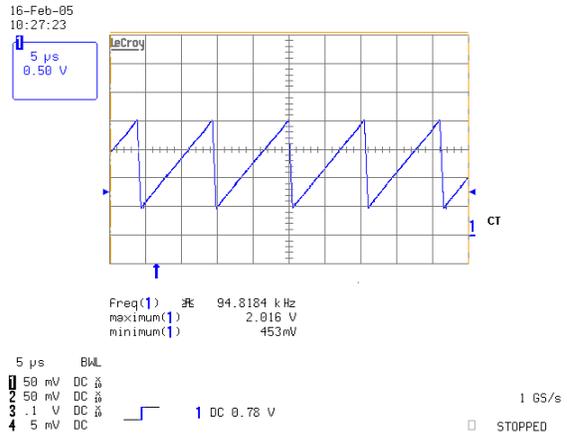


Figure 4. Main Oscillator Waveform

**Burst Oscillator & Burst Dimming:** The timing capacitors (BCTs) are charged by the reference current source, which is formed by the timing resistor (RT). The timing resistor's voltage is regulated at 1.25V. The sawtooth waveform charges up to 2V. Once this voltage is reached, the capacitors begin discharging down to 0.5V. Next, the timing capacitors start charging again and a new switching cycle begins. The burst dimming frequency can be programmed by adjusting the RT and BCT values. The burst dimming frequency can be calculated as shown in Equation 2.

$$f_{burst} = \frac{3.75}{96 \cdot RT \cdot CT} \quad (2)$$

To avoid visible flicker, the burst dimming frequency should be greater than 120Hz.

By comparing the input of BDIM pin with the 0.5~2V triangular wave of the burst oscillator, the PWM pulses for burst dimming. The PWM pulse controls EA\_OUT's voltage by summing 85 $\mu$ A into the EA\_IN pin.

