



# 10 Channel LED Backlight Driver with Integrated Power Supply

The 34844 is a high efficiency, LED driver for use in backlighting LCD displays from 10" to 20"+. Operating from supplies of 7V to 28V, the 34844 is capable of driving up to 160 LEDs in 10 parallel strings.

Current in the 10 strings is matched to within  $\pm 2\%$ , and can be programmed via the I<sup>2</sup>C/SM-Bus interface.

The 34844 also includes a Pulse Width Monitor (PWM) generator for LED dimming. The LEDs can be dimmed to one of 256 levels, programmed through the I<sup>2</sup>C/SM-Bus interface. Up to 65,000:1 (256:1 PWM, 256:1 Current DAC) dimming ratio.

The integrated boost converter generates the minimum output voltage required to keep all LEDs illuminated with the selected current, providing the highest efficiency possible. The integrated boost self-clocks at a default frequency of 600kHz, but may be programmed via I<sup>2</sup>C to 150/300/600/1200 kHz. The PWM frequency can be set from 100Hz to 25kHz, or can be synchronized to an external input. If not synchronized to another source, the internal PWM rate outputs on the CK pin. This enables multiple devices to be synchronized together.

The 34844 also supports optical/temperature closed loop operation and also features LED over-temperature protection, LED short protection, and LED open circuit protection. The IC also includes over-voltage protection, over-current protection, and under-voltage lockout.

## Features

- Input voltage of 7.0 to 28V
- Boost output voltage up to 60V, with auto V<sub>OUT</sub> selection.
- 3.0A integrated boost FET
- Up to 50mA LED current per channel
- 90% efficiency (DC:DC)
- 10-channel current mirror with  $\pm 2\%$  current matching
- I<sup>2</sup>C/SM-Bus interface
- PWM frequency programmable or synchronizable from 100Hz to 25,000Hz
- Pb-free packaging designated by suffix code EP

**34844**

**LED DRIVER**



| ORDERING INFORMATION |                                     |           |
|----------------------|-------------------------------------|-----------|
| Device               | Temperature Range (T <sub>A</sub> ) | Package   |
| PC34844EP/R2         | -40°C to 105°C                      | 32 QFN-EP |

## Applications

- Monitors - up to 27 inch
- Personal Computer Notebooks
- GPS Screens
- Small screen Televisions

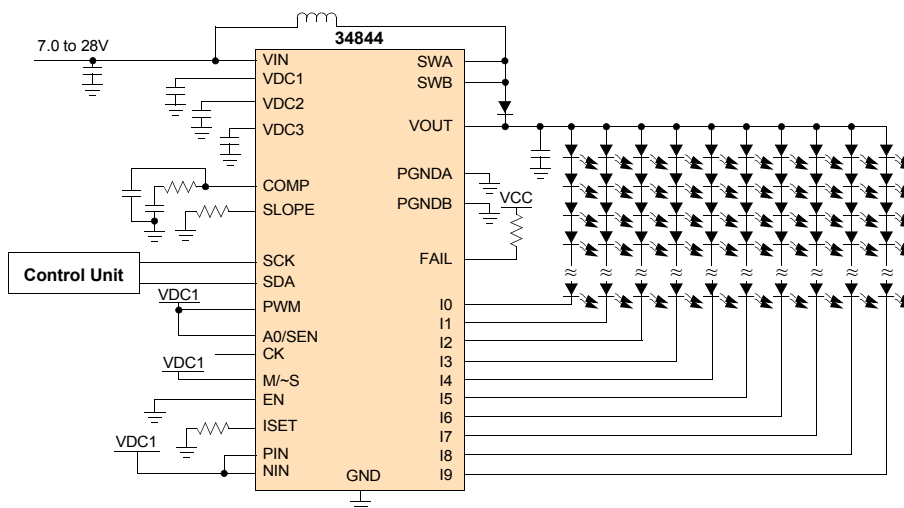


Figure 1. Simplified Application Diagram (SM-Bus Mode)

\* This document contains certain information on a product under development. Freescale reserves the right to change or discontinue this product without notice

### INTERNAL BLOCK DIAGRAM

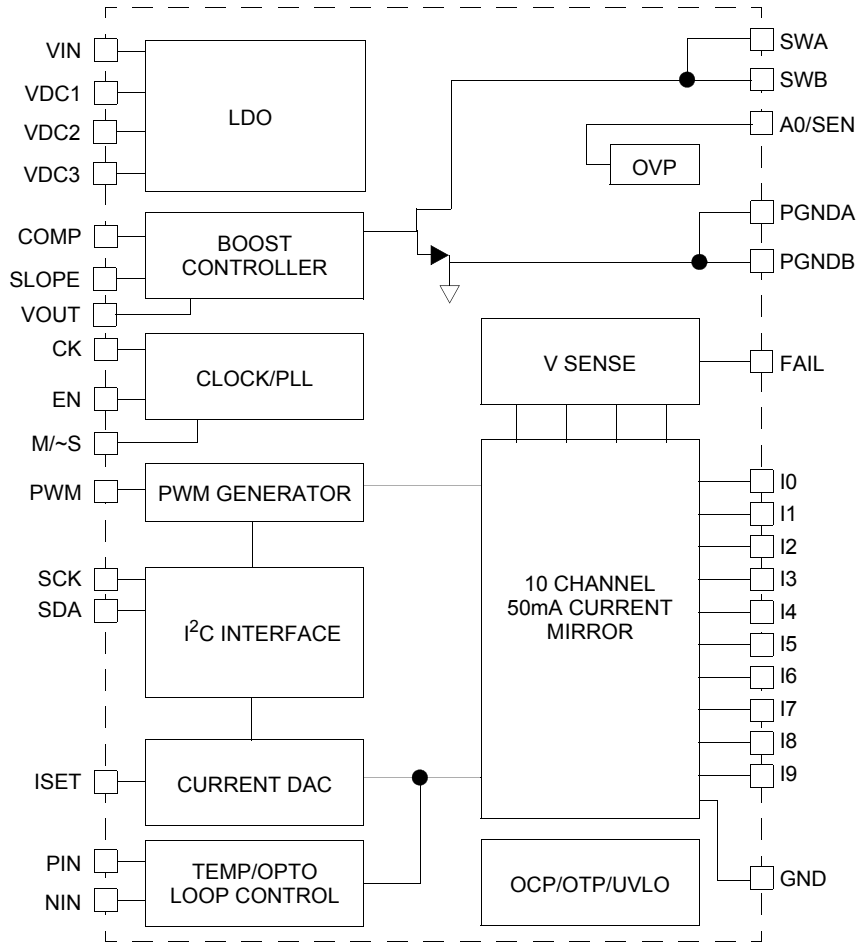
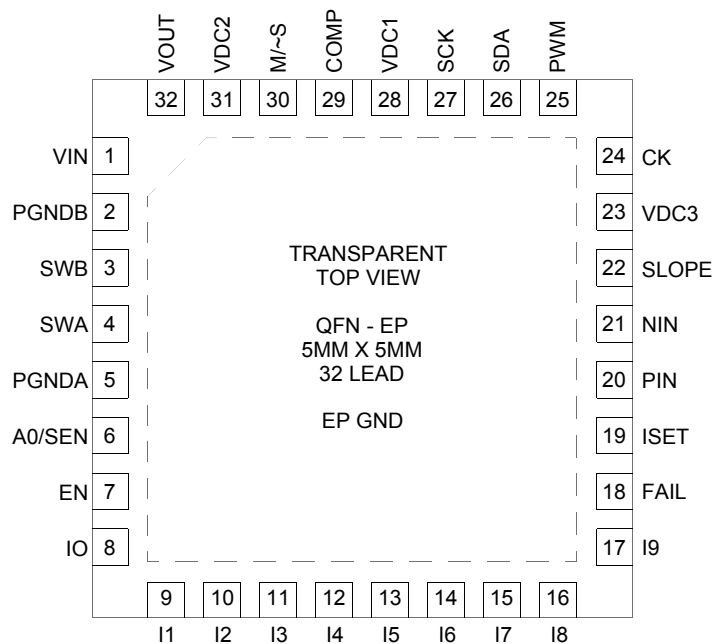


Figure 2. 34844 Simplified Internal Block Diagram

## PIN CONNECTIONS



EP = Exposed Pad

Figure 3. 34844 Pin Connections

Table 1. 34844 Pin Definitions

A functional description of each pin can be found in the Functional Pin Description section beginning on [page 12](#).

| Pin Number | Pin Name | Pin Function | Formal Name            | Definition  |
|------------|----------|--------------|------------------------|---|
| 1          | VIN      | Power        | Input voltage          | Input supply  |
| 2          | PGNDB    | Power        | Power Ground           | Power ground  |
| 3          | SWB      | Input        | Switch node B          | Boost switch connection B   |
| 4          | SWA      | Input        | Switch node A          | Boost switch connection A   |
| 5          | PGNDA    | Power        | Power Ground           | Power ground  |
| 6          | A0/SEN   | Input        | Device Select          | Address select, device select pin or OVP HW control   |
| 7          | EN       | Input        | Enable                 | Enable pin (active high, internal pull-up)  |
| 8 - 17     | I0-I9    | Input        | LED Channel            | LED string connections  |
| 18         | FAIL     | Open Drain   | Fault detection        | Fault detected pin (open drain):<br>No Failure = Low impedance<br>Failure = High Impedance  |
| 19         | ISET     | Passive      | Current set            | LED current setting resistor  |
| 20         | PIN      | Input        | Positive current scale | Positive input analog current control   |
| 21         | NIN      | Input        | Negative current scale | Negative input analog current control   |
| 22         | SLOPE    | Passive      | Boost Slope            | Boost slope compensation Setting resistor   |
| 23         | VDC3     | Output       | Internal Regulator 3   | Decoupling capacitor for internal phase locked loop power                                   |
| 24         | CK       | Input/Output | Clock signal           | Clock synchronization pin (input for M/~S = low - internal pull-up, output for M/~S = high) |
| 25         | PWM      | Input        | External PWM           | External PWM input (internal pull-down)   |

**Table 1. 34844 Pin Definitions (continued)**

A functional description of each pin can be found in the Functional Pin Description section beginning on [page 12](#).

| Pin Number | Pin Name | Pin Function  | Formal Name            | Definition  |
|------------|----------|---------------|------------------------|---|
| 26         | SDA      | Bidirectional | I <sup>2</sup> C data  | I <sup>2</sup> C data Line                                      |
| 27         | SCK      | Bidirectional | I <sup>2</sup> C clock | I <sup>2</sup> C clock line                                     |
| 28         | VDC1     | Output        | Internal Regulator 1   | Decoupling capacitor for internal logic rail                    |
| 29         | COMP     | Passive       | Compensation pin       | Boost converter Type compensation pin                           |
| 30         | M/~S     | Input         | Master/Slave selector  | Selects Master Mode (1) or Slave Mode (0)                       |
| 31         | VDC2     | Output        | Internal Regulator 2   | Decoupling capacitor for internal regulator                     |
| 32         | VOUT     | Input         | Voltage Output         | Boost Output voltage sense pin                                  |
| EP         | GND      | -             | Ground                 | Ground Reference for all internal circuits other than Boost FET |

## ELECTRICAL CHARACTERISTICS

## MAXIMUM RATINGS

**Table 2. Maximum Ratings**

All voltages are with respect to ground unless otherwise noted. Exceeding these ratings may cause a malfunction or permanent damage to the device.

| Ratings  | Symbol          | Value      | Unit |
|--|-----------------|------------|------|
| <b>ELECTRICAL RATINGS</b>                                    |                 |            |      |
| Maximum Pin Voltages   | $V_{MAX}$       |            | V    |
| A0/SEN   |                 | 7.0        |      |
| I0, I1, I2, I3, I4, I5, I6, I7, I8, I9, EN <sup>(4)</sup>    |                 | 45         |      |
| VIN  |                 | 30         |      |
| SWA, SWB, VOUT   |                 | 65         |      |
| FAIL, PIN, NIN, ISET, M/~S, CK                               |                 | 6.0        |      |
| Maximum LED Current  | $I_{MAX}$       | 55         | mA   |
| ESD Voltage <sup>(1)</sup>                                   | $V_{ESD}$       |            | V    |
| Human Body Model (HBM)                                       |                 | ±2000      |      |
| Machine Model (MM)   |                 | ±200       |      |
| <b>THERMAL RATINGS</b>                                       |                 |            |      |
| Ambient Temperature Range                                    | $T_A$           | -40 to 105 | °C   |
| Junction to Ambient Temperature <sup>(2)</sup>               | $T_{\theta JA}$ | 32         | °C/W |
| Junction to Case Temperature <sup>(2)</sup>                  | $T_{\theta JC}$ | 3.5        | °C/W |
| Maximum junction temperature                                 | $T_J$           | 150        | °C   |
| Storage temperature range                                    | $T_{STO}$       | -40 to 150 | °C   |
| Peak Package Reflow Temperature During Reflow <sup>(3)</sup> | $T_{PPRT}$      | 260        | °C   |
| Power Dissipation  |                 |            | W    |
| TA = 25°C  |                 | 3.9        |      |
| TA = 70°C  |                 | 2.5        |      |
| TA = 85°C  |                 | 2.0        |      |
| TA = 105°C   |                 | 1.4        |      |

## Notes

- ESD testing is performed in accordance with the Human Body Model (HBM) (AEC-Q100-2), and the Machine Model (MM) (AEC-Q100-003),  $R_{ZAP} = 0\Omega$
- Per JEDEC51 Standard for Multilayer PCB
- Pin soldering temperature limit is for 10 seconds maximum duration. Not designed for immersion soldering. Exceeding these limits may cause malfunction or permanent damage to the device.
- 45V is the Maximum allowable voltage on all LED channels in off-state.

