

# CCM Buck Controller for Precise Current Regulation and Wide Analog Dimming

## NCL35076

The NCL35076 is a DC-DC buck controller for wide dimming range down to 1% by analog dimming control to relieve audible noise and flicker in PWM dimming. ON Semiconductor's proprietary LED current calculation technique driven by zero input offset amplifiers performs precise constant current in the whole analog dimming range. Multi-mode operation provides low LED current ripple with small output capacitor by CCM at heavy load and deep analog dimming by DCM at light load.

PWM dimming is also provided in case that constant LED color temperature is required. NCL35076 ensures high system reliability with LED short protection, over current protection and thermal shutdown.

### Features

- Wide Analog Dimming Range: 1~100%
- Low CC Tolerance:  $\pm 2\%$  at 100% Load &  $\pm 20\%$  at 1% Load
- Low System BOM
- LED Off Mode at Standby
- Low Standby Current
- PWM Dimming Available
- Gate Sourcing and Sinking Current of 0.5 A/0.8 A
- Robust Protection Features
  - ◆ LED Short Protection
  - ◆ Over Current Protection
  - ◆ Thermal Shutdown
  - ◆ V<sub>DD</sub> Over Voltage Protection

### Typical Applications

- LED Lighting System



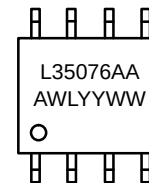
ON Semiconductor®

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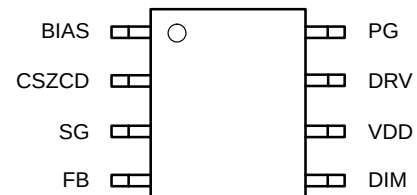
SOIC-8 NB  
CASE 751

### MARKING DIAGRAM



L30076 = Specific Device Code  
AA = Default Trimming Option  
A = Assembly Location  
WL = Wafer Lot Traceability Code  
YYWW = 4 Digit Data Code

### PIN ASSIGNMENT



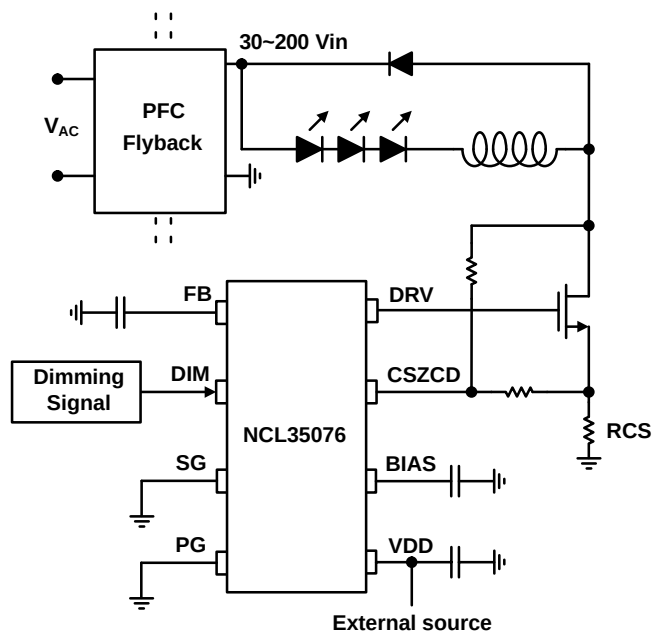
(Top View)

### ORDERING INFORMATION

| Device         | Package   | Shipping              |
|----------------|-----------|-----------------------|
| NCL35076AADR2G | SOIC-8 NB | 3000 /<br>Tape & Reel |

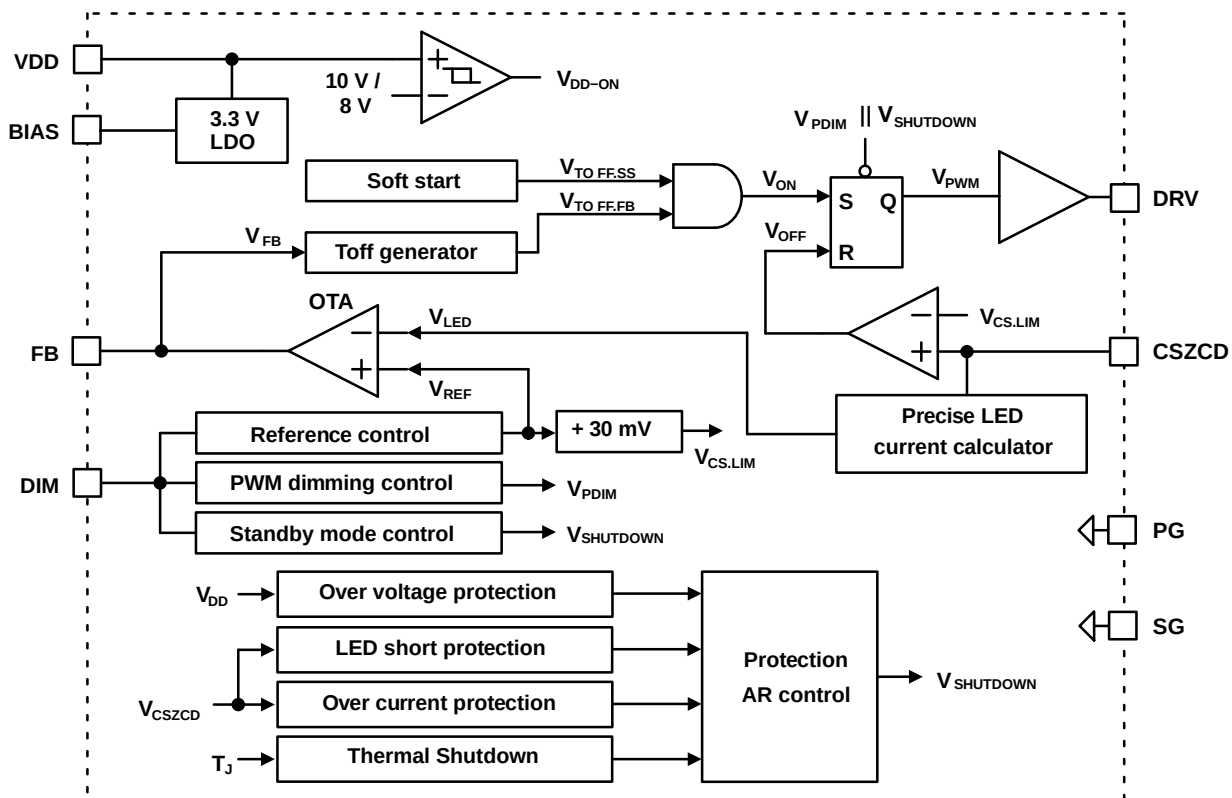
†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, BRD8011/D.