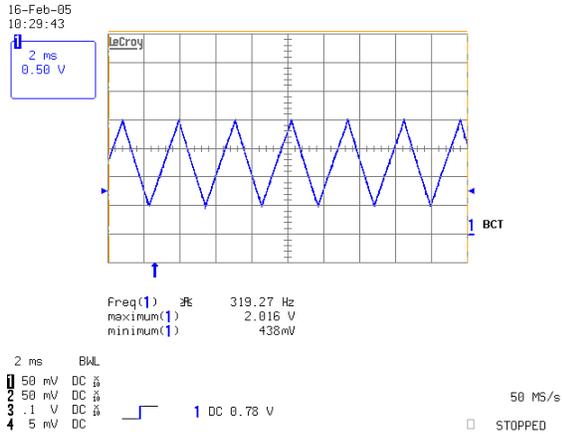


Figure 5. Burst Oscillator Waveform

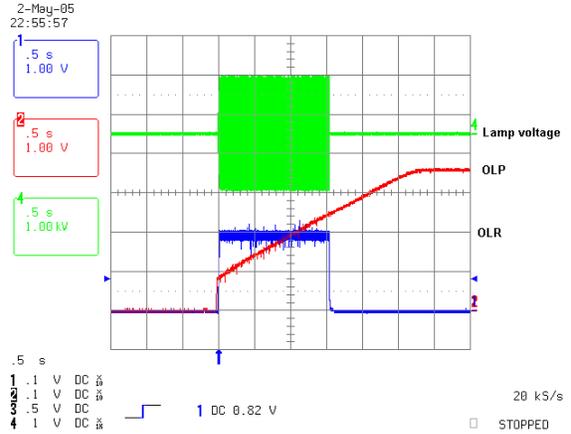


Figure 7. OLR Voltage During Striking Mode

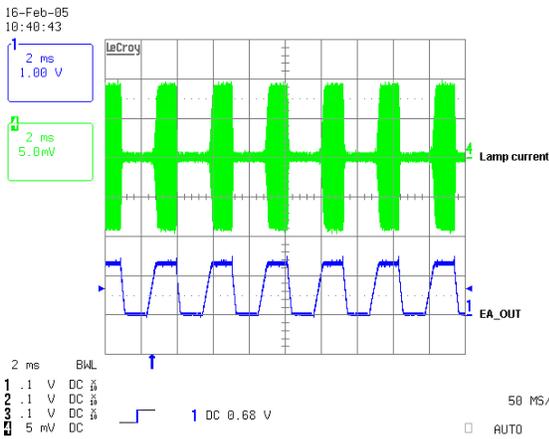


Figure 6. Burst Dimming

**Open Lamp Regulation and Open-Lamp Protection:** It is necessary to suspend power stage operation if an open lamp occurs because the power stage has high gain. When a voltage higher than 2V is applied to the OLR pin, the part enters regulation mode and controls the EA\_OUT voltage. This limits the lamp voltage by