### STATIC ELECTRICAL CHARACTERISTICS

**Table 3. Static Electrical Characteristics**

Characteristics noted under conditions  $V_{IN} = 12V$ ,  $V_{OUT} = 42V$ ,  $I_{LED} = 50mA$ ,  $PWM = VDC1$ ,  $M/\sim S = VDC1$ ,  $PIN \& NIN = VDC1$ ,  $-40^{\circ}C \leq T_A \leq 105^{\circ}C$ ,  $PGND = 0V$ , unless otherwise noted.

| Characteristic  | Symbol                   | Min       | Typ    | Max      | Unit       |
|---|--------------------------|-----------|--------|----------|------------|
| <b>SUPPLY</b>   |                          |           |        |          |            |
| Supply Voltage  | $V_{IN}$                 | 7.0       | 12     | 28       | V          |
| Supply Current when Shutdown Mode<br>Manual & SM-Bus: EN = Low, SCK & SDA=Low, PWM = Low<br>$I^2C$ : EN = Low, SET $I^2C$ bit = 1, CLR $I^2C$ bit = 0, PWM = Low  | $I_{SHUTDOWN}$           | -         | 2.0    | -        | $\mu A$    |
| Supply Current when Sleep Mode<br>SM-Bus: EN = low, SCK & SDA= Active, SET $I^2C$ bit = 0, PWM=Low, EN bit = 0<br>$I^2C$ : EN = High, SET $I^2C$ bit = 1, CLR $I^2C$ bit = 0, EN bit = 0, PWM=Low   | $I_{SLEEP}$              | -         | 3.0    | -        | mA         |
| Supply Current when Operational Mode<br>Boost=Pulse Skipping, Channels = 0% of Duty Cycle<br>Manual: EN= High, SCK & SDA=Low, PWM=Low<br>SM-Bus: EN= Low, SCK & SDA=Active, EN bit= 1, PWM=Low<br>$I^2C$ : EN = High, SET $I^2C$ bit = 1, CLR $I^2C$ bit = 0, EN bit = 1, PWM=Low | $I_{OPERATIONAL}$        | -         | 10.0   | -        | mA         |
| Under-voltage Lockout<br>$V_{IN}$ Rising  | UVLO                     | 5.4       | 6.0    | 6.4      | V          |
| Under-voltage Hysteresis<br>$V_{IN}$ Falling  | UVLO <sub>HYST</sub>     | 150       | 200    | 250      | mV         |
| VDC1 Voltage <sup>(5)</sup><br>$C_{VDC1} = 2.2\mu F$  | $V_{DC1}$                | 2.4       | 2.5    | 2.6      | V          |
| VDC2 Voltage <sup>(5)</sup><br>$C_{VDC2} = 2.2\mu F$  | $V_{DC2}$                | 5.5       | 6.0    | 6.5      | V          |
| VDC3 Voltage <sup>(5)</sup><br>$C_{VDC3} = 2.2\mu F$  | $V_{DC3}$                | 2.4       | 2.5    | 2.6      | V          |
| <b>BOOST</b>  |                          |           |        |          |            |
| Output Voltage Range <sup>(6)</sup><br>$V_{IN} = 7.0V$<br>$V_{IN} = 28V$  | $V_{OUT1}$<br>$V_{OUT2}$ | 8.0<br>31 | -<br>- | 43<br>60 | V          |
| Boost Switch Current Limit  | $I_{FET}$                | 2.6       | 2.8    | 3.0      | A          |
| RDSON of Internal FET<br>$I_{DRAIN} = 1.0A$   | $R_{DSON}$               | -         | 250    | 500      | m $\Omega$ |
| Boost Switch Off-state Leakage Current<br>$V_{SWA,SWB} = 65V$   | $I_{BOOST\_LEAK}$        | -         | -      | 10       | $\mu A$    |
| Peak Boost Efficiency <sup>(7)</sup>  | $EFF_{BOOST}$            | -         | 90     | -        | %          |

Notes

5. This output is for internal use only and not to be used for other purposes
6. Minimum and Maximum output voltages are dependent on Min/Max duty cycle condition.
7. Guaranteed by design

**Table 3. Static Electrical Characteristics (continued)**

Characteristics noted under conditions  $V_{IN} = 12V$ ,  $V_{OUT} = 42V$ ,  $I_{LED} = 50mA$ ,  $PWM = VDC1$ ,  $M/\sim S = VDC1$ ,  $PIN \& NIN = VDC1$ ,  $-40^{\circ}C \leq T_A \leq 105^{\circ}C$ ,  $PGND = 0V$ , unless otherwise noted.

| Characteristic   | Symbol            | Min  | Typ  | Max  | Unit       |
|--|-------------------|------|------|------|------------|
| Line Regulation <sup>(7)</sup><br>VIN=7.0V to 28V                    | $I_{OUT}/V_{IN}$  | -0.2 | -    | 0.2  | %/V        |
| Load Regulation <sup>(7)</sup><br>VLED = 8.0V to 65V (all Channels)  | $I_{OUT}/V_{LED}$ | -0.2 | -    | 0.2  | %/V        |
| Slope compensation voltage ramp<br>R <sub>SLOPE</sub> = 68K $\Omega$ | $V_{SLOPE}$       | -    | 0.49 | -    | V/ $\mu$ s |
| Current Sense Amplifier Gain   | $A_{CSA}$         | -    | 9.0  | -    |            |
| Current Sense Resistor   | $R_{SENSE}$       | -    | 22   | -    | m $\Omega$ |
| OTA Transconductance   | $G_M$             | -    | 200  | -    | $\mu$ S    |
| Transconductance Sink and Source Current Capability                  | $I_{SS}$          | -    | 100  | -    | $\mu$ A    |
| Output Voltage Precharge   | $V_{HOLD}$        | 0.45 | 0.5  | 0.55 | V          |

**FAIL PIN**

|   |                  |   |   |     |         |
|---|------------------|---|---|-----|---------|
| Off-state Leakage Current<br>V <sub>FAIL</sub> = 5.5V | $I_{FAIL\_LEAK}$ | - | - | 5   | $\mu$ A |
| On-state Voltage Drop<br>I <sub>SINK</sub> = 4.0mA    | $V_{OL}$         | - | - | 0.4 | V       |

Notes

5. This output is for internal use only and not to be used for other purposes
6. Minimum and Maximum output voltages are dependent on Min/Max duty cycle condition.
7. Guaranteed by design

**Table 3. Static Electrical Characteristics (continued)**

Characteristics noted under conditions  $V_{IN} = 12V$ ,  $V_{OUT} = 42V$ ,  $I_{LED} = 50mA$ ,  $PWM = VDC1$ ,  $M/\sim S = VDC1$ ,  $PIN \& NIN = VDC1$ ,  $-40^{\circ}C \leq T_A \leq 105^{\circ}C$ ,  $PGND = 0V$ , unless otherwise noted.

| Characteristic | Symbol | Min | Typ | Max | Unit |
|----------------|--------|-----|-----|-----|------|
|----------------|--------|-----|-----|-----|------|

**LED CHANNELS**

|   |                |       |       |       |         |
|---|----------------|-------|-------|-------|---------|
| Sink Current<br>ICHx Register = 255, RISET=5.1kΩ 0.1%, PIN&NIN = Disabled,<br>$T_A=25^{\circ}C$ | $I_{SINK}$     | 49    | 50    | 51    | mA      |
| Regulated minimum voltage across drivers  | $V_{MIN}$      | 675   | 750   | 825   | mV      |
| Current Matching Accuracy   | $I_{MATCH}$    | -2.0  | -     | 2.0   | %       |
| $I_{SET}$ Pin Voltage<br>RISET=5.1kΩ 0.1%   | $V_{SET}$      | 2.017 | 2.048 | 2.079 | V       |
| LED Current Amplitude Resolution<br>$1.0mA \leq I_{LED} \leq 50mA$                              | $I_{LED\_RES}$ | -     | 1.5   | -     | %       |
| Off-state Leakage Current, All channels<br>( $V_{CH} = 45V$ )                                   | $I_{CH\_LEAK}$ | -     | -     | 10    | $\mu A$ |

**PIN INPUT**

|   |                |                |          |                |         |
|---|----------------|----------------|----------|----------------|---------|
| Voltage to Disable PIN mode   | $V_{PIN\_DIS}$ | 2.2            | -        | -              | V       |
| PIN Bias Current<br>PIN = $V_{SET}$   | $I_{PIN}$      | -2.0           | -        | 2.0            | $\mu A$ |
| Analog Dimming Current<br>ICHx Register = 255, RISET=5.1kΩ 0.1%<br>PIN = $V_{SET}/2$<br>PIN = $V_{SET}$ | $I_{DIM\_PIN}$ | 23.75<br>47.50 | 25<br>50 | 26.25<br>52.50 | mA      |

**NIN INPUT**

|  |                |                |          |                |         |
|--|----------------|----------------|----------|----------------|---------|
| Voltage to Disable NIN mode  | $V_{NIN\_DIS}$ | 2.2            | -        | -              | V       |
| NIN Bias Current<br>NIN = $V_{SET}$  | $I_{NIN}$      | -2.0           | -        | 2.0            | $\mu A$ |
| Analog Dimming Current<br>ICHx Register = 255, RISET=5.1kΩ 0.1%<br>NIN = $V_{SET}/2$<br>NIN = 0V | $I_{DIM\_NIN}$ | 23.75<br>47.50 | 25<br>50 | 26.25<br>52.50 | mA      |

**OVER-TEMPERATURE PROTECTION**

|   |          |          |           |          |             |
|---|----------|----------|-----------|----------|-------------|
| Over-temperature Threshold <sup>(7)</sup><br>Rising<br>Hysteresis | $O_{TT}$ | 150<br>- | 165<br>25 | 175<br>- | $^{\circ}C$ |
|---|----------|----------|-----------|----------|-------------|

**I<sup>2</sup>C/SM-BUS PHYSICAL LAYER [SCK, SDA]**

|                          |             |      |         |     |        |
|--------------------------|-------------|------|---------|-----|--------|
| I <sup>2</sup> C Address | $ADR_{I2C}$ | -    | 1110110 | -   | Binary |
| SM-Bus Address           | $ADR_{SMB}$ | -    | 1110110 | -   | Binary |
| Input Low Voltage        | $V_{ILI}$   | -0.3 | -       | 0.8 | V      |

Notes

- This output is for internal use only and not to be used for other purposes
- Minimum and Maximum output voltages are dependent on Min/Max duty cycle condition.
- Guaranteed by design



**Table 3. Static Electrical Characteristics (continued)**

Characteristics noted under conditions  $V_{IN} = 12V$ ,  $V_{OUT} = 42V$ ,  $I_{LED} = 50mA$ ,  $PWM = VDC1$ ,  $M/\sim S = VDC1$ ,  $PIN \& NIN = VDC1$ ,  $-40^{\circ}C \leq T_A \leq 105^{\circ}C$ ,  $PGND = 0V$ , unless otherwise noted.

| Characteristic                                  | Symbol     | Min  | Typ | Max | Unit     |
|---|------------|------|-----|-----|----------|
| Input High Voltage                              | $V_{IHI}$  | 2.1  | -   | 5.5 | V        |
| Input Hysteresis                                | $V_{HYSI}$ | 0.3  | -   | -   | V        |
| Output Low Voltage<br>Sink Current $\leq 4.0mA$ | $V_{OLI}$  | -    | -   | 0.4 | V        |
| Input Current                                   | $I_{INI}$  | -5.0 | -   | 5.0 | $\mu A$  |
| Input Capacitance <sup>(7)</sup>                | $C_{INI}$  | -    | -   | 10  | $\rho F$ |

**LOGIC INPUTS / OUTPUTS (CK, M/~S, PWM, A0/SEN)**

|   |            |      |     |     |          |
|---|------------|------|-----|-----|----------|
| Input Low Voltage                                   | $V_{ILL}$  | -0.3 | -   | 0.5 | V        |
| Input High Voltage                                  | $V_{IHL}$  | 1.5  | -   | 5.5 | V        |
| Input Hysteresis                                    | $V_{HYSL}$ | -    | 0.1 | -   | V        |
| Input Current                                       | $I_{IIL}$  | -5.0 | -   | 5.0 | $\mu A$  |
| Output Low Voltage (CK)<br>$I_{SINK} \leq 2.0mA$    | $V_{OLL}$  | -    | -   | 0.2 | V        |
| Output High Voltage (CK)<br>$I_{SOURCE} \leq 2.0mA$ | $V_{OHL}$  | 2.2  | -   | 5.5 | V        |
| Input Capacitance <sup>(7)</sup>                    | $C_{INI}$  | -    | -   | 5.0 | $\rho F$ |