## APPLICATION SCHEMATIC



### Figure 1. Application Schematic

### BLOCK DIAGRAM



### Figure 2. Simplified Block Diagram

# NCL35076

## PIN CONFIGURATION

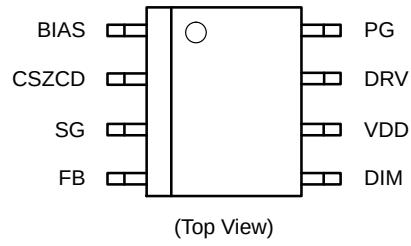


Figure 3. Pin Configuration

## PIN FUNCTION DESCRIPTION

| Pin No. | Pin Name | Function           | Description                                                                  |
|---------|----------|--------------------|------------------------------------------------------------------------------|
| 1       | BIAS     | 3.3 V BIAS         | This pin is 3.3 V LDO output to bias the internal digital circuit            |
| 2       | CSZCD    | CS and ZCD Sensing | This pin detects the switch current and the inductor current zero cross time |
| 3       | SG       | Signal Ground      | Signal Ground is close to control pin circuit such as CSZCD, DIM and FB      |
| 4       | FB       | Feedback           | Output of feedback OTA                                                       |
| 5       | DIM      | Dimming Input      | Dimming signal is provided to this pin                                       |
| 6       | VDD      | Power Supply       | IC operating current is supplied to this pin                                 |
| 7       | DRV      | Output Drive       | This pin is connected to drive external switch                               |
| 8       | PG       | Power Ground       | Power Ground is close to the capacitors at BIAS and VDD pin                  |

## SPECIFICATIONS

## MAXIMUM RATINGS

| Parameter                                              | Symbol          | Value       | Unit               |
|--------------------------------------------------------|-----------------|-------------|--------------------|
| VDD, DRV Pin Voltage Range                             | $V_{MV(MAX)}$   | -0.3 to 30  | V                  |
| DIM, FB, CSZCD, BIAS Pin Voltage Range                 | $V_{LV(MAX)}$   | -0.3 to 5.5 | V                  |
| Maximum Power Dissipation ( $T_A < 50^\circ\text{C}$ ) | $P_{D(MAX)}$    | 550         | mW                 |
| Maximum Junction Temperature                           | $T_{J(max)}$    | 150         | $^\circ\text{C}$   |
| Storage Temperature Range                              | $T_{STG}$       | -55 to 150  | $^\circ\text{C}$   |
| Junction-to-Ambient Thermal Impedance                  | $R_{\theta JA}$ | 145         | $^\circ\text{C/W}$ |
| ESD Capability, Human Body Model (Note 2)              | $ESD_{HBM}$     | 2           | kV                 |
| ESD Capability, Charged Device Model (Note 2)          | $ESD_{CDM}$     | 1           | kV                 |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. Refer to ELECTRICAL CHARACTERISTICS, RECOMMENDED OPERATING RANGES and/or APPLICATION INFORMATION for Safe Operating parameters.
2. This device series incorporates ESD protection and is tested by the following methods:
  - ESD Human Body Model per JEDEC Standard JESD22-A114
  - ESD Charged Device Model per JEDEC Standard JESD22-C101
  - Latch-up Current Maximum Rating  $\pm 100$  mA per JEDEC Standard JESD78

## RECOMMENDED OPERATING RANGES

| Parameter            | Symbol | Min | Max | Unit             |
|----------------------|--------|-----|-----|------------------|
| Junction Temperature | $T_J$  | -40 | 125 | $^\circ\text{C}$ |

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

ELECTRICAL CHARACTERISTICS ( $V_{DD} = 15$  V and  $T_J = -40\sim 125^\circ\text{C}$  unless otherwise specified)

| Parameter | Test Conditions | Symbol | Min | Typ | Max | Unit |
|-----------|-----------------|--------|-----|-----|-----|------|
|-----------|-----------------|--------|-----|-----|-----|------|

## VDD SECTION

|                               |                               |               |     |      |      |               |
|-------------------------------|-------------------------------|---------------|-----|------|------|---------------|
| IC Turn-On Threshold Voltage  |                               | $V_{DD(ON)}$  | 9.3 | 10.0 | 10.7 | V             |
| IC Turn-Off Threshold Voltage |                               | $V_{DD(OFF)}$ | 7.4 | 8.0  | 8.6  | V             |
| Startup Current               | $V_{DD} = V_{DD(ON)} - 1.6$ V | $I_{DD(ST)}$  | -   | 250  | 400  | $\mu\text{A}$ |
| Operating Current             |                               | $I_{DD(OP)}$  | -   | 6.5  | 8.0  | mA            |
| Standby Current               |                               | $I_{DD(SB)}$  | -   | 200  | 300  | $\mu\text{A}$ |

## BIAS SECTION

|              |                                           |            |      |      |      |   |
|--------------|-------------------------------------------|------------|------|------|------|---|
| BIAS Voltage |                                           | $V_{BIAS}$ | 3.23 | 3.30 | 3.37 | V |
|              | $T_J = 25\sim 100^\circ\text{C}$ (Note 4) |            | 3.25 | 3.30 | 3.35 | V |

## DIM SECTION

|                                |                   |                    |       |       |       |    |
|--------------------------------|-------------------|--------------------|-------|-------|-------|----|
| DIM Voltage for 100% $V_{REF}$ | $V_{DIM} = 2.6$ V | $V_{DIM(REF-MAX)}$ | 2.44  | 2.50  | 2.56  | V  |
| DIM Voltage for 99% $V_{REF}$  |                   | $V_{DIM(MAX-EFF)}$ | 2.400 | 2.475 | 2.528 | V  |
| Standby Enabling DIM Voltage   |                   | $V_{DIM(SB-ENA)}$  | 50    | 75    | 100   | mV |
| Standby Disabling DIM Voltage  |                   | $V_{DIM(SB-DIS)}$  | 60    | 100   | 140   | mV |
| Standby Delay Time             |                   | $t_{SB(DELAY)}$    | 9     | 10    | 11    | ms |

## FB SECTION

|                       |                                                                                                   |                  |       |       |      |               |
|-----------------------|---------------------------------------------------------------------------------------------------|------------------|-------|-------|------|---------------|
| FB OTA Source Current | $IFB = (V_{LED} - V_{REF}) \times g_{M(FB)} \times 12.5$<br>$V_{REF} = 120$ mV, $V_{LED} = 80$ mV | $I_{FB(SOURCE)}$ | -14.0 | -11.5 | -9.0 | $\mu\text{A}$ |
| FB OTA Sink Current   | $IFB = (V_{LED} - V_{REF}) \times g_{M(FB)} \times 12.5$<br>$V_{REF} = 40$ mV, $V_{LED} = 80$ mV  | $I_{FB(SINK)}$   | 9.0   | 11.5  | 14.0 | $\mu\text{A}$ |

**ELECTRICAL CHARACTERISTICS** ( $V_{DD} = 15\text{ V}$  and  $T_J = -40\sim 125^\circ\text{C}$  unless otherwise specified) (continued)

| Parameter | Test Conditions | Symbol | Min | Typ | Max | Unit |
|-----------|-----------------|--------|-----|-----|-----|------|
|-----------|-----------------|--------|-----|-----|-----|------|

**FB SECTION**

|                             |                                                            |                |     |     |     |                 |
|-----------------------------|------------------------------------------------------------|----------------|-----|-----|-----|-----------------|
| FB OTA Transconductance     | $g_{M(FB)} = I_{FB} / \{(V_{REF} - V_{LED}) \times 12.5\}$ | $g_{M(FB)}$    | 18  | 23  | 28  | $\mu\text{mho}$ |
| FB OTA High Voltage         | $V_{REF} = 120\text{ mV}$ , $V_{LED} = 80\text{ mV}$       | $V_{FB(HIGH)}$ | 4.7 | –   | –   | V               |
| FB Minimum Clamping Voltage | $V_{REF} = 0\text{ mV}$ , $V_{LED} = 80\text{ mV}$         | $V_{FB(CLP)}$  | 0.4 | 0.5 | 0.6 | V               |