summing 105µA into the feedback node. At the same time, the OLP capacitor, connected to the OLP pin, is charged by the 1.4µA internal current source. Once it reaches 2.5V, the IC enters shutdown where all output is high.

**Output Drives:** The four output drives are designed so that switches A and B, C and D never turn on simultaneously. The OUTA-OUTB pair is intended to drive one half-bridge in the external power stage. The OUTC-OUTD pair drives the other half-bridge.

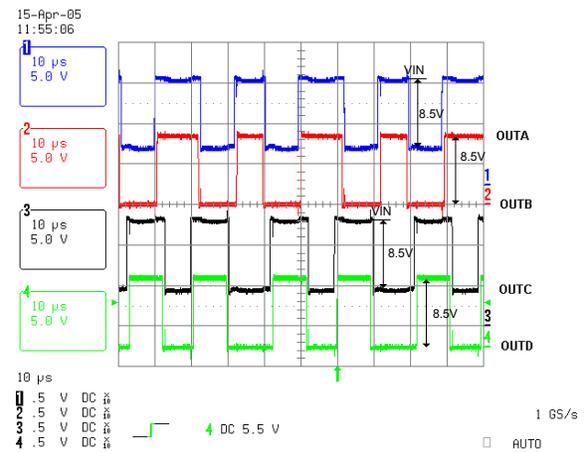
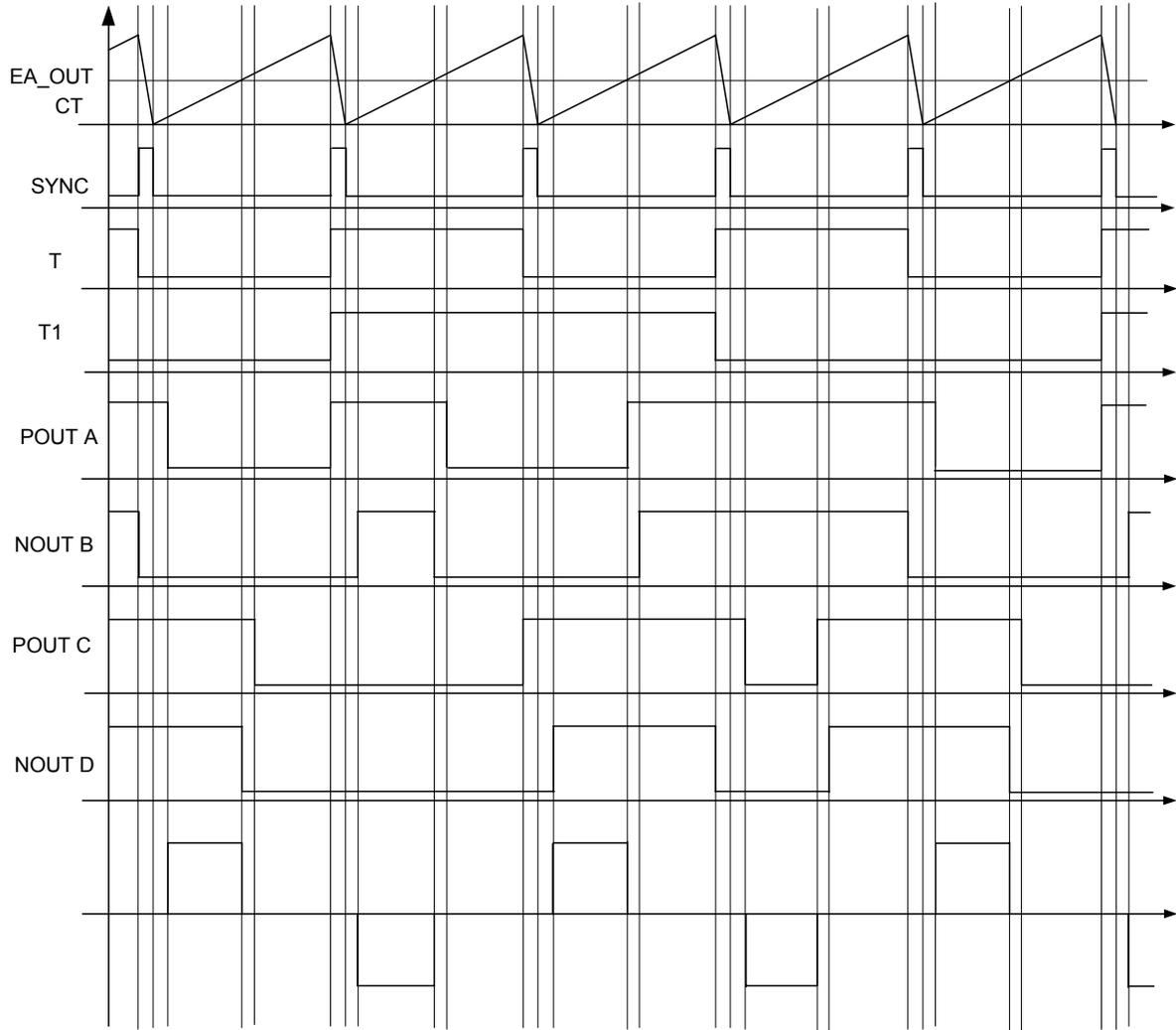