**OVER VOLTAGE PROTECTION**

|   |            |      |     |      |   |
|---|------------|------|-----|------|---|
| Over-voltage Clamp - OVP Register Table:                      |            |      |     |      |   |
| OVP = Fh  | $OVP_{FH}$ | 60   | 62  | 65   | V |
| OVP = Eh  | $OVP_{EH}$ | 56   | 59  | 62   | V |
| OVP = Dh  | $OVP_{DH}$ | 52   | 55  | 58   | V |
| OVP = Ch  | $OVP_{CH}$ | 48   | 51  | 54   | V |
| OVP = Bh  | $OVP_{BH}$ | 45   | 47  | 49   | V |
| OVP = Ah  | $OVP_{AH}$ | 41   | 43  | 45   | V |
| OVP = 9h  | $OVP_{9H}$ | 37   | 39  | 41   | V |
| OVP = 8h  | $OVP_{8H}$ | 33   | 35  | 37   | V |
| OVP = 7h  | $OVP_{7H}$ | 29   | 31  | 33   | V |
| OVP = 6h  | $OVP_{6H}$ | 26   | 27  | 28   | V |
| OVP = 5h  | $OVP_{5H}$ | 22   | 23  | 24   | V |
| OVP = 4h  | $OVP_{4H}$ | 18   | 19  | 20   | V |
| OVP = 3h  | $OVP_{3H}$ | 14   | 15  | 16   | V |
| OVP = 2h  | $OVP_{2H}$ | 10   | 11  | 12   | V |
| Over-voltage threshold,<br>Set by Hardware, Voltage at A0/SEN | $OVP_{HW}$ | 6.15 | 6.5 | 6.85 | V |

Notes

5. This output is for internal use only and not to be used for other purposes
6. Minimum and Maximum output voltages are dependent on Min/Max duty cycle condition.
7. Guaranteed by design

**DYNAMIC ELECTRICAL CHARACTERISTICS**

**Table 4. Dynamic Electrical Characteristics**

Characteristics noted under conditions  $V_{IN} = 12V$ ,  $V_{OUT} = 42V$ ,  $I_{LED} = 50mA$ ,  $PWM = VDC1$ ,  $M/\sim S = VDC1$ ,  $PIN \& NIN = VDC1$ ,  $-40^{\circ}C \leq T_A \leq 105^{\circ}C$ ,  $PGND = 0V$ , unless otherwise noted.

| Characteristic                        | Symbol    | Min  | Typ  | Max  | Unit |
|---------------------------------------|-----------|------|------|------|------|
| <b>BOOST</b>                          |           |      |      |      |      |
| Switching Frequency (BST [1:0]=0)     | $f_{SW0}$ | 0.14 | 0.15 | 0.17 | MHz  |
| Switching Frequency (BST [1:0]=1)     | $f_{SW1}$ | 0.27 | 0.30 | 0.33 | MHz  |
| Switching Frequency (BST [1:0]=2)     | $f_{SW2}$ | 0.54 | 0.60 | 0.66 | MHz  |
| Switching Frequency (BST [1:0]=3)     | $f_{SW3}$ | 1.08 | 1.2  | 1.32 | MHz  |
| Minimum Duty Cycle                    | $D_{MIN}$ | -    | 10   | 15   | %    |
| Maximum Duty Cycle                    | $D_{MAX}$ | 80   | 85   | -    | %    |
| Soft Start Period                     | $t_{SS}$  | -    | 6.5  | -    | ms   |
| Boost Switch Rise Time <sup>(9)</sup> | $t_{TR}$  | -    | 15   | -    | ns   |
| Boost Switch Fall Time <sup>(9)</sup> | $t_F$     | -    | 25   | -    | ns   |

**PWM GENERATOR**

|  |             |             |              |              |    |
|--|-------------|-------------|--------------|--------------|----|
| Input PWM Frequency Range <sup>(9)</sup><br>M/~S = Low (Slave Mode)                          | $f_{PWM_S}$ | 100         | -            | 25000        | Hz |
| PWM Frequency<br>M/~S = High (Master Mode)<br>FPWM Register = 768<br>FPWM Register = 192,000 | $f_{PWM_M}$ | 22500<br>90 | 25000<br>100 | 27500<br>110 | Hz |
| PWM dimming resolution   | $t_{fPWM}$  | -           | 0.39         | -            | %  |

**PWM PIN CHANNEL DRIVER**

|  |               |     |   |   |    |
|--|---------------|-----|---|---|----|
| Input PWM Pin Minimum Pulse <sup>(9)</sup> | $t_{PWM\_IN}$ | 150 | - | - | ns |
|--|---------------|-----|---|---|----|

**PHASE LOCK LOOP**

|  |                    |             |              |              |          |
|--|--------------------|-------------|--------------|--------------|----------|
| CK Slave Mode Frequency Lock Range <sup>(8)</sup><br>M/~S = Low (Slave Mode)                                   | $f_{CK_S}$         | 100         | -            | 25000        | Hz       |
| CK Slave Mode Input Jitter <sup>(9)</sup><br>M/~S = Low (Slave Mode)   | $f_{CK_S\_JITTER}$ | -           | -            | 0.1          | %        |
| Slave Mode Acquisition Time<br>M/~S = Low (Slave Mode)<br>FPWM <sub>S</sub> =25KHz<br>FPWM <sub>S</sub> =100Hz | $T_{S\_ACQ}$       | -<br>-      | -<br>2000    | 50<br>-      | ms<br>ms |
| CK Frequency (Master Mode)<br>FPWM Register = 768<br>FPWM Register = 192,000                                   | $f_{CK\_MASTER}$   | 22500<br>90 | 25000<br>100 | 27500<br>110 | Hz       |

**I<sup>2</sup>C/SM-BUS PHYSICAL LAYER [SCK, SDA]**

Notes

- Special considerations should be made for frequencies between 100Hz to 1KHz. Please refer to [Functional Device Operation](#) for further details.
- Guaranteed by design

**Table 4. Dynamic Electrical Characteristics**

Characteristics noted under conditions  $V_{IN} = 12V$ ,  $V_{OUT} = 42V$ ,  $I_{LED} = 50mA$ ,  $PWM = VDC1$ ,  $M/\sim S = VDC1$ ,  $PIN \& NIN = VDC1$ ,  $-40^{\circ}C \leq T_A \leq 105^{\circ}C$ ,  $PGND = 0V$ , unless otherwise noted.

| Characteristic                                 | Symbol    | Min | Typ | Max | Unit |
|--|-----------|-----|-----|-----|------|
| Interface Frequency Range                      | $f_{SCK}$ |     |     | 400 | kHz  |
| SM-Bus Power-on-Reset Time                     | $t_{RST}$ | -   | -   | 100 | ms   |
| Output fall time<br>$10pF \leq C_L \leq 400pF$ | $t_F$     | 40  | -   | 160 | ns   |
| Output rise time<br>$10pF \leq C_L \leq 400pF$ | $t_R$     | 20  | -   | 80  | ns   |

**LOGIC OUTPUT (CK)**

|  |           |   |   |    |    |
|--|-----------|---|---|----|----|
| Output Rise and Fall time <sup>(9)</sup><br>$C_L \leq 100pF$ | $t_R/t_F$ | - | - | 25 | ns |
|--|-----------|---|---|----|----|

**LED CHANNELS**

|  |           |   |    |    |    |
|--|-----------|---|----|----|----|
| Channels Rise and Fall Time <sup>(9)</sup> | $t_R/t_F$ | - | 23 | 50 | ns |
|--|-----------|---|----|----|----|

Notes

8. Special considerations should be made for frequencies between 100Hz to 1KHz. Please refer to [Functional Device Operation](#) for further details.
9. Guaranteed by design

## FUNCTIONAL DESCRIPTION

### INTRODUCTION

LED backlighting has become very popular for small and medium LCDs, due to some advantages over other backlighting schemes, such as the widely used cold cathode fluorescent lamp (CCFL). The advantages of LED backlighting are low cost, long life, immunity to vibration, low operational voltage, and precise control over its intensity.

However, there is an important drawback of this method. It requires more power than most of the other methods, and this is a major problem if the LCD size is large enough.

To address the power consumption problem, solid state optoelectronics technologies are evolving to create brighter LEDs with lower power consumption. These new technologies together with highly efficient power management LED drivers are turning LEDs, a more suitable solution for backlighting almost any size of LCD panel, with really conservative power consumption.

One of the most common schemes for backlighting with LED is the one known as "Array backlighting". This creates a matrix of LEDs all over the LCD surface, using defraction and diffused layers to produce an homogenous and even light at

the LCD surface. Each row or column is formed by a number of LEDs in series, forcing a single current to flow through all LEDs in each string.

Using a current control driver, per row or column, helps the system to maintain a constant current flowing through each line, keeping a steady amount of light even with the presence of line or load variations. They can also be use as a light intensity control by increasing or decreasing the amount of current flowing through each LED string.

To achieve enough voltage to drive a number of LEDs in series, a boost converter is implemented, to produce a higher voltage from a smaller one, which is typically used by the logical blocks to do their function.

The 34844 implements a single channel boost converter together with 10 input channels, for driving up to 16 LEDs per string to create a matrix of more than 160 LEDs. Together with its 90% efficiency and I<sup>2</sup>C programmable or external current control, among other features, makes the 34844 a perfect solution for backlighting small and medium size LCD panels, on low power portable and high definition devices.

### FUNCTIONAL PIN DESCRIPTION

#### INPUT VOLTAGE SUPPLY (VIN)

IC Power input supply voltage, is used internally to produce internal voltage regulation (VDC1, VDC3) for logic functioning, and also as an input voltage for the boost regulator.

#### INTERNAL VOLTAGE REGULATOR 1 (VDC1)

This pin is for internal use only, and not to be used for other purposes. A capacitor of 2.2 $\mu$ F should be connected between this pin and ground for decoupling purposes.

#### INTERNAL VOLTAGE REGULATOR 2 (VDC2)

This pin is for internal use only, and not to be used for other purposes. A capacitor of 2.2 $\mu$ F should be connected between this pin and ground for decoupling purposes.

#### INTERNAL VOLTAGE REGULATOR 3 (VDC3)

This pin is for internal use only, and not to be used for other purposes. A capacitor of 2.2 $\mu$ F should be connected between this pin and ground for decoupling purposes.

#### BOOST COMPENSATION PIN (COMP)

Passive terminal used to compensate the boost converter. Add a capacitor and a resistor in series to GND to stabilize the system.

#### IC ENABLE (EN)

The active high enable terminal is internally pulled high through pull-up resistors. Applying 0V to this terminal would stop the IC from working.

#### INPUT/OUTPUT CLOCK SIGNAL (CK)

This terminal can be used as an output clock signal (master mode), or input clock signal (slave mode), to synchronize more than one device.

#### MASTER/SLAVE MODE SELECTION (M/~S)

Setting this pin High puts the device into Master mode, producing an output synchronization clock at the CK terminal. Setting this pin low, puts the device in Slave mode, using the CK pin as an input clock.

#### EXTERNAL PWM INPUT (PWM)

This terminal is internally pulled down. An external PWM signal can be applied to modulate the LED channel directly in absence of an I<sup>2</sup>C interface.

#### CLOCK I<sup>2</sup>C SIGNAL (SCK)

Clock line for I<sup>2</sup>C communication.

#### ADDRESS I<sup>2</sup>C SIGNAL (SDA)

Address line for I<sup>2</sup>C communication.

**A0/SEN**

Address select, device select pin, or Hardware Over voltage Protection (OVP) Control.

**CURRENT SET (ISET)**

Each LED string can drive up to 50mA. The maximum current can be set by using a resistor from this pin to GND.

**POSITIVE CURRENT SCALING (PIN)**

Positive current scaling factor for the external analog current control. Applying 0V to this pin, scales the current to 0%, and in the same way, applying 2.048V (Vset), the scale factor is 100%. By applying a voltage higher than 2.2V, the scaling factor is disabled, and the internal pull-ups are activated.

If PIN pin and NIN pin are used at the same time then by applying 0V to the PIN pin and 2.048V to NIN pin, scales the current to 0%, and in the same way, applying 2.048V to the PIN pin and 0V to NIN pin, scales the current to 100%. By applying a voltage higher than 2.2V, the scaling factor is disabled and the internal pull-ups are activated in both pins.

**NEGATIVE CURRENT SCALING (NIN)**

Negative current scaling factor for the external analog current control. Setting 0V to this pin scales the current to 100%, in the same way, setting 2.048V (Vset) the scale factor is 0%. By applying a voltage higher than 2.2V, the scaling factor is disabled and the internal pull-ups are activated.

If PIN pin and NIN pin are used at the same time then by applying 0V to the PIN pin and 2.048V to NIN pin, scales the current to 0%, and in the same way, applying 2.048V to the PIN pin and 0V to NIN pin, scales the current to 100%. By

applying a voltage higher than 2.2V, the scaling factor is disabled and the internal pull-ups are activated in both pins.

**GROUND (GND)**

Ground Reference for all internal circuits other than the Boost FET.

The Exposed Pad (EP) should be used for thermal heat dissipation.

**I0-I9**

Current LED driver, each line has the capability of driving up to 50mA.

**FAULT DETECTION PIN (FAIL)**

When a fault situation is detected, this pin goes into high impedance.

**BOOST SLOPE COMPENSATION SETTING RESISTOR (SLOPE)**

Use an external resistor of about 68k $\Omega$  to configure the Boost compensation slope.