**CS SECTION**

|                           |  |                   |     |     |     |    |
|---------------------------|--|-------------------|-----|-----|-----|----|
| CS Regulation             |  | $V_{CS(REG-MAX)}$ | 175 | 180 | 185 | mV |
| CS Current Ripple Voltage |  | $V_{CS(RIPPLE)}$  | 25  | 30  | 35  | mV |
| CS Current Limit Minimum  |  | $V_{CS(LIM-MIN)}$ | 72  | 80  | 88  | mV |

**DUTY SECTION**

|                                       |                         |                    |      |      |      |               |
|---------------------------------------|-------------------------|--------------------|------|------|------|---------------|
| Leading Edge Blanking Time at Turn-on |                         | $t_{LEB(TON)}$     | 360  | 400  | 440  | ns            |
| Maximum Ton Time                      |                         | $t_{ON(MAX)}$      | 45   | 50   | 55   | $\mu\text{s}$ |
| Minimum Toff Time                     | $V_{FB} = 3.8\text{ V}$ | $t_{OFF(MIN)}$     | 400  | 850  | 1000 | ns            |
| Maximum Toff Time                     | $V_{FB} = 0.5\text{ V}$ | $t_{OFF(MAX)}$     | 1.17 | 1.30 | 1.43 | ms            |
| Maximum FB Voltage for Min. Toff      |                         | $V_{FB(MAX-TOFF)}$ | 3.30 | 3.43 | 3.55 | V             |
| Minimum FB Voltage for Max. Toff      |                         | $V_{FB(MIN-TOFF)}$ | 0.9  | 1.1  | 1.3  | V             |

**DRV SECTION**

|                  |                           |                 |    |     |     |    |
|------------------|---------------------------|-----------------|----|-----|-----|----|
| DRV Low Voltage  |                           | $V_{DRV(LOW)}$  | –  | –   | 0.2 | V  |
| DRV High Voltage | $V_{DD} = 15\text{ V}$    | $V_{DRV(HIGH)}$ | 11 | 12  | 13  | V  |
| DRV Rising Time  | $C_{DRV} = 3.3\text{ nF}$ | $t_{DRV(R)}$    | 60 | 100 | 145 | ns |
| DRV Falling Time | $C_{DRV} = 3.3\text{ nF}$ | $t_{DRV(F)}$    | 25 | 55  | 105 | ns |

**AUTO RESTART SECTION**

|                                 |  |                |     |     |     |   |
|---------------------------------|--|----------------|-----|-----|-----|---|
| Auto Restart Time at Protection |  | $t_{AR(Prot)}$ | 0.9 | 1.0 | 1.1 | s |
|---------------------------------|--|----------------|-----|-----|-----|---|

**VDD OVER VOLTAGE PROTECTION SECTION**

|                                    |  |               |    |    |    |   |
|------------------------------------|--|---------------|----|----|----|---|
| VDD Over Voltage Threshold Voltage |  | $V_{DD(OVP)}$ | 22 | 23 | 24 | V |
|------------------------------------|--|---------------|----|----|----|---|

**SHORT LED PROTECTION SECTION**

|                                        |  |                    |      |      |      |    |
|----------------------------------------|--|--------------------|------|------|------|----|
| SLP Monitoring Triggering Delay Time   |  | $t_{SLP(MON-DEL)}$ | 18   | 20   | 22   | ms |
| SLP Monitoring Disable Time at Startup |  | $t_{SLP(MON-DIS)}$ | 10.8 | 12.0 | 13.2 | ms |

**OVER CURRENT PROTECTION SECTION**

|                                      |  |               |     |     |     |   |
|--------------------------------------|--|---------------|-----|-----|-----|---|
| CS Over Current Protection Threshold |  | $V_{CS(OCp)}$ | 0.4 | 0.5 | 0.6 | V |
|--------------------------------------|--|---------------|-----|-----|-----|---|

**THERMAL SHUTDOWN SECTION**

|                                        |  |               |     |     |     |                  |
|----------------------------------------|--|---------------|-----|-----|-----|------------------|
| Thermal Shut Down Temperature (Note 3) |  | $T_{SD}$      | 130 | 150 | 170 | $^\circ\text{C}$ |
| Thermal Shut Down Hysteresis (Note 3)  |  | $T_{SD(HYS)}$ | 25  | 30  | 35  | $^\circ\text{C}$ |

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

3. Guaranteed by design.

4. Guaranteed by characterization.

# TYPICAL CHARACTERISTICS

(These characteristic graphs are normalized at  $T_A = 25^\circ\text{C}$ )

