

ZXSC310

LED DRIVER SOLUTION FOR LCD BACKLIGHTING

DEVICE DESCRIPTION

The ZXSC310 is a single or multi cell LED driver designed for LCD backlighting applications. The input voltage range of the device is between 0.8V and 8V. This means the ZXSC310 is compatible with single NiMH, NiCd or Alkaline cells, as well as multi-cell or Lilon batteries.

The device features a shutdown control, resulting in a standby current less than 5 μ A, and an output capable of driving serial or parallel LED's. The circuit generates constant power output, which are ideal for driving single or multiple LED's over a wide range of operating voltages. These features make the device ideal for driving LED's particularly in LCD backlight applications for Digital Still cameras and PDA's.

FEATURES

- 94% efficiency
- Minimum operating input voltage 0.8V
- Maximum operating input voltage 8V
- Standby current less than 5 μ A
- Programmable output current
- Series or parallel LED configuration
- Low saturation voltage switching transistor
- SOT23-5 package

APPLICATIONS

- LCD backlights:
 - Digital still camera
 - PDA
 - Mobile phone
- LED flashlights and torches
- White LED driving
- Multiple LED driving

ORDERING INFORMATION

| DEVICE | REEL SIZE | TAPE WIDTH | QUANTITY PER REEL |
|-----------|-----------|------------|-------------------|
| ZXSC310E5 | 180mm | 8mm | 3000 |

DEVICE MARKINGS

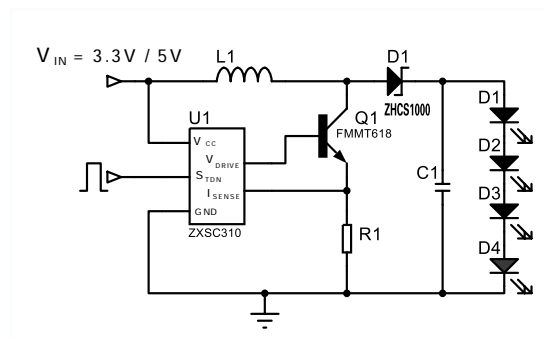
- C310

The ZXSC310 is a PFM DC-DC controller IC that drives an external Zetex switching transistor with a very low saturation resistance. These transistors are the best switching devices available for this type of conversion enabling high efficiency conversion with low input voltages. The drive output of the ZXSC310 LED driver generates a dynamic drive signal for the switching transistor.

The circuit can start up under full load and operates down to an input voltage of 0.8 volts. The solution configuration ensures optimum efficiency over a wider range of load currents; several circuit configurations are possible depending on battery life versus brightness considerations.

The ZXSC310 is offered in the SOT23-5 package which, when combined with a SOT23 switching transistor, generates a high efficiency small size circuit solution. The IC and discrete combination offers the ultimate cost Vs performance solution for LED backlight applications.

TYPICAL APPLICATIONS CIRCUIT



ZXSC310

ABSOLUTE MAXIMUM RATINGS:

| | |
|----------------------------|-----------------------|
| Supply Voltage | -0.3 to 10V |
| Maximum Voltage other pins | -0.3 to $V_{CC}+0.3V$ |
| Power Dissipation | 450mW |
| Operating Temperature | -40 to 85 °C |
| Storage Temperature | -55 to 125°C |

ELECTRICAL CHARACTERISTICS:

Test conditions unless otherwise stated: $V_{CC}=1.5V$, $T_{AMB}=25^{\circ}C$

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|-----------------------------|--|--|------------------|------------|----------|---------------|
| η | Efficiency ¹ | | | | 94 | % |
| V_{CC} | Recommended supply voltage range | | 0.8 | | 8 | V |
| $V_{CC(min)}$ | Minimum startup and operating voltage | $I_{DRIVE}=-600\mu A$, $V_{DRIVE}=0.7V$ $I_{DRIVE}=-600\mu A$, $V_{DRIVE}=0.7V$, $T_{AMB}=-10^{\circ}C^3$ | | 0.8 0.9 | 0.92 | V |
| I_Q | Quiescent current ² | $V_{EN} = V_{CC}$ (enabled) $V_{EN} = 0V$ (standby) | | 0.2 4 | 5 | mA μA |
| I_{VDRIVE} | Base drive current | $V_{DRIVE} = 0.7V$, $V_{ISENSE} = 0V$ | 1.5 | | 3.5 | mA |
| I_{CC} | Supply current ³ | $V_{DRIVE} = 0.7V$, $V_{ISENSE} = 0V$ | 2 | | 4 | mA |
| $V_{VDRIVE(high)}$ | High level drive voltage | $V_{ISENSE} = 0V$, $I_{VDRIVE} = -0.5mA$ | V_{CC} -0.3 | | V_{CC} | V |
| $V_{VDRIVE(low)}$ | Low level drive voltage | $V_{ISENSE} = 50mV$, $I_{VDRIVE} = 5mA$ | 0 | | 0.2 | V |
| $V_{STDN(high)}$ | Device enabled | | 0.7 | | | V |
| $V_{STDN(low)}$ | Device in standby mode | | | | 0.15 | V |
| I_{STDN} | Enable input current | | -1 | | 1 | μA |
| V_{ISENSE} (threshold) | Output current reference voltage | | 14 | 19 | 24 | mV |
| $T_{CVISENSE}$ | I_{ISENSE} voltage temp co. ² | | | 0.4 | | %/°C |
| I_{ISENSE} | I_{ISENSE} input current | $V_{ISENSE} = 0V$ | 0 | -30 | -65 | μA |

ELECTRICAL CHARACTERISTICS: AC PARAMETERS²

Test conditions unless otherwise stated: $V_{CC}=1.5V$, $T_{AMB}=0$ to $70^{\circ}C$

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|-----------|--|------------|-----|-----|-----|---------|
| T_{DRV} | Discharge Pulse Width | | 1.2 | 1.7 | 3.2 | μs |
| F_{OSC} | Recommended operating frequency ⁴ | | | | 200 | kHz |

1 Application dependent, see reference designs

2 These parameters guaranteed by Design

3 Total supply current = $I_Q + I_{VDRIVE}$, see typical characteristics

4 Operating frequency is application circuit dependent. See applications section.

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FMMT618

For the circuits described in the applications section Zetex FMMT618 is the recommended pass transistor.

The following indicates outline data for the device, more detailed information can be found in the Zetex surface mount products data book or on Zetex Web page: www.zetex.com

ELECTRICAL CHARACTERISTICS:

Test conditions unless otherwise stated: $T_{AMB}=25^{\circ}\text{C}$

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|---------------|---|------------------------------------|-----|-----|-----|-------|
| $V_{CE(sat)}$ | Collector-Emitter Saturation Voltage ⁵ | $I_C=0.1\text{A}, I_B=10\text{mA}$ | | 8 | 15 | mV |
| | | $I_C=1\text{A}, I_B=10\text{mA}$ | | 70 | 150 | |
| | | $I_C=2.5\text{A}, I_B=50\text{mA}$ | | 130 | 200 | |
| $V_{(BR)CEO}$ | Collector-Emitter Breakdown Voltage ⁵ | $I_C=10\text{mA}$ | 20 | 27 | | V |

⁵ Measured under pulse conditions. Pulse width=300 μs . Duty cycle $\leq 2\%$

ZHCS1000

For the maximum brightness circuit described in the applications section Zetex ZHCS1000 is the recommended Schottky diode.