**POWER GROUND TERMINALS (PGNDA, PGND B)**

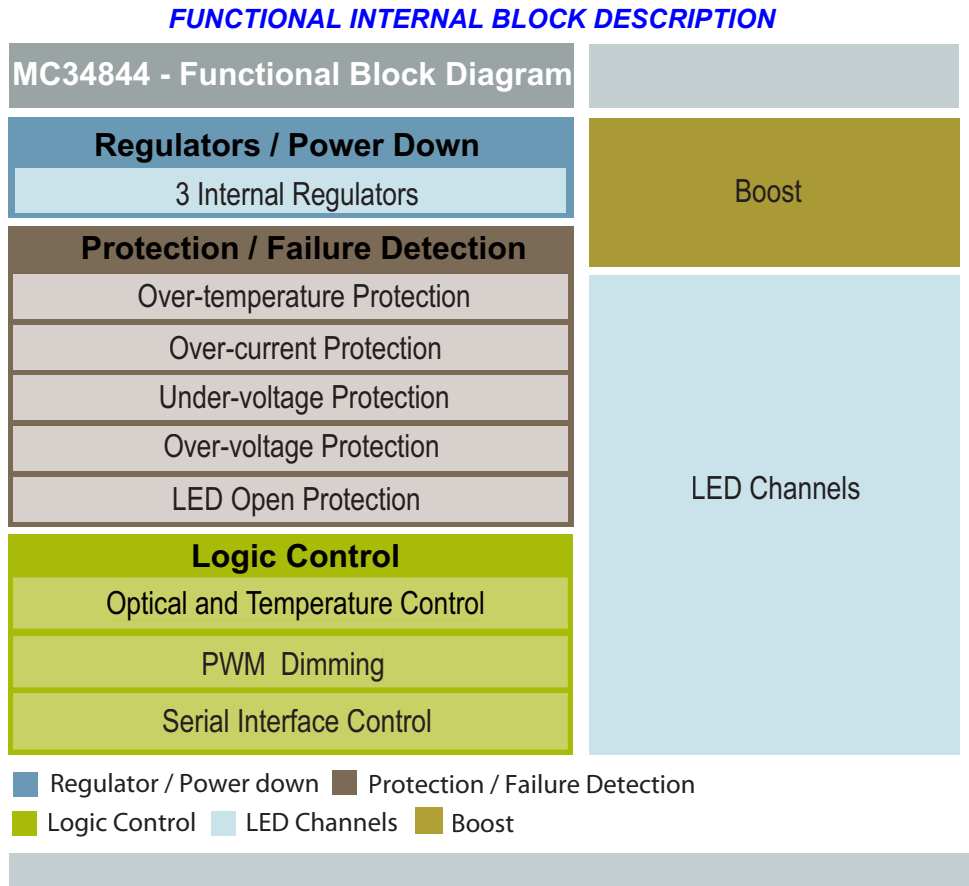
Ground terminal for the internal Boost FET.

**OUTPUT VOLTAGE SENSE TERMINAL (VOUT)**

Input terminal to monitor the output voltage. It also supplies the input voltage for the internal regulator 2 (VDC2).

**SWITCHING NODE TERMINALS (SWA, SWB)**

Switching node of boost converter.



**Figure 4. Functional Internal Block Diagram**

**REGULATORS/ POWER DOWN**

The 34844 is designed to operate from input voltages in the 7.0 to 28V range. This is stepped down internally by LDOs to 2.5V (VDC1 and VDC3) and 6V (VDC3) for powering internal circuitry. If the input voltage falls below the UVLO threshold, the device automatically enters in power down mode.

**Operating Modes:**

The device can be operated by the EN pin and/or SDA/ SCK bus lines, resulting in three distinct operation modes:

- Manual mode, there is no I<sup>2</sup>C capability, the bus line pins must be tied low, and the EN pin controls the ON/OFF operation.

- SM-Bus mode, EN pin must be tied low and the device is turned ON by any activity on the bus lines. The part shuts down if the bus lines are held low for more than 27ms, the 27ms watchdog timer can be disabled by I<sup>2</sup>C (setting SETI2C bit high) or tying the EN pin high. In Sleep mode (EN bit=1) the device reduces the power consumption by leaving "alive" only the blocks required for I<sup>2</sup>C communication.
- I<sup>2</sup>C mode, has to be configured by I<sup>2</sup>C communication (SETI2C bit = 1) right after the IC is turned ON, it prevents the part from being turned ON/OFF by the bus. Sleep mode is also present and it is intended to save power, but still keep the IC prepared to communicate by I<sup>2</sup>C. Turning the EN pin OFF, the chip enters into a low power mode.

| MODE             | EN Pin | SCK/SDA Pins | I <sup>2</sup> C Bit Command | Current Consumption Mode              | Comments             |
|------------------|--------|--------------|------------------------------|---------------------------------------|----------------------|
| Manual           | Low    | Low          | N/A                          | Shutdown                              |                      |
|                  | High   | Low          | N/A                          | Operational                           |                      |
| SM-Bus           | Low    | Low (> 27ms) | EN bit = X                   | Shutdown                              |                      |
|                  | Low    | Active       | EN bit = 0                   | Sleep                                 |                      |
|                  | Low    | Active       | EN bit = 1                   | Operational                           |                      |
| I <sup>2</sup> C | Low    | X            | SETI2C bit = 1               | I <sup>2</sup> C Low Power (Shutdown) | Part Doesn't Wake-up |
|                  |        |              | CLRI2C bit = 0               |                                       |                      |
|                  |        |              | EN bit = X                   |                                       |                      |
|                  | High   | X            | SETI2C bit = 1               | Sleep                                 |                      |
|                  |        |              | CLRI2C bit = 0               |                                       |                      |
|                  |        |              | EN bit = 0                   |                                       |                      |
|                  | High   | X            | SETI2C bit = 1               | Operational                           |                      |
|                  |        |              | CLRI2C bit = 0               |                                       |                      |
|                  |        |              | EN bit = 1                   |                                       |                      |

**Table 5. Operation Current Consumption Modes**

## BOOST

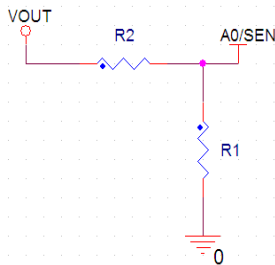
The integrated boost converter operates in non-synchronous mode and integrates a 3A FET. An integrated sense circuit is used to sense the voltage at the LED current mirror inputs and automatically sets the boost output voltage to the minimum voltage needed to keep all LEDs biased with the required current.

The boost converter also features internal Over-current Protection (OCP) and has a user programmable Over-voltage Protection (OVP).

The OVP can be set from 11 to 62V, ~4V spaced, using the I<sup>2</sup>C interface (OVP Register). If I<sup>2</sup>C capability is not present, the OVP can be controlled by a resistor divider connected from VOUT to GND with its mid point tied to A0/SEN pin (threshold = 6.5V). During an OVP condition, the output voltage will go to the OVP level which is programmed via the I<sup>2</sup>C interface or settled by a resistor divider on A0/SEN pin.

Hardware OVP:

$$\frac{(OVP \cdot R1)}{R1 + R2} = 6.5V$$



The OVP value should be set to greater than the maximum LED voltage over the whole temperature range. A good practice is to set it 5V or so above the max LED voltage.

The OCP operates on a cycle by cycle basis. However, if the OCP condition remains for more than 10ms then the device turns off the LED Drivers, the Boost goes to Sleep Mode and the output FAULT pin goes into high impedance. The device can only be restarted by recycling the enable or creating a Power On Reset (POR).

The user can program the boost frequency by I<sup>2</sup>C (BST[1:0]) only after the IC is powered up and before the boost circuit is turned ON for the first time (PWM pin low to high). This sequence avoids boost frequency to be changed inadvertently during operation. The first I<sup>2</sup>C command has to wait for 5.0ms after the part is turned ON, in order to allow sufficient time for the device power up sequence to be completed.

The boost controller has an integral track and hold amplifier with indefinite hold time capability, to enable immediate LED on cycles after extended off times. During extended off times, the external LEDs cool down from their normal quiescent operating temperature and thereby experience a forward voltage change, typically an increase in the forward voltage. This change can be significant for applications with a large number of series LEDs in a string operating at high current. If the boost controller did not track this increased change, the potential on the LED drivers would saturate for a few cycles once the LED channels are re-enabled.

Also the device has a precharge voltage that add 0.5 Volts to the Boost, cycle by cycle of the PWM. It helps the boost to respond faster every time the load turns back on again.

## CURRENT MIRROR

The programmable current mirror matches the current in 10 LED strings to within 2%. The maximum current is set using a resistor to GND from the ISET pin. This can be scaled down using the I<sup>2</sup>C interface to 255 levels.

Zero current is achieved by turning off the LED Driver by I<sup>2</sup>C (registers CHENx = 0h) for a Duty Cycle from 0% to 99% or by pulling PWM pin low regardless of the Duty Cycle.

I<sup>2</sup>C capability allow the channels to be controlled individually or in parallel.

**Current on LED Channel (PIN and NIN mode disabled) Eqn. 1**

$$\text{Current[A]} = \frac{\text{ICH[RegisterValue]}}{\text{RSET[ohms]}}$$

In the off state, the LEDs current is set to 0 and the boost converter stops switching.

This feature allows to drive more than 50mA of current by connecting the LED string to 2 or more LED channels in parallel. For example; if the application requires to drive 5 channels at 100mA, then the bottom of each LED string should be connected to two channels in order to duplicate the current capability (Example: CH0+CH1 = 100mA).

## PWM GENERATOR

The PWM generator can operate in either master or slave modes, as set by the M/~S pin.

In master mode, the internal PWM generator frequency is programmed through the I<sup>2</sup>C interface (registers FPWM). The default programmed value set the number of 25kHz clocks (40μs) in one PWM cycle. The 18-bit resolution allows minimum PWM frequencies of 100Hz to be programmed. The resulting frequency is output on the CK pin.

**PWM Frequency Eqn. 2**

$$\text{PWMFrequency[Hz]} = \frac{19.2\text{Mhz}}{\text{FPWM[RegisterValue]}}$$

In slave mode, the CK pin acts as an input. The internal digital PLL uses this frequency as the PWM frequency. By setting one device as master, and connecting the CK output to the input on a number of slave configured devices, all PWM frequencies are synchronized together.

The duty cycle of the PWM waveform in both master and slave modes is set using a second register on the I<sup>2</sup>C interface (register DPWM), and can be controlled from 100% duty cycle to 1/256 T<sub>pwm</sub> = 0.39%. Zero percent of duty cycle is achieved by turning LED Drivers off (register CHENx = 0h) or pulling PWM pin low.

An external PWM can also be used. The PWM input is 'AND'ed with the internal signal. By setting the serial interface

to 100% duty cycle (default), the external pin has full control of the PWM duty cycle. This pin can also be used to modulate the LED at a lower frequency than the PWM dimming frequency (Minimum pulse width = 150ns).

A pulsed mode can also be programmed using the I<sup>2</sup>C interface (STROBE bit = 1). In this mode, each rising edge of the PWM signal turns on the next channel, while turning off all other channels. The duration that the channel is illuminated is set by the duty cycle of the PWM input pin. This can be used to scan the output channels.

## FAIL PIN

If an LED fails open, the voltage at the LED channel will be pulled to GND and the LED string open is detected. An error is registered for that channel, the fail output is set high, and that channel is turned off. The malfunction channel can be re-enabled by I<sup>2</sup>C commands, first clearing the fail (CLRFAIL bit =1), removing the failure and then re-enabling the channel driver (Register CHEN). All fails are cleared when the device is powered up.

If the fail pin cannot be cleared by software then it indicates that the failure is because of an over-current in the Boost. Since this is a critical failure the only way to clear it is by releasing the part from the over-current condition and then shutdown the part (refer to [Table 5](#)).

If I<sup>2</sup>C communication is not present, FAIL condition should be reset by removing the failure and re-enabling the device through the EN pin.

## OPTICAL AND TEMPERATURE CONTROL LOOP

The 34844 supports both optical and temperature loop control.

For temperature loop control, the LED brightness can be adjusted depending on the temperature of the LEDs.

For optical loop control, the 34844 supports both optical closed loop backlight control, where the brightness of the backlight is maintained at a required level by adjusting the light output, until the desired level is achieved, or with ambient light control, where the backlight brightness increases as ambient light increases.

Both temperature and optical loops are supported through the PIN and NIN pins. Each pin supports a 0-2.048V input range which affects the current through the LEDs. The PIN pin increases current as the voltage rises from 0-2.048V. The NIN pin reduces current as the voltage rises from 0-2.048V.

A 10.2k resistor or higher value must be used at the ISET pin if the part is configured to use PIN+NIN control loop functionality, the 50mA maximum current is achieved at the higher allowed level of PIN/NIN pins, ensuring the maximum current of the LED Drivers are not exceeded.



The optical and temperature control loop can be disabled by I<sup>2</sup>C setting bits (PINEN & NINEN), or by tying PIN and NIN pins high (>2.2V) it is called Vset mode, and the LED Driver maximum current is set to 50mA by using a 5.1k resistor at the ISET pin.

**Current on LED Channel (PIN mode)** Eqn. 3

$$\text{Current[A]} = \frac{(\text{VPIN[Volts]} \times \text{ICH[RegisterValue]})}{\text{RSET[ohms]}}$$

**Current on LED Channel (NIN mode)** Eqn. 4

$$\text{Current[A]} = \frac{(2.048 - \text{VNIN})(\text{[Volts]} \times \text{ICH[RegisterValue]})}{\text{RSET[ohms]}}$$

**Current on LED Channel (PIN+NIN mode)** Eqn. 5

$$\text{Current[A]} = \frac{(2.048 - \text{VNIN} + \text{VPIN})(\text{[Volts]} \times \text{ICH[RegisterValue]})}{\text{RSET[ohms]}}$$

## LED FAILURE PROTECTION

### Open LED Protection

If LED fails open in any of the LED strings, the voltage in that channel will be pulled close to zero, which will cause the channel to be disabled. As a result, the boost output voltage

will go to the OVP level and then come down to the regulation level to continue powering the rest of the LED strings.

### Short LED Protection

If an LED shorted in any of the LED strings, the device will continue to operate without interruption. However, if the shorted LED happens to be in the LED string with the highest forward voltage, the dynamic headroom control circuit will automatically regulate the output voltage with respect to the new highest LED voltage. If more LEDs are shorted in the same LED string, it may cause excessive power dissipation in the channel which may cause the OTT circuit to trip which will completely shutdown the device.