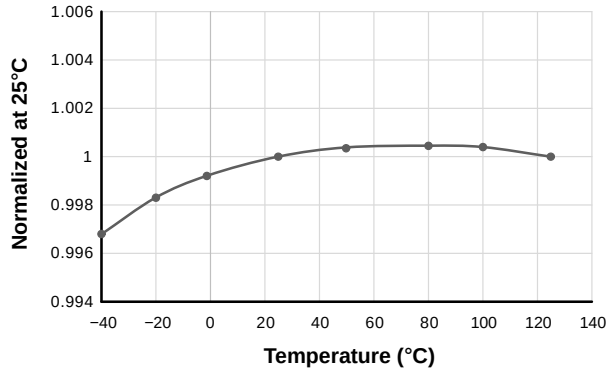


Figure 4.  $V_{\text{BIAS}}$  vs. Temperature

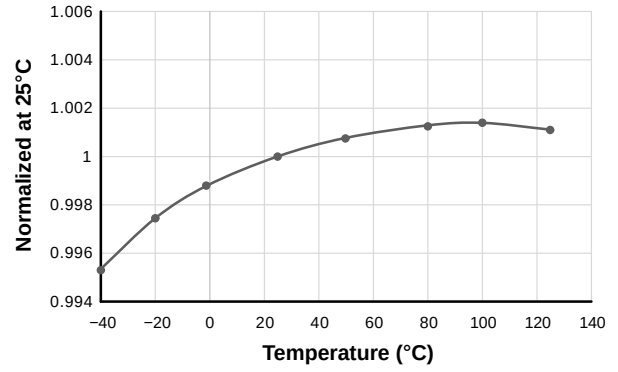


Figure 5.  $V_{\text{DIM(MAX)}}$  vs. Temperature

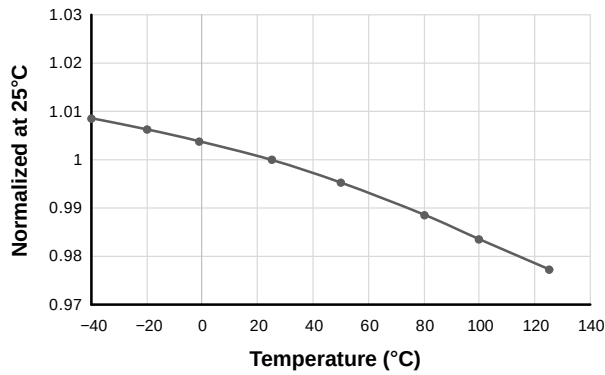


Figure 6.  $g_{\text{M(FB)}}$  vs. Temperature

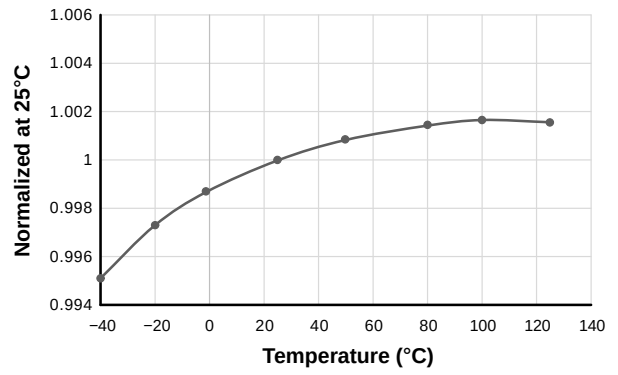


Figure 7.  $V_{\text{CS(REG-MAX)}}$  vs. Temperature

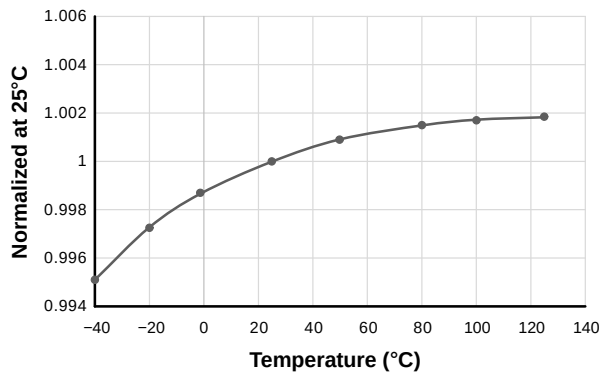


Figure 8.  $V_{\text{CS(LIM-MIN)}}$  vs. Temperature

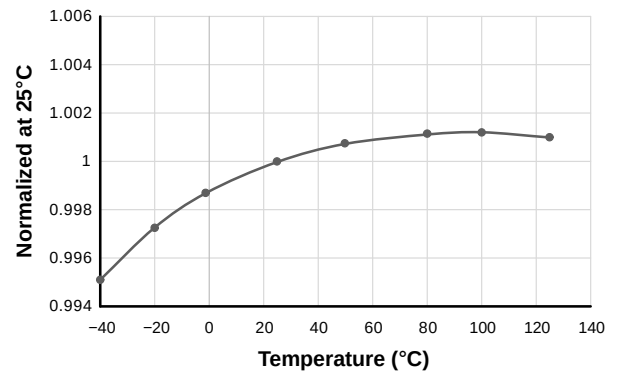


Figure 9.  $V_{\text{DD(OVP)}}$  vs. Temperature

**APPLICATION INFORMATION****General**

NCL35076 provides wide analog dimming down to 1% with high CC accuracy. According to buck inductor, input voltage and output voltage, deep dimming down to 0.1~0.2% load can be achieved. Thanks to the ON semiconductor's proprietary LED current calculation technique, NCL35076 is able to measure the current of LED load connected at input voltage node without the upper limit of the input voltage with high system reliability. LED current is sensed and regulated by internal zero input offset amplifiers so that NCL35076 performs precise CC regulation in the whole analog dimming range. Therefore, CC tolerance is tightly controlled in  $\pm 2\%$  at 100% load and  $\pm 20\%$  at 1% load.

**Wide Analog Dimming**

Wide analog dimming range is obtained by transitioning multi-mode between CCM and DCM according to the dimming condition. At full load condition, CCM with  $\pm 17\%$  inductor current ripple minimizes the conduction loss with high efficiency and DCM is entered at light load condition to perform analog deep dimming. Dimming curve linearity is obtained by a digital compensator in the entire dimming range.

**PWM Dimming**

Analog dimming has benefits for less audible noise and flicker compared to PWM dimming. However, there is a need of PWM dimming method to keep the constant LED color temperature in specific applications. NCL35076 supports PWM dimming by simply inputting PWM dimming signal to DIM pin.

**Precise CC Regulation**

CC regulation is very important especially in programmable LED driver because the driver should keep precise CC control under the system variation of LED load, inductor, temperature, etc. Since NCL35076 applies zero input offset amplifiers at LED current calculator block and

OTA, CC tolerance is less than  $\pm 2\%$  at 100% load and  $\pm 20\%$  at 1% load in the system variation.

**Soft start**

Without soft start in the closed loop CC control, the LED current overshoot is easily occurred at startup so that the overshoot can affect a lifetime of LEDs and incur an undesirable flash. NCL35076 provides soft start technique to prevent the LED current overshoot by  $T_{OFF}$  time control.

**Standby Mode**

When  $V_{DIM}$  is lower than a standby threshold voltage for 10 ms, standby mode is triggered with LED turn-off and IC current consumption is minimized.

**Auto Restart (AR) at Protection**

Once protection is triggered, IC operation stops for 1 second and begins soft start operation after the auto restart time delay.

**VDD Over Voltage Protection (OVP)**

When VDD is higher than 23 V, over voltage protection is triggered.

**Short LED Protection (SLP)**

When LED is short circuited, the buck stage operates in CCM with maximum turn-off time. By detecting this condition, short LED protection is triggered.

**Over Current Protection (OCP)**

When CSZCD voltage exceeds the over current threshold voltage, switching is immediately shut down after leading edge blanking time in the short circuit condition of the inductor, the freewheeling diode or the LED load.

**Thermal Shot Down (TSD)**

When IC junction temperature is higher than  $150^{\circ}\text{C}$ , TSD is triggered and released when the temperature is lower than  $120^{\circ}\text{C}$ .

## BASIC OPERATION

NCL35076 is the current mode buck controller in which DRV is off when  $V_{CSZCD}$  reaches to  $V_{CS.LIM}$  ( $= V_{REF} + 30 \text{ mV}$ ) and DRV is on by  $T_{OFF}$  generator controlled by  $V_{FB}$ .  $V_{LED}$  is calculated based on  $V_{CSZCD}$  in precise LED current calculator block composed of zero input offset amplifiers and  $V_{REF}$  is controlled by DIM signal. In reference control block,  $V_{REF}$  is obtained by below equation.

$$V_{REF} [\text{V}] = \frac{V_{DIM} - 0.25 \text{ V}}{12.5} \quad (\text{eq. 1})$$

$V_{LED}$  is compared with  $V_{REF}$  at OTA to generate  $V_{FB}$  which controls  $T_{OFF}$  time in  $T_{OFF}$  generator.  $T_{OFF}$  is inversely proportional to  $V_{FB}$ . Therefore,  $T_{OFF}$  is shorter as  $V_{FB}$  increases.  $T_{OFF}$  is set by below equation.

$$T_{OFF} [\mu\text{s}] = \frac{1.8}{V_{FB} - 1.1} + 0.1 \quad (\text{eq. 2})$$

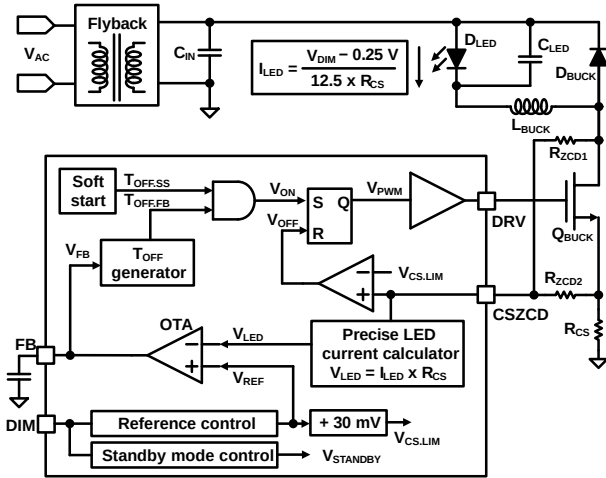
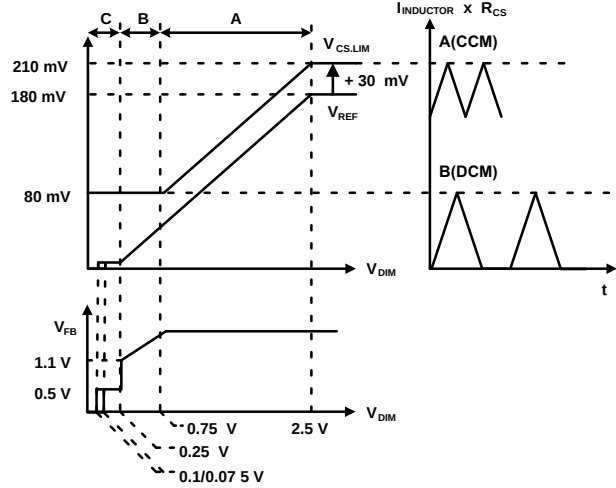