The following indicates outline data for the ZHCS, more detailed information can be found on Zetex Web page: www.zetex.com

ELECTRICAL CHARACTERISTICS:

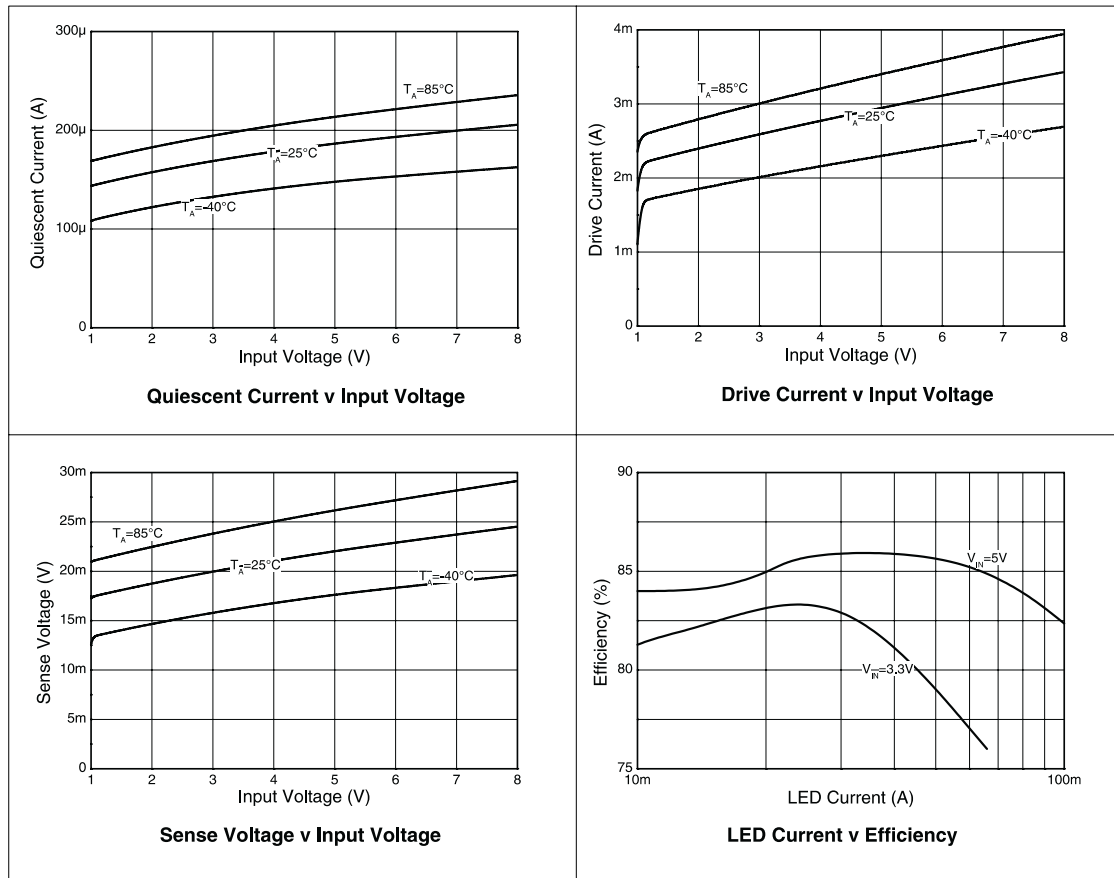
Test conditions unless otherwise stated: $T_{AMB}=25^{\circ}\text{C}$

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|----------|-----------------------|---|-----|-----|------------|---------------|
| V_F | Forward voltage | $I_F = 500\text{mA}$ $I_F = 1\text{A}$ | | | 400 500 | mV |
| t_{rr} | Reverse Recovery Time | Switched from $I_F=500\text{mA}$ to $I_R=500\text{mA}$. Measured at $I_R=50\text{mA}$ | | 12 | | ns |
| I_R | Reverse Current | $V_R = 30\text{V}$ | | 50 | 100 | μA |