## OVER-TEMPERATURE PROTECTION

The 34844 has an on-chip temperature sensor that measures die temperature. If the IC temperature exceeds the OTT threshold, the IC will turn off all power sources inside the IC (LED drivers, boost and internal regulators) until the temperature falls below the falling OTT threshold. Once it comes back on, it will operate with the default configuration (please refer to [Table 7](#)).

## SERIAL INTERFACE CONTROL

The 34844 uses an I<sup>2</sup>C interface capable of operating in standard (100kHz) or fast (400kHz) modes.

The A0/SEN pin can be used an address select pin to allow more than 2 devices in the system. The A0/SEN pin should be held low on all chips expect the one to be addressed, where it is taken HIGH.

## FUNCTIONAL DEVICE OPERATION

### OPERATIONAL MODES

#### NORMAL MODE

In normal operation the 34844 is programmed via I<sup>2</sup>C to drive up to 50mA of current through each one of the LED channels. The 34844 can be configured in master or slave mode as set by the M/~S pin.

In **Master mode**, the internal PWM generator frequency is programmed through the I<sup>2</sup>C interface. The programmed value sets the number of 25kHz clocks (40μs) in one PWM cycle. The 18-bit resolution allows minimum PWM frequencies of 100Hz to be programmed. The resulting frequency is output on the CK pin.

In slave mode, the CK pin acts as an input. The internal digital PLL uses this frequency as the PWM frequency.

By setting one device as a master, and connecting the CK output to the input on a number of slave configured devices, all PWM frequencies are synchronized together. For this application A0/SEN pin indicates which device is enable for I<sup>2</sup>C control.

In **Slave mode**, an internal phase lock loop will lock the internal PWM generator period to the period of the signal present at the CK pin. The PLL can lock to any frequency from 100Hz to 25KHz provided the jitter is below 1000ppm. At frequencies above 1KHz, the PLL will maintain lock regardless of the transient power conditions imposed by the user (i.e. going from 0% duty cycle to 100% at 20W LED display power). Below 1KHz, thermal time constants on the die are such that the PLL may momentarily lose lock if the die temperature changes substantially during a large load power step. As explained below, this anomaly can be avoided by controlling the rate of change in PWM duty cycle.

To better understand this issue, consider that the on chip PLL uses a VCO that is subject to thermal drift on the order of 1000 ppm/C. Further consider that the thermal time constant of the chip is on the order of single digit milliseconds. Therefore, if a large power load step is imposed by the user (i.e. going from 0% duty cycle to 100% duty cycle with a load power of 20W), the die will experience a large temperature wave gradient that will propagate across the chip surface and thereby affect the instantaneous frequency of the VCO. As long as such changes are within the bandwidth of the PLL, the PLL will be able to track and maintain lock. Exceeding this rate of change may cause the PLL to lose lock and the backlight will momentarily be blanked until lock is reacquired.

At 100Hz lock, the PLL has a bandwidth of approximately 10Hz. This means that temperature changes on the order of 100ms are tolerable without losing lock. But full load power changes on the order of 10ms (i.e. 100Hz PWM) are not tracked out and the PLL can momentarily lose lock. If this happens, as stated above, the LED drivers are momentarily disabled until lock is reacquired. This will be manifested as a

perceivable short flash on the backlight immediately after the load change.

To avoid this problem, one can simply limit large instantaneous changes in die temperature by invoking only small power steps when raising or lowering the display power at low PWM frequencies. For example, to maintain lock while transitioning from 0% to 100% duty cycle at 20W load power and a PWM frequency of 100Hz would entail stepping the power at a rate not to exceed 1% per 10ms. If a load of less than 20W is used, then the rate of rise can be increased. As the locked PWM frequency increases (i.e. use 600Hz instead of 100Hz), the step rate can be further increased to approximately 4% per 2ms. The exact step rate to avoid loss of PLL lock is a function of essentially three things: (a) the composite thermal resistance of the user's PCB assembly, (b) the load power, and (c) the PWM frequency. For all cases below 1KHz, simply using a rate of 1% duty cycle change per PWM period will be adequate. If this is too slow, the value can be optimized experimentally once the hardware design is complete. At PWM rates above 1KHz, it is not necessary to control the rate of change in PWM duty cycle.

It is important to point out that when operating in the master mode, one does not need to concern themselves with loss of lock since the reference clock and the VCO clock are collocated on the die and therefore experience the same thermal shift. Hence, in master mode, once lock is initially acquired, it is not lost and no blanking of the display occurs.

The duty cycle of the PWM in both master and slave mode is set using a second register on the I<sup>2</sup>C interface.

An external PWM signal can also be applied in the PWM pin. This pin is AND'ed with the internal signal, giving the ability to control the duty cycle either via I<sup>2</sup>C or externally by setting any of the 2 signals to 100% duty cycle.

#### STROBE MODE

A strobe mode can be programmed via I<sup>2</sup>C.

In this mode, each rising edge of the PWM signal turns on the next channel, while turning off all other channels. The duration that the channel is illuminated is set by the duty cycle of the PWM input pin.

This mode can be also programmed by controlling the ON and OFF state of each LED channel via I<sup>2</sup>C.

#### MANUAL MODE

The 34844 can also be used in Manual mode without using the I<sup>2</sup>C interface. By setting the pin M/~S High, the LED dimming will be controlled by the external PWM signal. The over-voltage protection limit can be settled by a resistor divider on A0/SEN pin.

During manual mode, all internal Registers are in Default Configuration, please refer [Table 7](#), under this configuration

the PIN and NIN pins are enabled to scale the current capability per string and may be disabled by setting 2.2V in the corresponding terminal.

Also in this mode, the device can be enabled as follows:

+ EN pin + PWM signal (Two Signals): In this configuration the PWM signal applied to PWM pin will be in charge of controlling the LED dimming and a second signal will enable or disable the chip through the EN pin. [Figure 17](#)

+ PWM Signal tied to SDA pin (Just ONE signal): In this configuration the PWM pin should be tied to SDA pin. The PWM signal applied to PWM pin will be in charge of

controlling LED dimming and enable the device every time the PWM is active. For this configuration EN pin should be LOW.

### POWER DOWN MODE

If the input voltage falls below the UVLO threshold, the device enters automatically into power down mode. The device operates only when the EN pin is high, or the EN bit in Register 2 is set high. When in power down, the supply current is reduced below 2 $\mu$ A when there is no I<sup>2</sup>C activity, and it rises up when I<sup>2</sup>C interface is enabled.

**LOGIC COMMANDS AND REGISTERS**

**Table 6. Write Registers**

| REG / DB | D7     | D6      | D5      | D4     | D3     | D2     | D1     | D0     |
|----------|--------|---------|---------|--------|--------|--------|--------|--------|
| 00       | OVP3   | OVP2    | OVP1    | OVP0   |        | NINEN  | PINEN  | EN     |
| 01       |        |         |         |        |        |        | CLRI2C | SETI2C |
| 04       |        |         | FPWM5   | FPWM4  | FPWM3  | FPWM2  | FPWM1  | FPWM0  |
| 05       |        |         | FPWM11  | FPWM10 | FPWM9  | FPWM8  | FPWM7  | FPWM6  |
| 06       |        |         | FPWM17  | FPWM16 | FPWM15 | FPWM14 | FPWM13 | FPWM12 |
| 07       | DPWM7  | DPWM6   | DPWM5   | DPWM4  | DPWM3  | DPWM2  | DPWM1  | DPWM0  |
| 08       |        |         |         | CHEN4  | CHEN3  | CHEN2  | CHEN1  | CHEN0  |
| 09       | STRB   | CLRFAIL | ALL_OFF | CHEN9  | CHEN8  | CHEN7  | CHEN6  | CHEN5  |
| 14       |        |         |         |        |        |        | BST1   | BST0   |
| F0       | ICH0_7 | ICH0_6  | ICH0_5  | ICH0_4 | ICH0_3 | ICH0_2 | ICH0_1 | ICH0_0 |
| F1       | ICH1_7 | ICH1_6  | ICH1_5  | ICH1_4 | ICH1_3 | ICH1_2 | ICH1_1 | ICH1_0 |
| F2       | ICH2_7 | ICH2_6  | ICH2_5  | ICH2_4 | ICH2_3 | ICH2_2 | ICH2_1 | ICH2_0 |
| F3       | ICH3_7 | ICH3_6  | ICH3_5  | ICH3_4 | ICHG_3 | ICH3_2 | ICH3_1 | ICH3_0 |
| F4       | ICH4_7 | ICH4_6  | ICH4_5  | ICH4_4 | ICH4_3 | ICH4_2 | ICH4_1 | ICH4_0 |
| F5       | ICH5_7 | ICH5_6  | ICH5_5  | ICH5_4 | ICH5_3 | ICH5_2 | ICH5_1 | ICH5_0 |
| F6       | ICH6_7 | ICH6_6  | ICH6_5  | ICH6_4 | ICH6_3 | ICH6_2 | ICH6_1 | ICH6_0 |
| F7       | ICH7_7 | ICH7_6  | ICH7_5  | ICH7_4 | ICH7_3 | ICH7_2 | ICH7_1 | ICH7_0 |
| F8       | ICH8_7 | ICH8_6  | ICH8_5  | ICH8_4 | ICH8_3 | ICH8_2 | ICH8_1 | ICH8_0 |
| F9       | ICH9_7 | ICH9_6  | ICH9_5  | ICH9_4 | ICH9_3 | ICH9_2 | ICH9_1 | ICH9_0 |
| FA       | ICHG_7 | ICHG_6  | ICHG_5  | ICHG_4 | ICHG_3 | ICHG_2 | ICHG_1 | ICHG_0 |

**Table 7. Register Description**

| REGISTER NAME | DEFAULT VALUE (HEX) | DESCRIPTION  |
|---------------|---------------------|--|
| EN            | 1                   | Chip Enable by software. This signal is 'OR'ed with external EN (0=off, 1 =on)             |
| PINEN         | 1                   | PIN pin enable (0=off, 1 =on)  |
| NINEN         | 1                   | NIN pin enable (0=off, 1 =on)  |
| OVP[3:0]      | F                   | OVP voltage  |
| SETI2C        | 0                   | SET I <sup>2</sup> C communication (Disable SM-Bus Mode)                                   |
| CLR I2C       | 0                   | Clear set I <sup>2</sup> C   |
| FPWM[17:0]    | 300                 | PWM Frequency  |
| DPWM[7:0]     | FF                  | PWM Duty Cycle (FFh =100%)   |
| CHEN[9:0]     | 3FF                 | Channel Enable (0=off, 1=on)   |
| ALL_OFF       | 0                   | All 10 channels OFF at the same. In order to reactivate channels this bit should be clear. |
| CLRFAIL       | 0                   | Clear fail if channels are re-enable.  |
| STRB          | 0                   | Strobe MODE (0=Parallel, 1=Strobe)   |
| BST[1:0]      | 2                   | Boost Frequency (150,300,600,1200 kHz) [0h=150Hz]  |
| ICH#[7:0]     | FF                  | Channel Current Program (FFh = Maximum Current)  |
| ICG[7:0]      | FF                  | Global Current Program   |

**Table 8. Over Voltage Protection**

| REGISTER (HEX) | OVP VALUE (VOLTS) |
|----------------|-------------------|
| 2              | 11                |
| 3              | 15                |
| 4              | 19                |
| 5              | 23                |
| 6              | 27                |
| 7              | 31                |
| 8              | 35                |
| 9              | 39                |
| A              | 43                |
| B              | 47                |
| C              | 51                |
| D              | 55                |
| E              | 59                |
| F              | 62                |