Figure 10. NCL35076 Block Diagram

## Wide Analog Dimming

NCL35076 operates in CCM at heavy load and in DCM at light load for a wide analog dimming. Figure 11 shows how NCL35076 operates with  $V_{DIM}$ .

- **A:**  $V_{CS.LIM}$  follows  $V_{REF} + 30 \text{ mV}$  which is  $\pm 17\%$  inductor current ripple at  $2.5 V_{DIM}$ .  $V_{FB}$  is almost constant with same  $T_{OFF}$  in the CCM region.
- **B:**  $V_{CS.LIM}$  is clamped to  $80 \text{ mV}$  and doesn't change by  $V_{DIM}$ .  $T_{OFF}$  is lengthened for dimming as  $V_{FB}$  is decreased. Operating mode is transitioned from CCM to DCM at the boundary of A and B region.
- **C:** When  $V_{DIM}$  is lower than  $0.25 \text{ V}$ ,  $V_{REF}$  is set to  $0 \text{ V}$  and  $V_{FB}$  is pulled down to  $0.5 \text{ V}$  clamping voltage with min. LED current under open loop control. When  $V_{DIM}$  is further lower than  $0.1/0.075 \text{ V}$ , standby is triggered with LED turn-off.

Figure 11. Operation Mode vs.  $V_{DIM}$ 

## Precise CC Regulation

The output of the precise LED current calculator,  $V_{LED}$ , is generated by analog sensing amplifiers and  $V_{LED}$  is compared with  $V_{REF}$  by OTA to generate  $V_{FB}$ . Those sensing amplifiers and OTA have zero input offset compensation technique which performs the excellent CC regulation.

Table 1 shows CC tolerance measured by changing inductor ( $\pm 20\%$ ), temperature ( $-10, 25, 90^\circ\text{C}$ ), output voltage ( $10, 30, 50 \text{ V}$ ) and controller 150 pcs (3 lot variation) in  $60 \text{ V}$  input  $75 \text{ W}$  driver. As a result, CC tolerance with system variables at  $1\%$  deep dimming condition is less than  $\pm 20\%$  and less than  $\pm 2.0\%$  at full load condition.

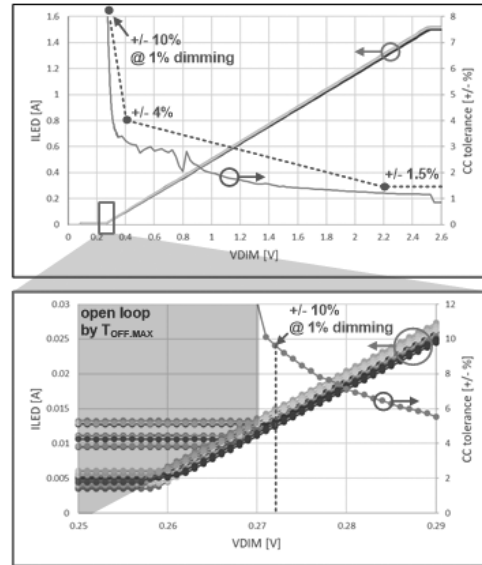


Figure 12. NCL35076 Dimming Curve and CC Tolerance



Table 1. CC TOLERANCE (150 pcs)

| Inductor : $\pm 20\%$<br>Temp. : $-10 / 25 / 90\text{ }^{\circ}\text{C}$ | 100% Load | 50% Load | 10% Load | 5% Load | 2% Load | 1% Load |
|--------------------------------------------------------------------------|-----------|----------|----------|---------|---------|---------|
| $V_{OUT} : 10\text{ V}$                                                  | 1.52      | 1.92     | 3.24     | 4.18    | 7.43    | 13.06   |
| $V_{OUT} : 30\text{ V}$                                                  | 1.40      | 1.54     | 3.26     | 4.38    | 7.99    | 13.87   |
| $V_{OUT} : 50\text{ V}$                                                  | 1.25      | 1.37     | 2.68     | 3.57    | 7.17    | 14.06   |
| $V_{OUT} : 10 / 30 / 50\text{ V}$                                        | 1.62      | 1.98     | 4.10     | 4.94    | 8.24    | 15.40   |

### Standby Mode

Standby mode is triggered by  $V_{DIM}$  as shown in Figure 13.

- **A:** When  $V_{DIM}$  is lower than  $V_{DIM(SB-ENA)}$ , DRV block is shut down. So, LED lamps turn off.
- **B:** After  $t_{SB(DELAY)}$  (10 ms), standby mode is entered and NCL35076 current consumption drops to  $I_{DD(SB)}$ .
- **C:** When  $V_{DIM}$  is higher than  $V_{DIM(SB-DIS)}$ , standby mode is immediately terminated and IC starts up.

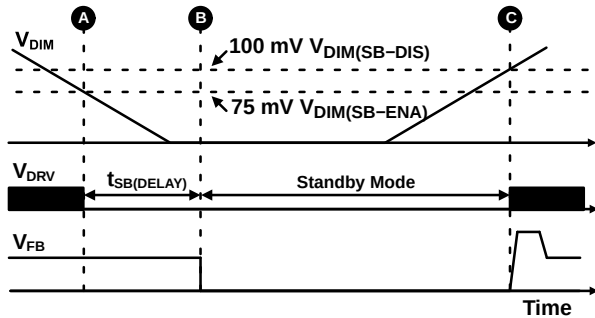


Figure 13. NCL35076 Standby Mode

### Soft Start

During soft start operation,  $T_{OFF}$  is decided by either  $T_{OFF\_SS}$  or  $T_{OFF\_FB}$ .  $T_{OFF}$  is governed by  $T_{OFF\_SS}$  in early start up because  $T_{OFF\_SS}$  decreases from  $t_{OFF(MAX)}$ . When  $T_{OFF\_SS}$  reaches to the steady state level,  $V_{FB}$  is settled to the regulation level and  $T_{OFF}$  is finally decided by  $T_{OFF\_FB}$ . In the end of the soft start time,  $T_{OFF\_SS}$  reaches to 0 and doesn't affect  $T_{OFF}$  control anymore. Figure 14 shows how the soft start operates.