| Part Number | V_R | I_F | I_{FSM} | V_F at | | I_R at | | Capacitance at $V_R = 25\text{V}, f = 1\text{MHz}$ Typ. pF | Package |
|-------------|-----------|------------|-----------|------------|-------------|-----------------------|------------|---|---------|
| | Max. V | Max. mA | Max. A | Max. mV | I_F mA | Max. μA | V_R V | | |
| BAT54 | 30 | 200 | 0.6 | 500 | 30 | 250 | 25 | 10 | SOT23-6 |
| ZHCS2000 | 40 | 2000 | 20 | 500 | 2000 | 1000 | 30 | 60 | SOT23 |
| ZHCS1000 | 40 | 1000 | 12 | 500 | 1000 | 100 | 30 | 25 | SOT23 |
| ZHCS750 | 40 | 750 | 12 | 540 | 750 | 100 | 30 | 25 | SOT23 |
| ZHCS500 | 40 | 500 | 6.75 | 550 | 500 | 40 | 30 | 20 | SOT23 |
| ZHCS400 | 40 | 400 | 6.75 | 500 | 400 | 40 | 30 | 20 | SOT323 |

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TYPICAL CHARACTERISTICS



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DEVICE DESCRIPTION

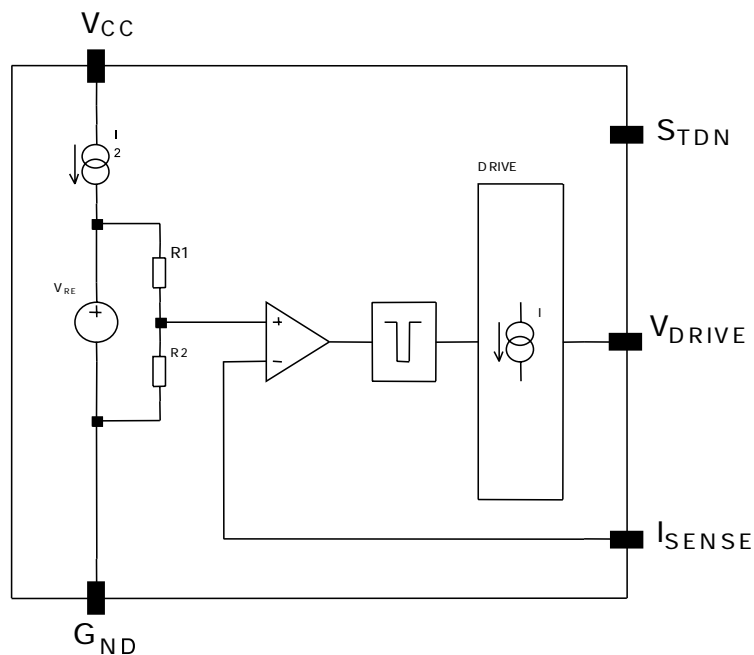
The ZXSC310 is PFM, controller IC which, when combined with a high performance external transistor, enables the production of a high efficiency boost converter for LED driving applications. A block diagram is shown for the ZXSC310 below.

The on chip comparator forces the driver circuit and therefore the external switching transistor off if the voltage at I_{SENSE} exceeds 19mV. An internal reference circuit and divider set this threshold.

The voltage at I_{SENSE} is taken from a current sense resistor connected in series with the emitter of the switching transistor. A monostable following the output of the comparator forces the turn-off time of the output stage to be typically 1.7 μ s. This ensures that there is sufficient time to discharge the inductor coil before the next on period.

With every on pulse the switching transistor is kept on until the voltage across the current-sense resistor exceeds the threshold of the I_{SENSE} input. The on-pulse length, and therefore the switching frequency, is determined by the programmed peak current, the input voltage and the input to output voltage differential. See applications section for details.

The driver circuit supplies the external switching transistor with a fixed drive current. To maximise efficiency the external transistor switched quickly, typically being forced off within 30ns.