Figure 8. Phase-Shift Control Waveforms

### Timing Diagram

The FAN7311B uses the improved phase-shift control full-bridge to drive CCFL. As a result, the temperature difference between the left and the right leg is almost zero. The detail timing is shown below.



FAN7311 Rev.04

Figure 9. Phase-Shift Control Waveforms

## Typical Application Circuits

| Application         | Lamps | Input Voltage |
|---------------------|-------|---------------|
| 19-inch LCD Monitor | 4     | 13V           |

### 1. Schematic

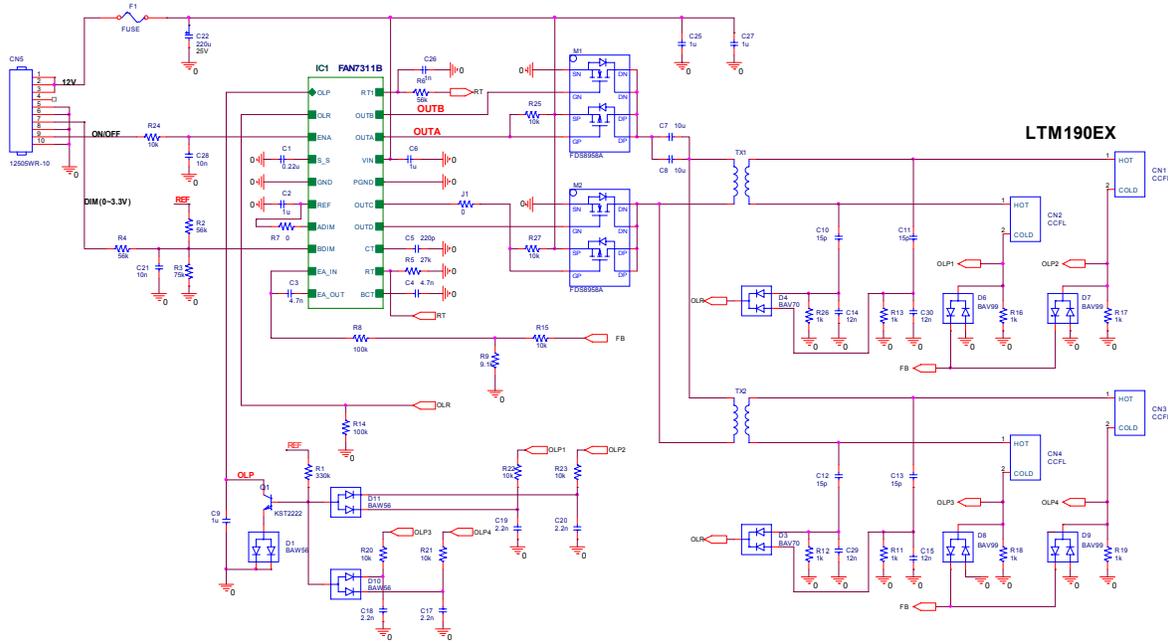
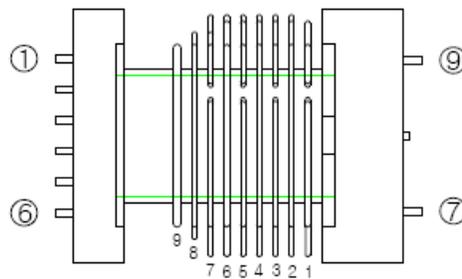