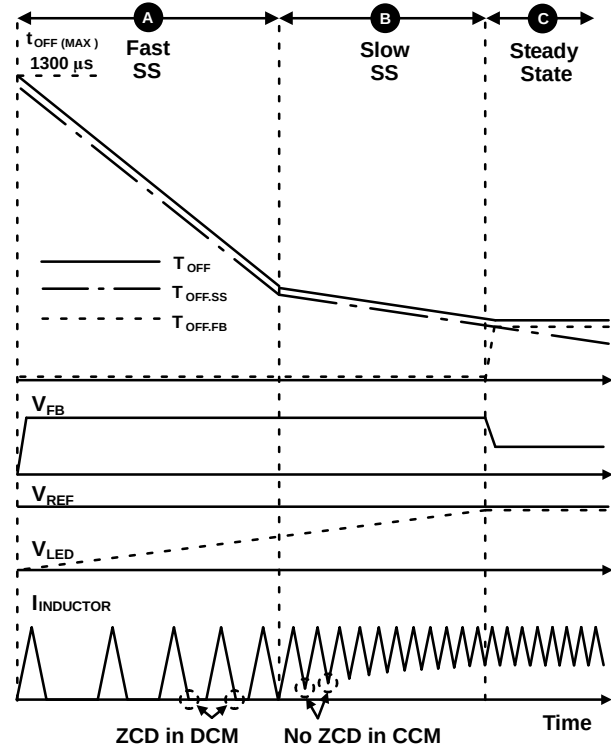


Figure 14. Soft Start Sequence

- **A:**  $V_{FB}$  is pulled up as  $V_{LED}$  is far below  $V_{REF}$ .  $T_{OFF\_SS}$  is reduced quickly from  $t_{OFF(MAX)}$  in Fast SS. Fast SS ends when inductor current zero cross (ZCD) is not detected.
- **B:** Slow SS starts when there is no ZCD in CCM.
- **C:**  $V_{LED}$  is closer to  $V_{REF}$ , and  $V_{FB}$  starts falling. Then,  $T_{OFF}$  is determined by  $T_{OFF\_FB}$  and the steady state starts.

### Protections

When protection is triggered, all functional blocks stop operating and begin to start up after 1 second AR time.

- VDD Over Voltage Protection (OVP)

When VDD is higher than  $V_{DD(OVP)}$  (23 V), VDD OVP is triggered. Open LED protection can be implemented by VDD OVP when VDD is supplied by auxiliary winding in the buck inductor.

- Over Current Protection (OCP)

When CSZCD voltage is higher than  $V_{CS(OCP)}$  (0.5 V) after leading edge blanking time,  $t_{LEB(TON)}$  (400 ns), IC immediately shuts down.

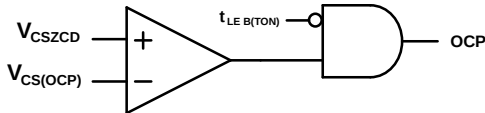


Figure 15. OCP Block

- Short LED Protection (SLP)

When LED load is short-circuited, demagnetizing time of the inductor is very long due to zero output voltage so that  $T_{OFF}$  is lengthened and  $T_{ON}$  is very short. If CCM and  $t_{OFF(MAX)}$  are detected for SLP monitoring time,  $t_{SLP(MON-DEL)}$  (20 ms), SLP is triggered. In order to prevent abnormal SLP triggering at startup, SLP monitoring is disabled for  $t_{SLP(MON-DIS)}$  (12 ms) after 1<sup>st</sup> switching begins.

- Thermal Shut Down (TSD)

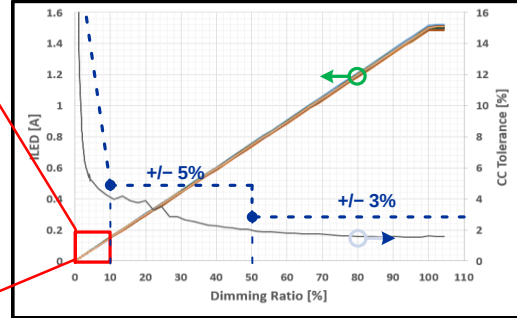
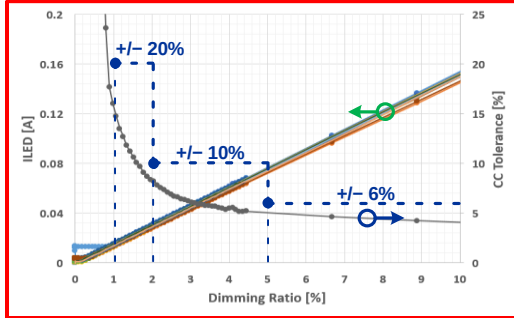
When the junction temperature is higher than  $T_{SD}$ , the system shuts down and the junction temperature is monitored at every 1 second delay time (AR time). When the temperature is lower than  $T_{SD} - T_{SD(HYS)}$ , the system restarts.

APPENDIX: DIMMING CURVE AND CC TOLERANCE WITH SYSTEM VARIABLES

- System: NCL35076 75 W ( $V_{IN}$ : 60V /  $V_{OUT}$ : 10 ~ 50V /  $I_{OUT(MAX)}$ : 1.5 A)
- Temperature variation: -10 / 25 / 90 °C
- Inductance variation:  $\pm 20\%$  (120 uH ~ 180 uH)
- Output Voltage: 10 / 30 / 50 V
- NCL35076 Controller: 150 pcs (3 lot variation)

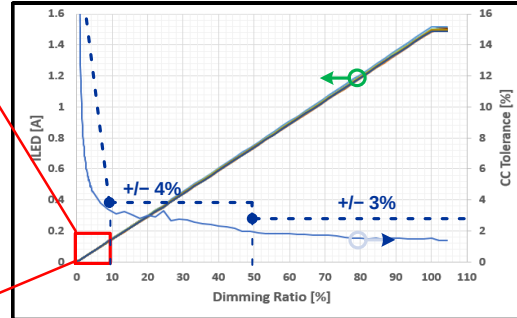
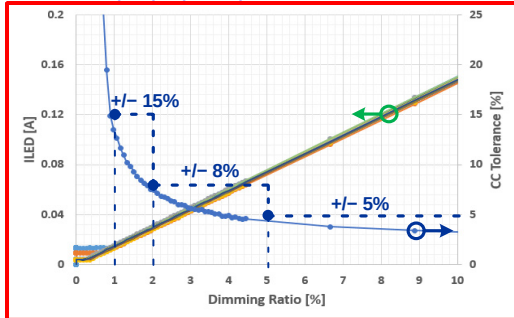
Wide Output Condition (10/30/50V)

NCL35076 150pcs (3lot) + Temp & Inductor variation



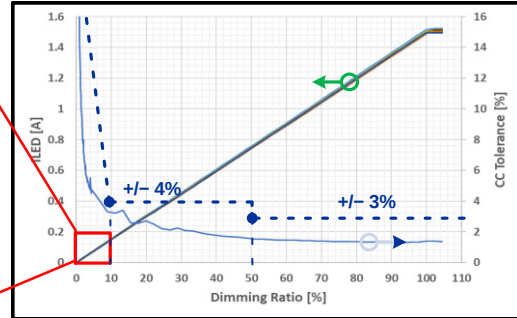
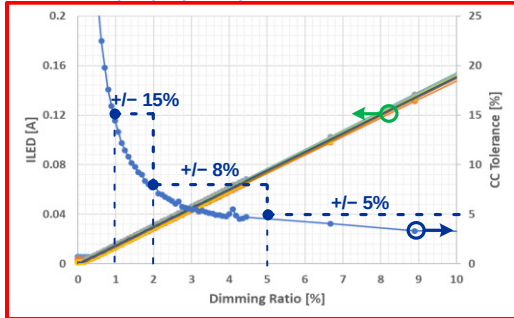
Single Output Condition (10V)