### TYPICAL PERFORMANCE CURVES (TA=25°C)

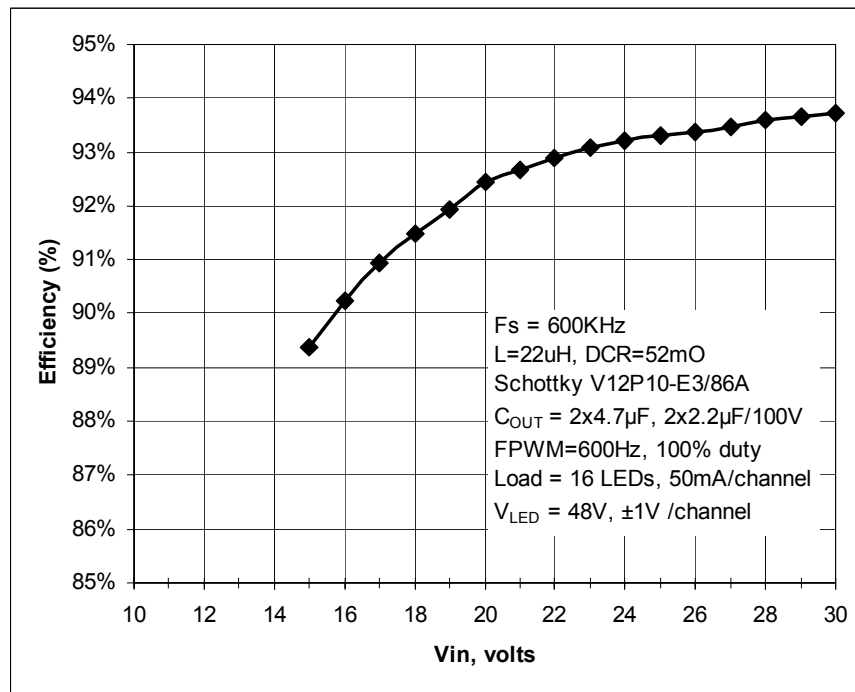


Figure 5. Boost efficiency vs Input Voltage

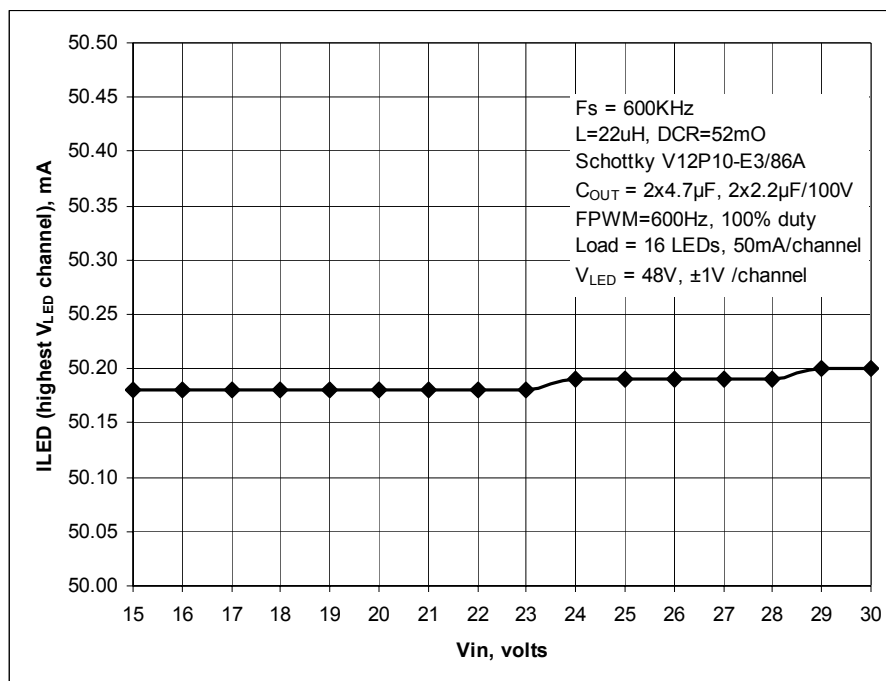


Figure 6. Line Regulation, Vin Changing

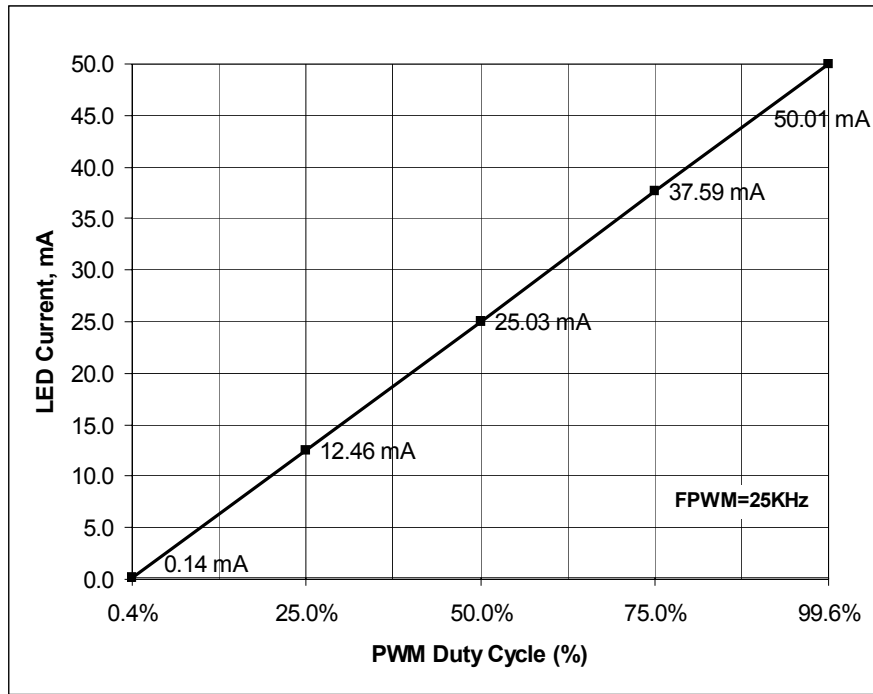


Figure 7. PWM Dimming Linearity

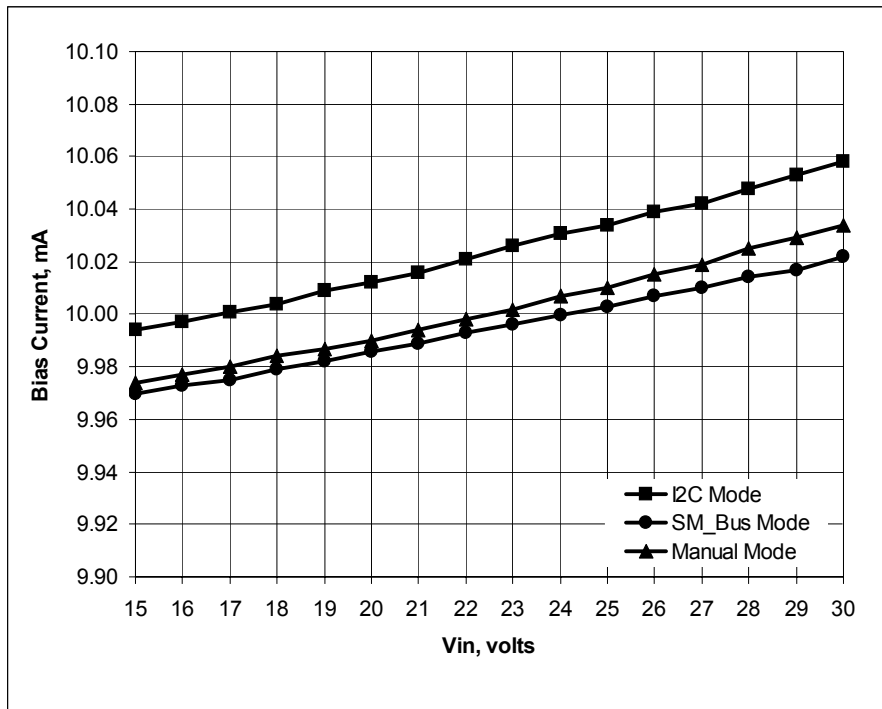


Figure 8. Bias Current vs Input Voltage (Operational Mode)



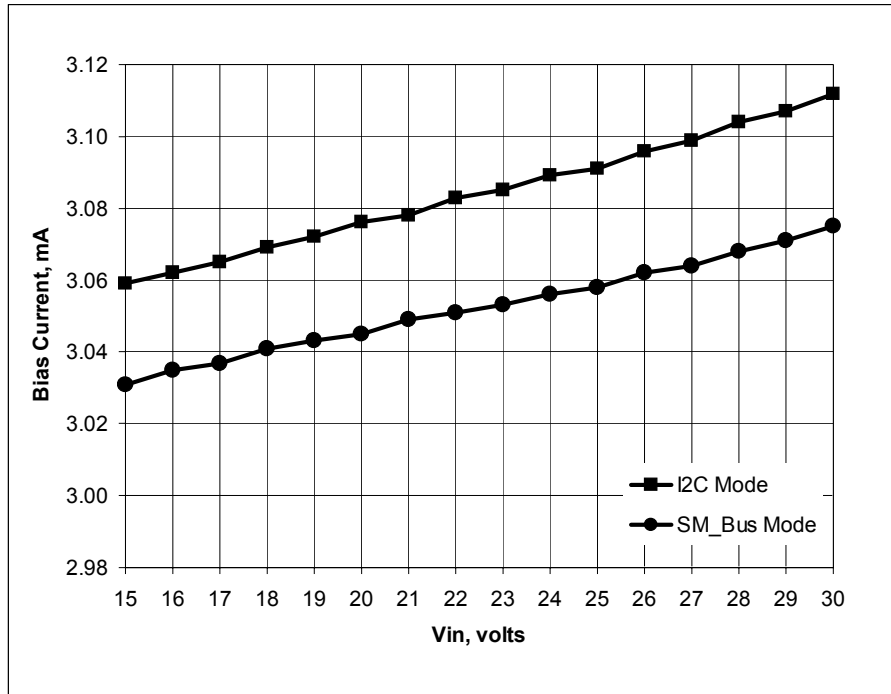


Figure 9. Bias Current vs Input Voltage (Sleep Mode)