Figure 10. Typical Application Circuit

### 2. Transformer Schematic Diagram

- Supported by Namyang electronics (<http://www.namyangelec.co.kr>)



FAN7311 Rev. 04

Figure 11. Transformer Schematic

### 3. Core & Bobbin

- Core: EFD2124
- Material: PL7
- Bobbin: EFE2124

#### 4. Winding Specification

| Pin No. | Wire              | Turns | Inductance  | Leakage Inductance | Remarks  |
|---------|-------------------|-------|-------------|--------------------|----------|
| 5 --> 2 | 1 UEW 0.45 $\phi$ | 19    | 115 $\mu$ H | 21.5 $\mu$ H       | 1KHz, 1V |
| 7 --> 9 | 1 UEW 0.04 $\phi$ | 2300  | 1.5H        | 280mH              | 1KHz, 1V |

#### 5. BOM of the Application Circuit

| Part Ref.              | Value         | Description / Vendor | Part Ref.               | Value       | Description / Vendor    |
|------------------------|---------------|----------------------|-------------------------|-------------|-------------------------|
| <b>Fuse</b>            |               |                      | C5                      | 220pF       | 50V 1608 J              |
| F1                     | 24V 3A        | Fuse                 | C6                      | 1 $\mu$ F   | 50V 2012 K              |
| <b>Resistor (SMD)</b>  |               |                      | C7                      | 10 $\mu$ F  | 16V 3216                |
| R1                     | 330k $\Omega$ | 1608 J               | C8                      | 10 $\mu$ F  | 16V 3216                |
| R2                     | 56k $\Omega$  | 1608 F               | C9                      | 1 $\mu$ F   | 16V 1608 K              |
| R3                     | 75k $\Omega$  | 1608 F               | C10                     | 15pF        | 3KV 3216                |
| R4                     | 56k $\Omega$  | 1608 F               | C11                     | 15pF        | 3KV 3216                |
| R5                     | 27k $\Omega$  | 1608 F               | C12                     | 15pF        | 3KV 3216                |
| R6                     | 82k $\Omega$  | 1608 F               | C13                     | 15pF        | 3KV 3216                |
| R8                     | 100k $\Omega$ | 1608 F               | C14                     | 10nF        | 50V 1608 K              |
| R9                     | 9.1k $\Omega$ | 1608 F               | C15                     | 10nF        | 50V 1608 K              |
| R11                    | 1k $\Omega$   | 1608 F               | C17                     | 2.2nF       | 50V 1608 Z              |
| R12                    | 1k $\Omega$   | 1608 F               | C18                     | 2.2nF       | 50V 1608 Z              |
| R13                    | 1k $\Omega$   | 1608 F               | C19                     | 2.2nF       | 50V 1608 Z              |
| R14                    | 100k $\Omega$ | 1608 F               | C20                     | 2.2nF       | 50V 1608 Z              |
| R15                    | 10k $\Omega$  | 1608 F               | C21                     | 10nF        | 50V 1608 Z              |
| R16                    | 1k $\Omega$   | 1608 F               | C25                     | 1 $\mu$ F   | 50V 2012 K              |
| R17                    | 1k $\Omega$   | 1608 F               | C26                     | 0.1 $\mu$ F | 16V 1608 K              |
| R18                    | 1k $\Omega$   | 1608 F               | C27                     | 1 $\mu$ F   | 50V 2012 K              |
| R19                    | 1k $\Omega$   | 1608 F               | C28                     | 10nF        | 50V 1608 Z              |
| R20                    | 10k $\Omega$  | 1608 J               | C29                     | 10nF        | 50V 1608 K              |
| R21                    | 10k $\Omega$  | 1608 J               | C30                     | 10nF        | 50V 1608 K              |
| R22                    | 10k $\Omega$  | 1608 J               | <b>Diode / TR (SMD)</b> |             |                         |
| R23                    | 10k $\Omega$  | 1608 J               | D1                      | BAW56       | Fairchild Semiconductor |
| R24                    | 10k $\Omega$  | 1608 J               | D3                      | BAV70       | Fairchild Semiconductor |
| R25                    | 10k $\Omega$  | 1608 J               | D4                      | BAV70       | Fairchild Semiconductor |
| R26                    | 1k $\Omega$   | 1608 F               | D6                      | BAV99       | Fairchild Semiconductor |
| R27                    | 10k $\Omega$  | 1608 J               | D7                      | BAV99       | Fairchild Semiconductor |
| <b>Capacitor (SMD)</b> |               |                      | D8                      | BAV99       | Fairchild Semiconductor |
| C1                     | 0.22 $\mu$ F  | 16V 1608 K           | D9                      | BAV99       | Fairchild Semiconductor |
| C2                     | 1 $\mu$ F     | 50V 2012 K           | D10                     | BAW56       | Fairchild Semiconductor |
| C3                     | 4.7nF         | 50V 1608 K           | D11                     | BAW56       | Fairchild Semiconductor |
| C4                     | 4.7nF         | 50V 1608 K           | Q1                      | KST2222     | Fairchild Semiconductor |

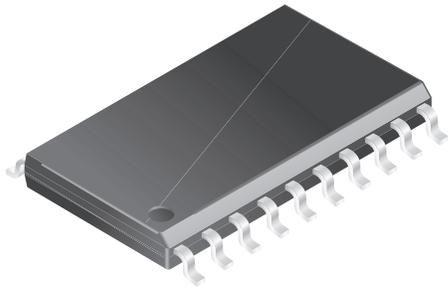
**5. BOM of the Application Circuit (Continued)**

| Part Ref.                     | Value       | Description / Vendor  | Part Ref.          | Value       | Description / Vendor |
|-------------------------------|-------------|---|--------------------|-------------|----------------------|
| <b>Electrolytic capacitor</b> |             |   | <b>Wafer (SMD)</b> |             |                      |
| C22                           | 220 $\mu$ F | 25V   | CN1                | 35001WR-02A |                      |
| <b>MOSFET (SMD)</b>           |             |   | CN2                | 35001WR-02A |                      |
| M1                            | FDS8958A    | Fairchild Semiconductor   | CN3                | 35001WR-02A |                      |
| M2                            | FDS8958A    | Fairchild Semiconductor   | CN4                | 35001WR-02A |                      |
| <b>Transformer (SMD)</b>      |             |   | CN5                | 12505WR-10  |                      |
| TX1                           | EFD2124     | <b>Supported by Namyang electronics (<a href="http://www.namyangelec.co.kr">http://www.namyangelec.co.kr</a>)</b> |                    |             |                      |
| TX2                           | EFD2124     |   |                    |             |                      |