NCL35076 150pcs (3lot) + Temp & Inductor variation



Single Output Condition (30V)

NCL35076 150pcs (3lot) + Temp & Inductor variation



Single Output Condition (50V)

NCL35076 150pcs (3lot) + Temp & Inductor variation

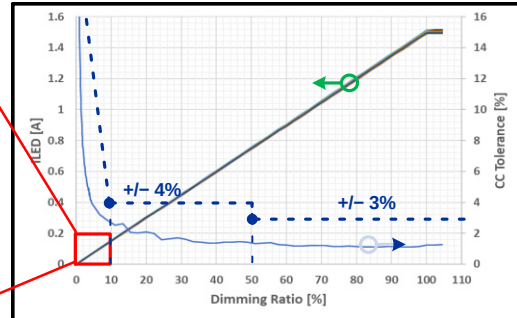
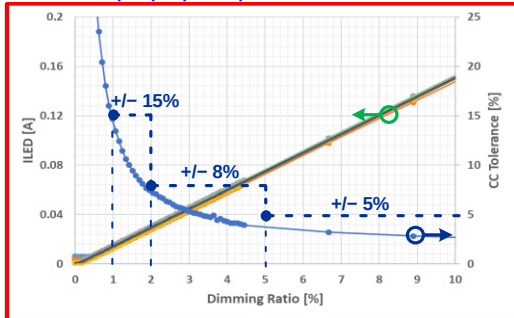


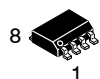
Figure 16. CC Tolerance (150 pcs)



(PCB Layout Guidance)



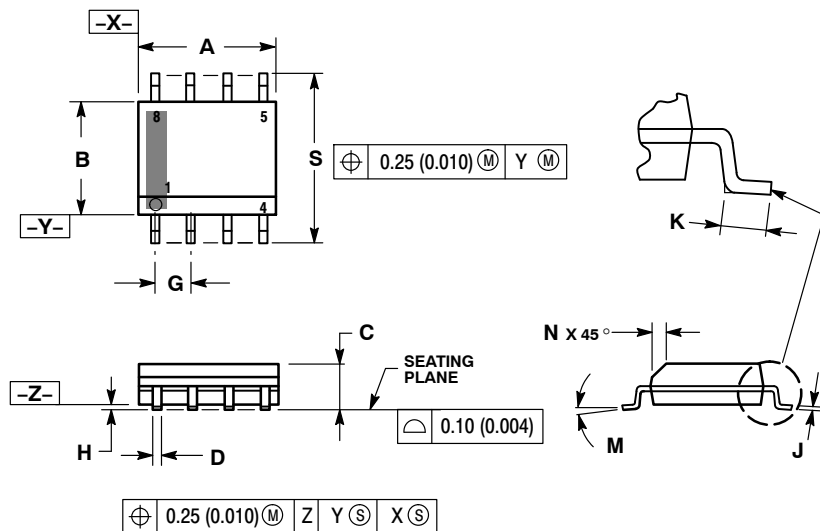
### Figure 17. Layout Guidance



SCALE 1:1

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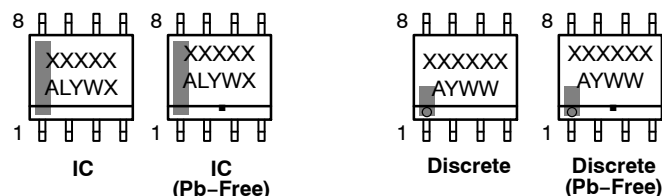
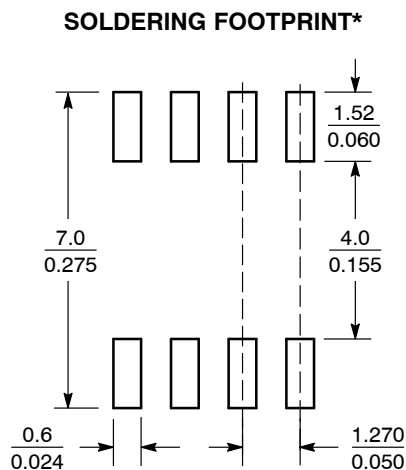


NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. 751-01 THRU 751-06 ARE OBSOLETE. NEW STANDARD IS 751-07.

| DIM | MILLIMETERS |      | INCHES    |       |
|-----|-------------|------|-----------|-------|
|     | MIN         | MAX  | MIN       | MAX   |
| A   | 4.80        | 5.00 | 0.189     | 0.197 |
| B   | 3.80        | 4.00 | 0.150     | 0.157 |
| C   | 1.35        | 1.75 | 0.053     | 0.069 |
| D   | 0.33        | 0.51 | 0.013     | 0.020 |
| G   | 1.27 BSC    |      | 0.050 BSC |       |
| H   | 0.10        | 0.25 | 0.004     | 0.010 |
| J   | 0.19        | 0.25 | 0.007     | 0.010 |
| K   | 0.40        | 1.27 | 0.016     | 0.050 |
| M   | 0°          | 8°   | 0°        | 8°    |
| N   | 0.25        | 0.50 | 0.010     | 0.020 |
| S   | 5.80        | 6.20 | 0.228     | 0.244 |

GENERIC  
MARKING DIAGRAM\*



XXXXXX = Specific Device Code  
A = Assembly Location  
L = Wafer Lot  
Y = Year  
W = Work Week  
▪ = Pb-Free Package

XXXXXX = Specific Device Code  
A = Assembly Location  
Y = Year  
WW = Work Week  
▪ = Pb-Free Package

\*This information is generic. Please refer to device data sheet for actual part marking. Pb-Free indicator, "G" or microdot "▪", may or may not be present. Some products may not follow the Generic Marking.

\*For additional information on our Pb-Free strategy and soldering details, please download the **onsemi** Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

STYLES ON PAGE 2

|                  |             |                                                                                                                                                                                     |
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**ISSUE AK**