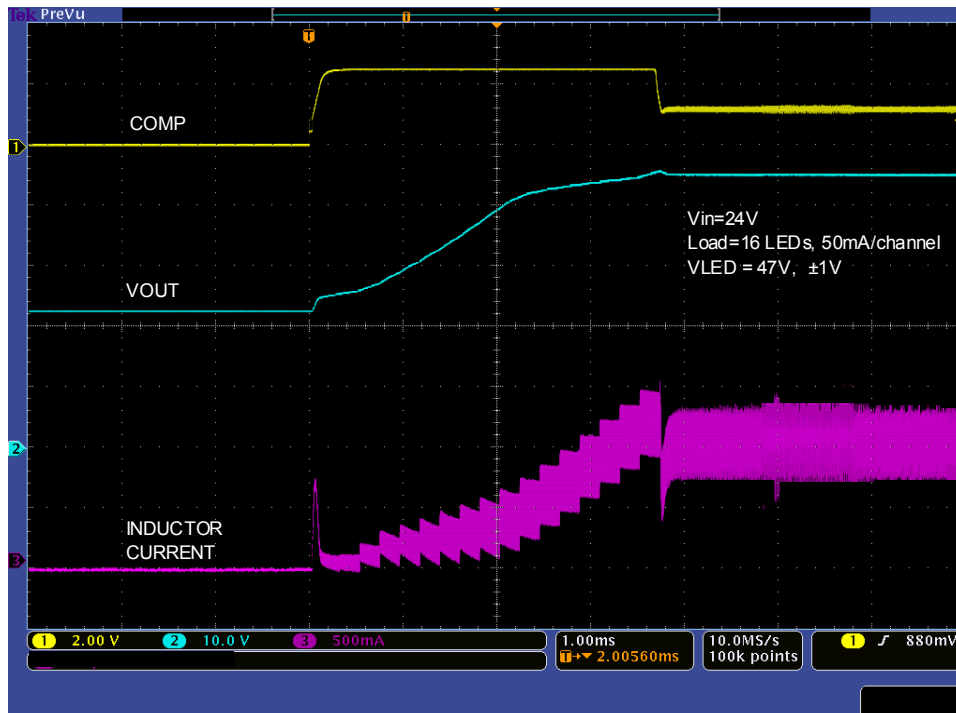


Figure 10. Boost Soft Start

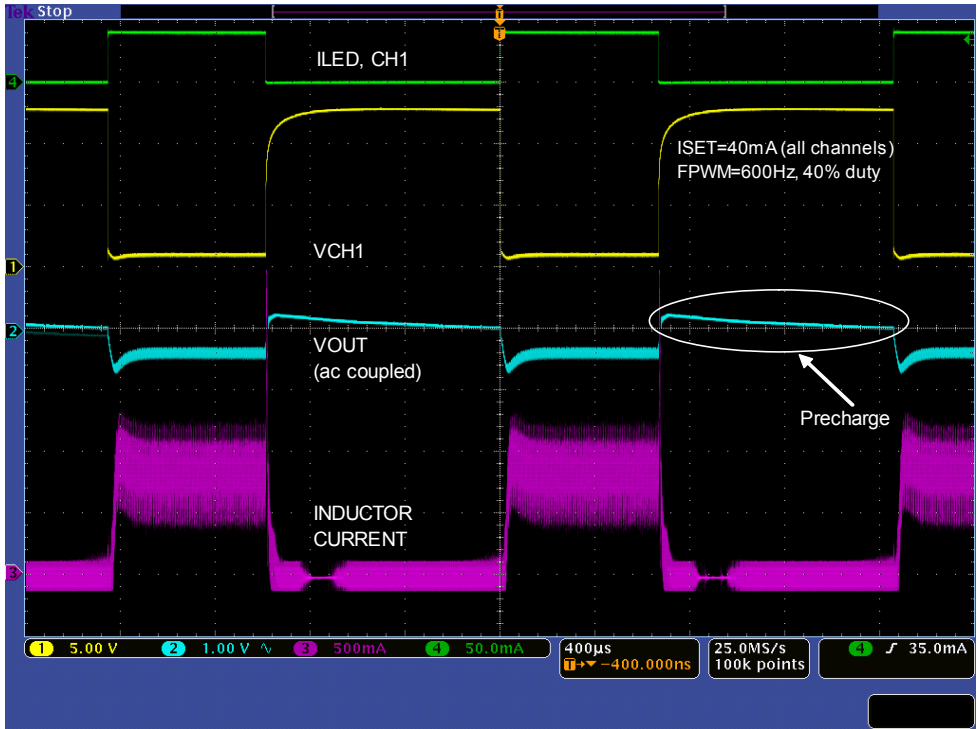


Figure 11. Typical Operation Waveforms for FPWM=600Hz, 40% Duty

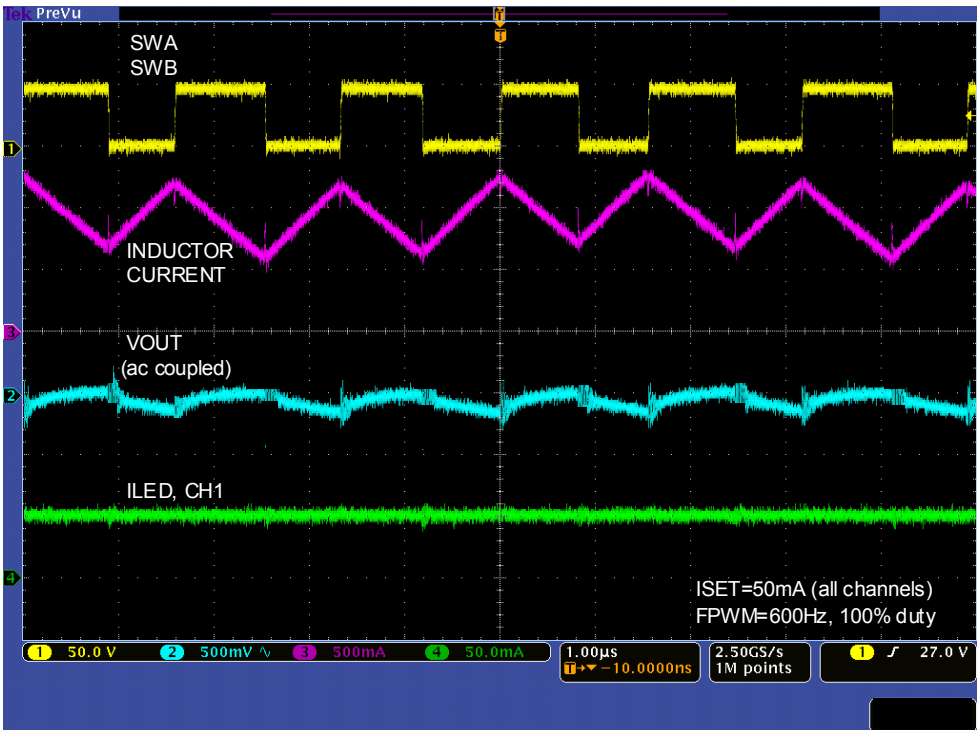


Figure 12. Typical Operation Waveforms for FPWM=600Hz, 100% Duty

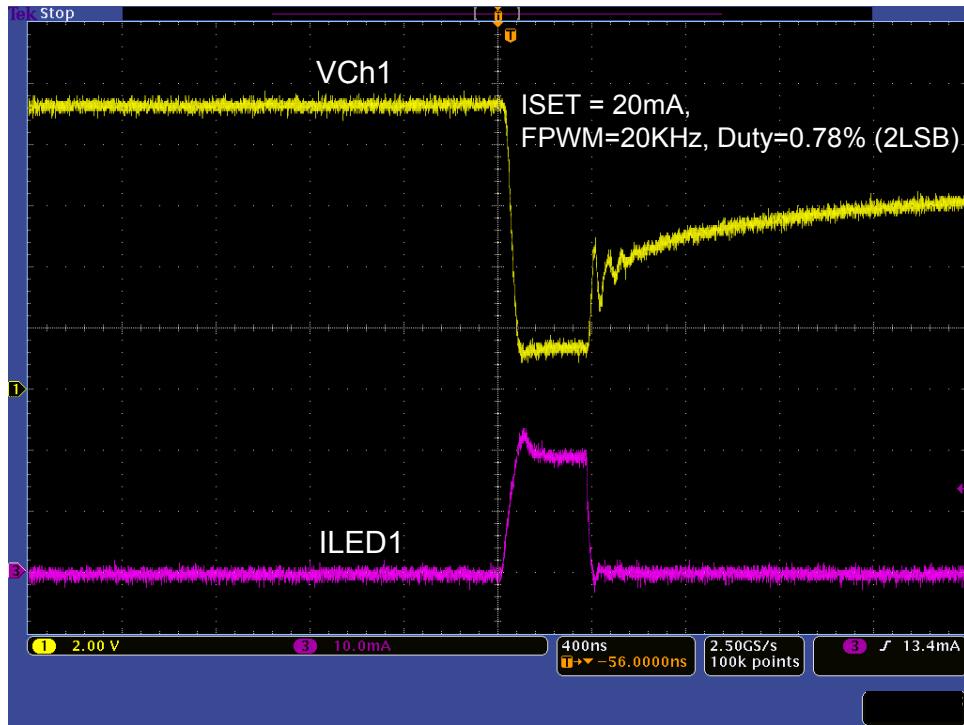


Figure 13. Low Duty Dimming Operation Waveforms (FPWM=20KHz, 2LSB)

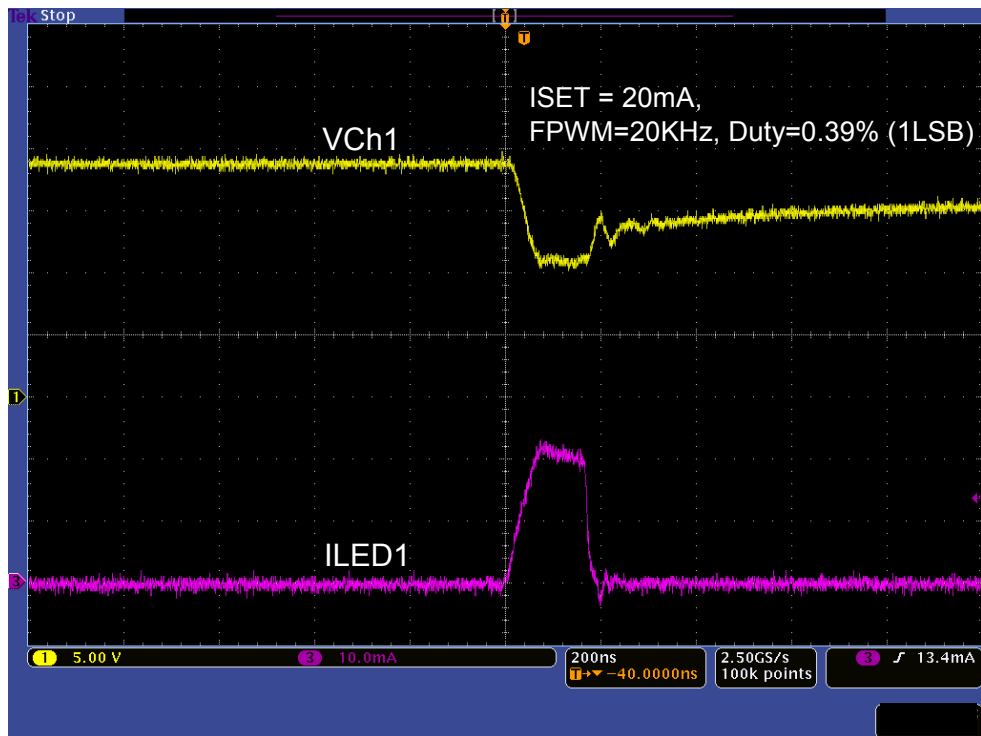


Figure 14. Low Duty Dimming Operation Waveforms (FPWM=20KHz, 1LSB)

## TYPICAL APPLICATIONS

MANUAL MODE (Single Wire Control)

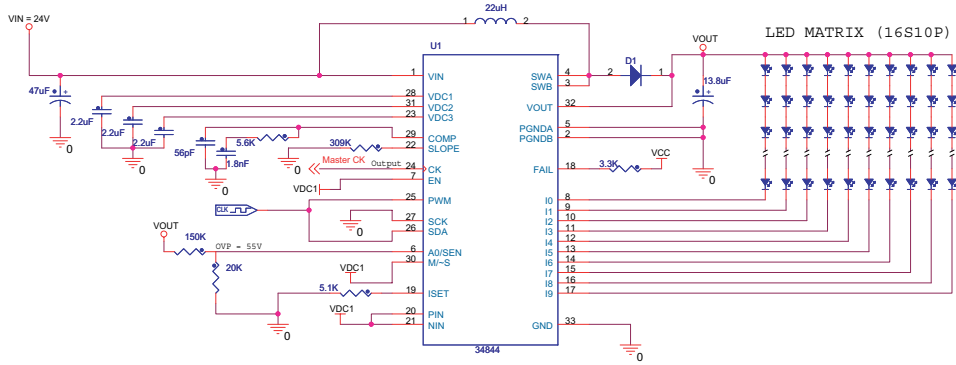


Figure 15. Manual Mode (Single Wire Control)

MANUAL MODE (Two Wire Control)

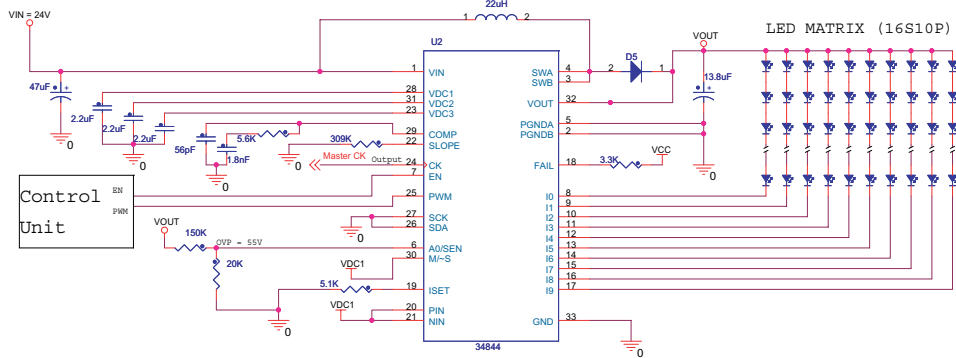


Figure 16. Manual Mode (Two Wire Control)

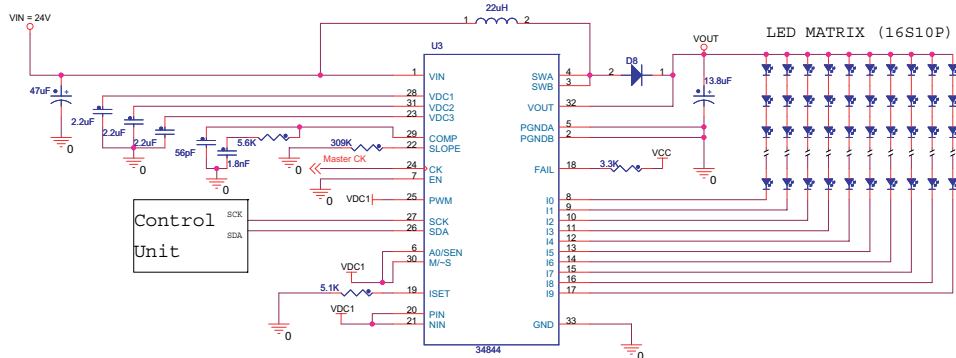


Figure 17. SM-Bus Mode

## TYPICAL APPLICATIONS

### MASTER - SLAVE Connection

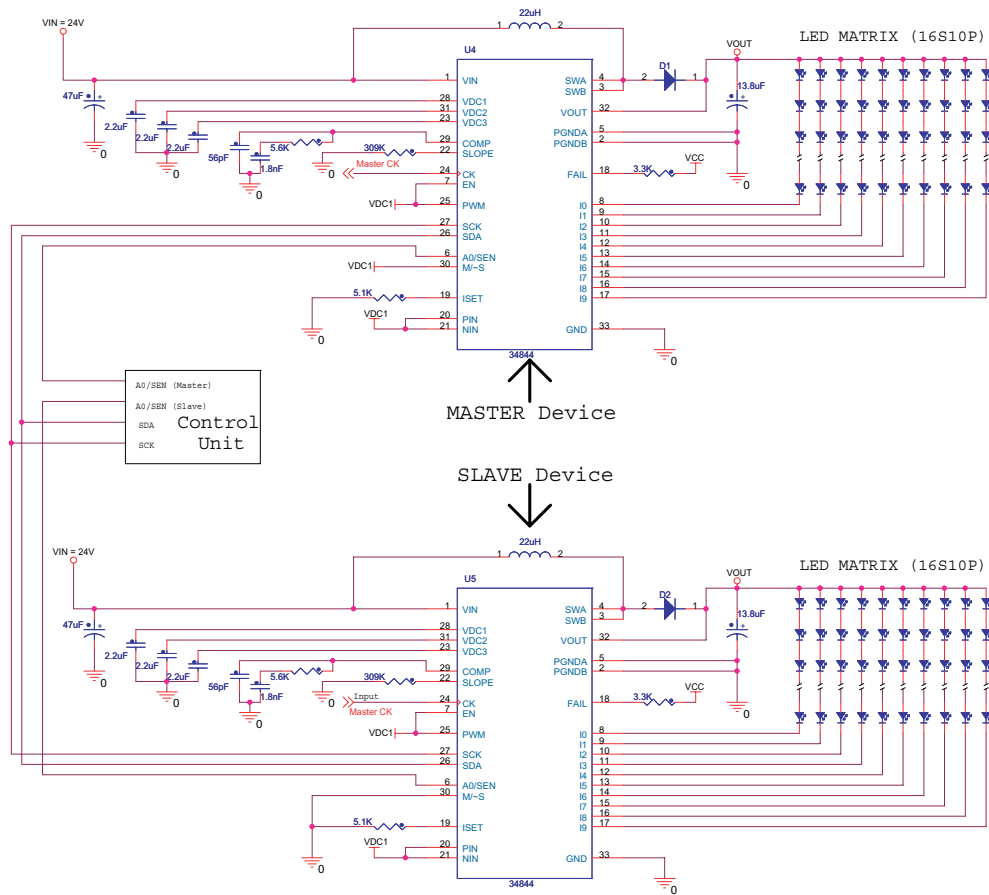


Figure 18. Master - Slave Connection

## COMPONENTS CALCULATION

The following formulas are intended for the calculation of all external components related with the Boost converter and Network compensation.