## Mechanical Dimensions

### 20-SOIC

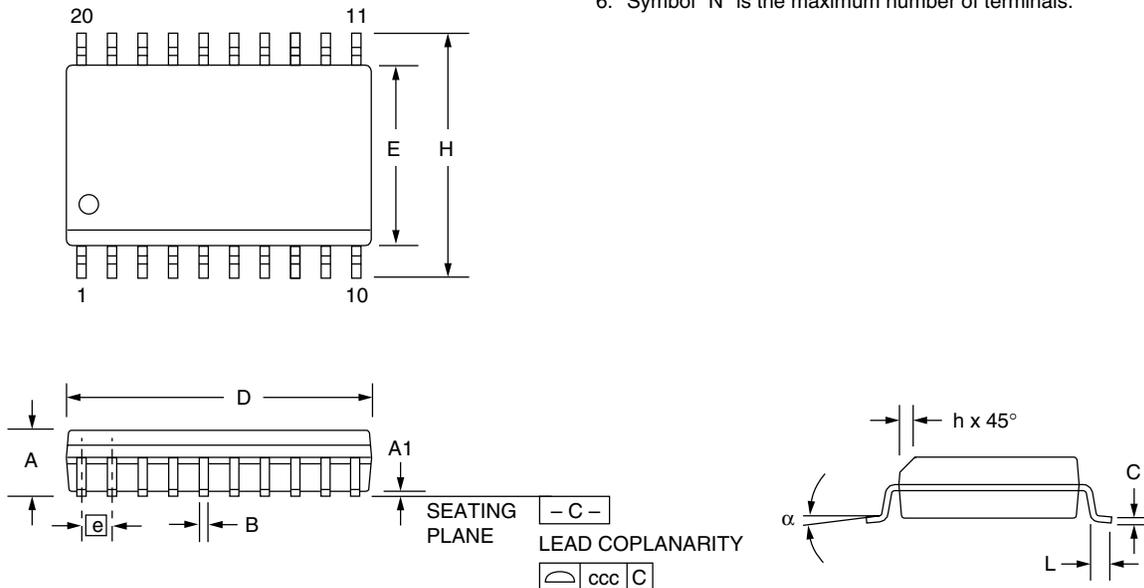
Dimensions are in millimeters unless otherwise specified.



| Symbol   | Inches   |      | Millimeters |       | Notes |
|----------|----------|------|-------------|-------|-------|
|          | Min.     | Max. | Min.        | Max.  |       |
| A        | .093     | .104 | 2.35        | 2.65  |       |
| A1       | .004     | .012 | 0.10        | 0.30  |       |
| B        | .013     | .020 | 0.33        | 0.51  |       |
| C        | .009     | .013 | 0.23        | 0.32  | 5     |
| D        | .496     | .512 | 12.60       | 13.00 | 2     |
| E        | .291     | .299 | 7.40        | 7.60  | 2     |
| e        | .050 BSC |      | 1.27 BSC    |       |       |
| H        | .394     | .419 | 10.00       | 10.65 |       |
| h        | .010     | .029 | 0.25        | 0.75  |       |
| L        | .016     | .050 | 0.40        | 1.27  | 3     |
| N        | 20       |      | 20          |       | 6     |
| $\alpha$ | 0°       | 8°   | 0°          | 8°    |       |
| ccc      | —        | .004 | —           | 0.10  |       |

**Notes:**

1. Dimensioning and tolerancing per ANSI Y14.5M-1982.
2. "D" and "E" do not include mold flash. Mold flash or protrusions shall not exceed .010 inch (0.25mm).
3. "L" is the length of terminal for soldering to a substrate.
4. Terminal numbers are shown for reference only.
5. "C" dimension does not include solder finish thickness.
6. Symbol "N" is the maximum number of terminals.



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soic20\_dim.pdf

**Figure 12. 20-Lead Small Outline Integrated Circuit (SOIC)**

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