DATE 16 FEB 2011

|                                                                                                                                                                                                   |                                                                                                                                                                                          |                                                                                                                                                                                    |                                                                                                                                                                                                        |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>STYLE 1:</b><br>PIN 1. EMITTER<br>2. COLLECTOR<br>3. COLLECTOR<br>4. EMITTER<br>5. EMITTER<br>6. BASE<br>7. BASE<br>8. EMITTER                                                                 | <b>STYLE 2:</b><br>PIN 1. COLLECTOR, DIE, #1<br>2. COLLECTOR, #1<br>3. COLLECTOR, #2<br>4. COLLECTOR, #2<br>5. BASE, #2<br>6. EMITTER, #2<br>7. BASE, #1<br>8. EMITTER, #1               | <b>STYLE 3:</b><br>PIN 1. DRAIN, DIE #1<br>2. DRAIN, #1<br>3. DRAIN, #2<br>4. DRAIN, #2<br>5. GATE, #2<br>6. SOURCE, #2<br>7. GATE, #1<br>8. SOURCE, #1                            | <b>STYLE 4:</b><br>PIN 1. ANODE<br>2. ANODE<br>3. ANODE<br>4. ANODE<br>5. ANODE<br>6. ANODE<br>7. ANODE<br>8. COMMON CATHODE                                                                           |
| <b>STYLE 5:</b><br>PIN 1. DRAIN<br>2. DRAIN<br>3. DRAIN<br>4. DRAIN<br>5. GATE<br>6. GATE<br>7. SOURCE<br>8. SOURCE                                                                               | <b>STYLE 6:</b><br>PIN 1. SOURCE<br>2. DRAIN<br>3. DRAIN<br>4. SOURCE<br>5. SOURCE<br>6. GATE<br>7. GATE<br>8. SOURCE                                                                    | <b>STYLE 7:</b><br>PIN 1. INPUT<br>2. EXTERNAL BYPASS<br>3. THIRD STAGE SOURCE<br>4. GROUND<br>5. DRAIN<br>6. GATE 3<br>7. SECOND STAGE Vd<br>8. FIRST STAGE Vd                    | <b>STYLE 8:</b><br>PIN 1. COLLECTOR, DIE #1<br>2. BASE, #1<br>3. BASE, #2<br>4. COLLECTOR, #2<br>5. COLLECTOR, #2<br>6. EMITTER, #2<br>7. EMITTER, #1<br>8. COLLECTOR, #1                              |
| <b>STYLE 9:</b><br>PIN 1. EMITTER, COMMON<br>2. COLLECTOR, DIE #1<br>3. COLLECTOR, DIE #2<br>4. EMITTER, COMMON<br>5. EMITTER, COMMON<br>6. BASE, DIE #2<br>7. BASE, DIE #1<br>8. EMITTER, COMMON | <b>STYLE 10:</b><br>PIN 1. GROUND<br>2. BIAS 1<br>3. OUTPUT<br>4. GROUND<br>5. GROUND<br>6. BIAS 2<br>7. INPUT<br>8. GROUND                                                              | <b>STYLE 11:</b><br>PIN 1. SOURCE 1<br>2. GATE 1<br>3. SOURCE 2<br>4. GATE 2<br>5. DRAIN 2<br>6. DRAIN 2<br>7. DRAIN 1<br>8. DRAIN 1                                               | <b>STYLE 12:</b><br>PIN 1. SOURCE<br>2. SOURCE<br>3. SOURCE<br>4. GATE<br>5. DRAIN<br>6. DRAIN<br>7. DRAIN<br>8. DRAIN                                                                                 |
| <b>STYLE 13:</b><br>PIN 1. N.C.<br>2. SOURCE<br>3. SOURCE<br>4. GATE<br>5. DRAIN<br>6. DRAIN<br>7. DRAIN<br>8. DRAIN                                                                              | <b>STYLE 14:</b><br>PIN 1. N-SOURCE<br>2. N-GATE<br>3. P-SOURCE<br>4. P-GATE<br>5. P-DRAIN<br>6. P-DRAIN<br>7. N-DRAIN<br>8. N-DRAIN                                                     | <b>STYLE 15:</b><br>PIN 1. ANODE 1<br>2. ANODE 1<br>3. ANODE 1<br>4. ANODE 1<br>5. CATHODE, COMMON<br>6. CATHODE, COMMON<br>7. CATHODE, COMMON<br>8. CATHODE, COMMON               | <b>STYLE 16:</b><br>PIN 1. EMITTER, DIE #1<br>2. BASE, DIE #1<br>3. EMITTER, DIE #2<br>4. BASE, DIE #2<br>5. COLLECTOR, DIE #2<br>6. COLLECTOR, DIE #2<br>7. COLLECTOR, DIE #1<br>8. COLLECTOR, DIE #1 |
| <b>STYLE 17:</b><br>PIN 1. VCC<br>2. V2OUT<br>3. V1OUT<br>4. TXE<br>5. RXE<br>6. VEE<br>7. GND<br>8. ACC                                                                                          | <b>STYLE 18:</b><br>PIN 1. ANODE<br>2. ANODE<br>3. SOURCE<br>4. GATE<br>5. DRAIN<br>6. DRAIN<br>7. CATHODE<br>8. CATHODE                                                                 | <b>STYLE 19:</b><br>PIN 1. SOURCE 1<br>2. GATE 1<br>3. SOURCE 2<br>4. GATE 2<br>5. DRAIN 2<br>6. MIRROR 2<br>7. DRAIN 1<br>8. MIRROR 1                                             | <b>STYLE 20:</b><br>PIN 1. SOURCE (N)<br>2. GATE (N)<br>3. SOURCE (P)<br>4. GATE (P)<br>5. DRAIN<br>6. DRAIN<br>7. DRAIN<br>8. DRAIN                                                                   |
| <b>STYLE 21:</b><br>PIN 1. CATHODE 1<br>2. CATHODE 2<br>3. CATHODE 3<br>4. CATHODE 4<br>5. CATHODE 5<br>6. COMMON ANODE<br>7. COMMON ANODE<br>8. CATHODE 6                                        | <b>STYLE 22:</b><br>PIN 1. I/O LINE 1<br>2. COMMON CATHODE/VCC<br>3. COMMON CATHODE/VCC<br>4. I/O LINE 3<br>5. COMMON ANODE/GND<br>6. I/O LINE 4<br>7. I/O LINE 5<br>8. COMMON ANODE/GND | <b>STYLE 23:</b><br>PIN 1. LINE 1 IN<br>2. COMMON ANODE/GND<br>3. COMMON ANODE/GND<br>4. LINE 2 IN<br>5. LINE 2 OUT<br>6. COMMON ANODE/GND<br>7. COMMON ANODE/GND<br>8. LINE 1 OUT | <b>STYLE 24:</b><br>PIN 1. BASE<br>2. EMITTER<br>3. COLLECTOR/ANODE<br>4. COLLECTOR/ANODE<br>5. CATHODE<br>6. CATHODE<br>7. COLLECTOR/ANODE<br>8. COLLECTOR/ANODE                                      |
| <b>STYLE 25:</b><br>PIN 1. VIN<br>2. N/C<br>3. REXT<br>4. GND<br>5. IOUT<br>6. IOUT<br>7. IOUT<br>8. IOUT                                                                                         | <b>STYLE 26:</b><br>PIN 1. GND<br>2. dv/dt<br>3. ENABLE<br>4. ILIMIT<br>5. SOURCE<br>6. SOURCE<br>7. SOURCE<br>8. VCC                                                                    | <b>STYLE 27:</b><br>PIN 1. ILIMIT<br>2. OVLO<br>3. UVLO<br>4. INPUT+<br>5. SOURCE<br>6. SOURCE<br>7. SOURCE<br>8. DRAIN                                                            | <b>STYLE 28:</b><br>PIN 1. SW_TO_GND<br>2. DASIC_OFF<br>3. DASIC_SW_DET<br>4. GND<br>5. V_MON<br>6. VBULK<br>7. VBULK<br>8. VIN                                                                        |
| <b>STYLE 29:</b><br>PIN 1. BASE, DIE #1<br>2. EMITTER, #1<br>3. BASE, #2<br>4. EMITTER, #2<br>5. COLLECTOR, #2<br>6. COLLECTOR, #2<br>7. COLLECTOR, #1<br>8. COLLECTOR, #1                        | <b>STYLE 30:</b><br>PIN 1. DRAIN 1<br>2. DRAIN 1<br>3. GATE 2<br>4. SOURCE 2<br>5. SOURCE 1/DRAIN 2<br>6. SOURCE 1/DRAIN 2<br>7. SOURCE 1/DRAIN 2<br>8. GATE 1                           |                                                                                                                                                                                    |                                                                                                                                                                                                        |

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