In order to calculate a Duty Cycle, the internal losses of the MOSFET and Diode should be taken into consideration.

$$D = \frac{V_{out} + V_D - V_{in}}{V_{out} + V_D - V_{SW}}$$

The average input current depends directly to the output current when the internal switch is off.

$$I_{in_{avg}} = \frac{I_{out}}{1-D}$$

### Inductor

For calculating the Inductor we should consider the losses of the internal switch and winding resistance of the inductor.

$$L = \frac{(V_{in} - V_{SW} - (I_{in_{avg}} \times r_w)) \times D}{I_{in_{avg}} \times \Delta I_{out} \times F_{SW}}$$

It is important to look for an inductor rated at least for the maximum input current.

$$I_{in_{max}} = I_{in_{avg}} + \frac{V_{in} \times (V_{out} - V_{in})}{2 \times L \times F_{SW} \times V_{out}}$$

### Input Capacitor

The input capacitor should handle at least the following RMS current.

$$I_{rms_{Cin}} = \left( \frac{V_{in} \times (V_{out} - V_{in})}{2 \times L \times F_{SW} \times V_{out}} \right) \times 0.3$$

### Output Capacitor

For the output capacitor selection the internal current sense gain (CSG) and the Transconductance should be taken in consideration.

The CSG is the internal  $R_{Sense}$  times the current sense amplifier gain ( $A_{CSA}$ ).

$$CSG = A_{CSA} \times R_{Sense}$$

$$C_{out} = \frac{R_{Comp} \times 5 \times G_M \times I_{out} \times L}{(1-D) \times V_{out} \times CSG}$$

The output voltage ripple ( $\Delta V_{out}$ ) depends on the ESR of the Output capacitor, for a low output voltage ripple it is recommended to use Ceramic capacitors that usually have very low ESR. Since ceramic capacitor are expensive, Electrolytic or Tantalum capacitors can be mixed with ceramic capacitors to have a cheaper solution.

$$ESR_{C_{out}} = \frac{V_{out} \times \Delta V_{out} \times F_{SW} \times L}{V_{out} \times (1-D)}$$

The output capacitor should handle at least the following RMS current.

$$I_{rms_{C_{out}}} = I_{out} \times \sqrt{\frac{D}{1-D}}$$

### Network Compensation

Since this Boost converter is current controlled, Type II compensation is needed.

In order to calculate the Network Compensation, first we need to calculate all Boost Converter components.

For this type of compensations we need to push out the Right Half Plane Zero to higher frequencies where it can't affect the overall loop significantly.

$$f_{RHPZ} = \frac{V_{out} \times (1-D)^2}{I_{out} \times 2 \times \pi \times L}$$

The Crossover frequency must be set much lower than the location of the Right half plane zero

$$f_{Cross} = \frac{f_{RHPZ}}{5}$$

Since our system has a fixed Slope compensation set by  $R_{SLOPE}$ ,  $R_{Comp}$  should be fixed for all configurations.

$$R_{Comp} = 5.6Kohm$$

$C_{Comp1}$  and  $C_{Comp2}$  should be calculated as follows:

$$C_{Comp1} = \frac{2}{f_{Cross} \times R_{Comp} \times \pi \times 2}$$

$$C_{\text{Comp2}} = \frac{G_M}{6.28 \times F_{\text{SW}}}$$

### Slope Compensation

Slope Compensation can be expressed either in terms of Amperes/Second or as Volts/Second, through the use of the transfer resistance.

The following formula express the Slope Compensation in terms of V/μs:

$$V_{\text{SLOPE}} = \frac{(V_{\text{out}} - V_{\text{in}}) \times \text{CSG}}{L \times 2}$$

Where “L” is in μH

In order to have this slope compensation, the following resistor should be set.

$$R_{\text{SLOPE}} = \frac{33 \times 10^3}{V_{\text{SLOPE}}}$$

### Variable Definition

D= Duty Cycle

Vout= Output Voltage

V<sub>D</sub>= Diode Voltage

Vin= Input Voltage

V<sub>SW</sub>= Internal Switch Volute

ΔVout= Output Voltage Ripple Ratio

I<sub>in,avg</sub>= Average Input Current

I<sub>out</sub>= Output Current Ripple

I<sub>in,max</sub>= Maximum input current

ΔI<sub>out</sub>= Output Current Ripple Ratio

I<sub>rms,Cin</sub>= RMS current for Input Capacitor

I<sub>rms,Cout</sub>= RMS current for Output Capacitor

L= Inductor

r<sub>w</sub>= Inductor winding resistor

F<sub>SW</sub>= Boost Switching Frequency

CSG= Current Sense Gain = 0.2 V/A

A<sub>CSA</sub>= Current Sense Amplifier Gain = 9

R<sub>Sense</sub>= Current Sense Resistor = 22mohm

C<sub>out</sub>= Output Capacitor

R<sub>Comp</sub>= Compensation Resistor

G<sub>M</sub>= OTA Transconductance

ESR<sub>Cout</sub>= ESR of Output Capacitor

f<sub>RHPZ</sub>= Right Half Plane Zero Frequency

f<sub>Cross</sub>= Crossover Frequency

C<sub>Comp1</sub>= Compensation Capacitor

C<sub>Comp2</sub>= Shunt Compensation Capacitor

V<sub>SLOPE</sub>= Slope Compensation (V/s)

R<sub>SLOPE</sub>= External Resistor for Slope Compensation

## LAYOUT GUIDELINES

### RECOMMENDED STACK-UP

The following table shows the recommended layer stack-up for the signals to have good shielding and Thermal Dissipation.

**Table 9. Layer Stacking Recommendations**

|                   | Stack-Up |
|-------------------|----------|
| Layer 1 (Top)     | Signal   |
| Layer 2 (Inner 1) | Ground   |
| Layer 3 (Inner 2) | Signal   |
| Layer 4 (Bottom)  | Ground   |

### DECOUPLING CAPS

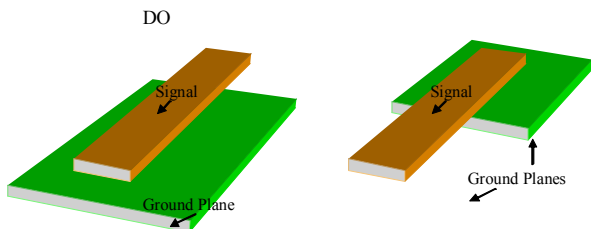
It is recommended to place decoupling caps of 100pf at the beginning and at the end of any power signal traces to filter high frequency noise.

Decoupling caps of 100pf should be also placed at the end of any long trace to cancel antenna effects on it.

These caps should be located as closed as possible to the point to be decoupled and the connection to GND should be as short as possible.

### SM\_BUS/I2C COMMUNICATION AND CLOCK SIGNALS (SDA, SCK AND CK)

To avoid contamination of these signals by nearby high power or high frequency signals, it is a good practice to shield them with ground planes placed on adjacent layers. Make sure the ground plane is uniform through the whole signal trace length.



**Figure 19. Recommended shielding for critical signals.**

These signals shall not run parallel to power signals or other clock signals in the same routing layer. If they have to cross or to be routed close to a power signal, it is a good practice to trace them perpendicularly or at 45° on a different layer to avoid coupling noise.

### SWITCHING NODE (SWA & SWB)

The components associated to this node must be placed as close as possible to each other to keep the switching loop small enough so that it does not contaminate other signals. However, care must be taken to ensure the copper traces used to connect these components together on this node are capable to handle the necessary current and voltage.

As a reference, a 10mils trace with a thickness of 1 oz of copper is capable of handling one ampere.

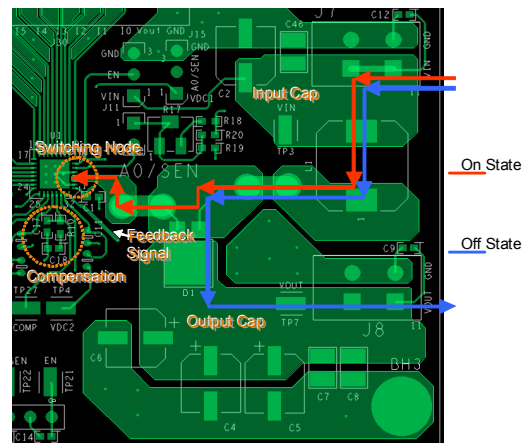
Traces for connecting the inductor, input and output caps should be as wide and short as possible to avoid adding inductance or resistance to the loop. The placement of these components should be selected far away from sensitive signals like compensation, feedback and internal regulators to avoid power noise coupling.

### COMPENSATION COMPONENTS

Components related with COMP pin need to be placed as close as possible. The trace of the feedback signal (VOUT) should be routed perpendicularly or at 45° on a different layer to avoid coupling noise, preferably between ground or power planes.

### FEEDBACK SIGNAL

The trace of the feedback signal (VOUT) should be routed perpendicularly or at 45° on a different layer to avoid coupling noise, preferably between ground or power planes.



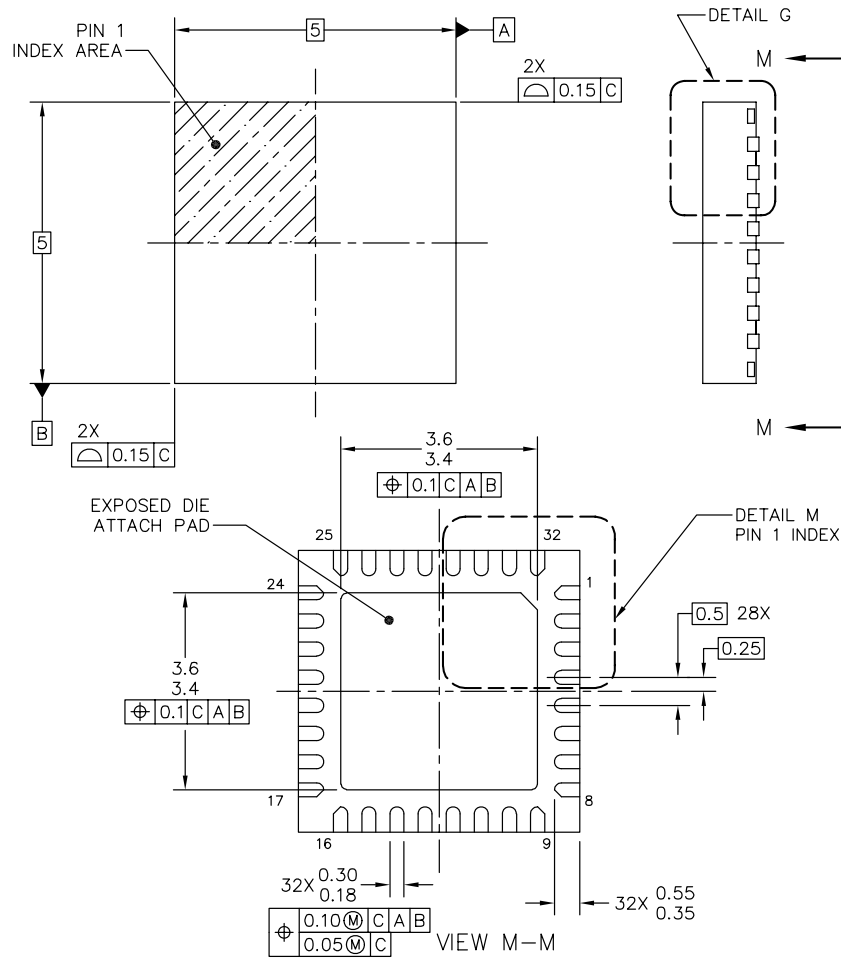
**Figure 20. Feedback Signal Tracing**



# PACKAGING

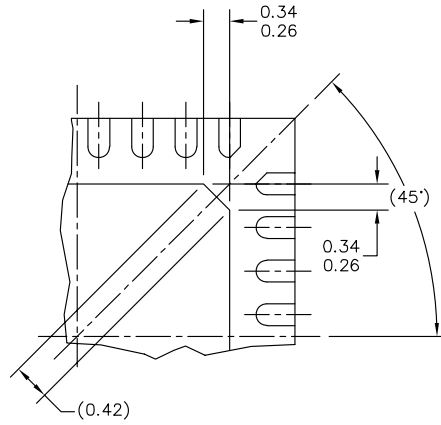
## PACKAGE DIMENSIONS

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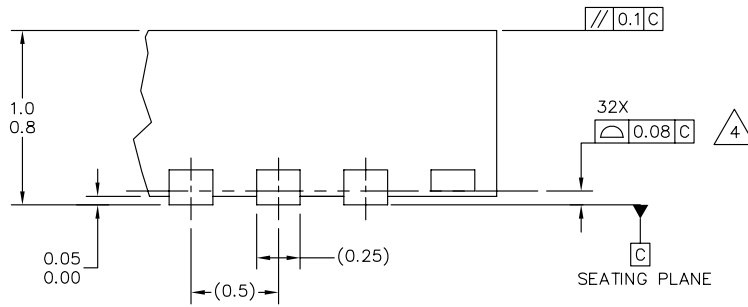


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|  | CASE NUMBER: 1972-01      | 29 AUG 2007                |  |
|  | STANDARD: NON-JEDEC       |                            |  |

**EP SUFFIX**  
32-PIN  
98ASA10800D  
REVISION O



DETAIL M  
PIN 1 BACKSIDE IDENTIFIER




DETAIL G  
VIEW ROTATED 90° CW

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REVISION O

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994.
3. RADIUS ON TERMINAL IS OPTIONAL.
4.  COPLANARITY APPLIES TO LEADS, AND DIE ATTACH PAD.
5. MINIMUM METAL GAP SHOULD BE 0.2 MM.

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REVISION O

## REVISION HISTORY

| REVISION | DATE   | DESCRIPTION OF CHANGES  |
|----------|--------|---|
| 2.0      | 9/2008 | <ul style="list-style-type: none"><li>Initial Release</li></ul> |

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