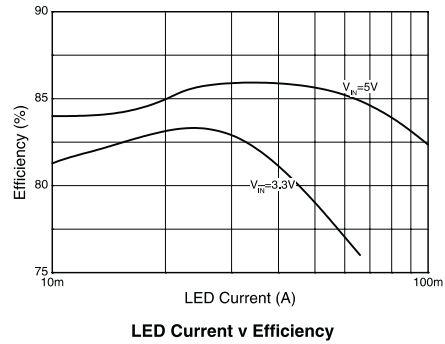
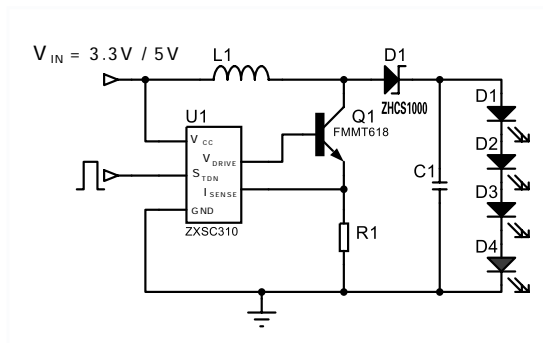
ZXSC310 Block Diagram

ZXSC310

REFERENCE DESIGNS

Three typical LED driving applications are shown. Firstly a typical LCD backlight circuit, then maximum brightness LED driving solution and lastly an optimised battery life LED driving solution.

LCD backlight circuit



(Notes)

This application shows the ZXSC310 in a typical LCD backlight application for Digital Still Cameras and PDA's. The input voltage for these backlight circuits are usually fixed from the main system power, typically 3.3V or 5V. The LED's are connected serially so that the light is distributed uniformly in each LED. The current provided to the LED's can either be pulsed or DC. The DC current is programmable via a sense resistor, R_{SENSE}, and is set to an optimum LED current of 20mA for the reference designs. DC current is achieved by adding a Schottky rectifying diode and an output capacitor, as shown in the reference design below.

Materials list

| Ref | Value | Part Number | Manufacture | Comments |
|-----------------|-------|-------------|-------------|-------------------------------------|
| U1 | N/A | ZXSC310E5 | Zetex Plc | Single cell converter, SOT23-5 |
| Q1 | N/A | FMMT618 | Zetex Plc | Low V _{CE(sat)} NPN, SOT23 |
| D1 | N/A | ZHCS1000 | Zetex Plc | 1A Schottky diode, SOT23 |
| C1 | 2.2μF | Generic | Various | 0805 Size |
| R1 ⁶ | 150mΩ | Generic | Various | 1206 Size |
| R1 ⁷ | 250mΩ | Generic | Various | 1206 Size |
| L1 ⁸ | 68μH | | | Surface mount inductor |

⁶Used for 3.3V input, I_{LED} set to 20mA ±10%.

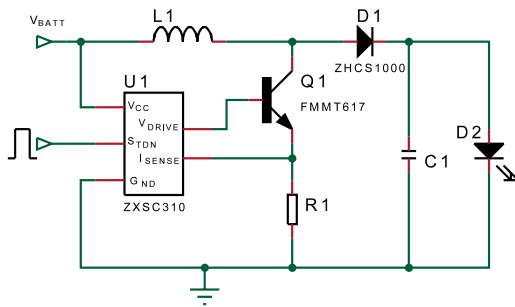
⁷Used for 5V input, I_{LED} to 20mA ±10%.

⁸See Application section.

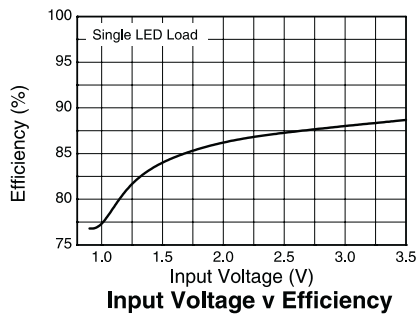
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Maximum brightness solution

(Notes)



This circuit provides a continuous current output to the LED by rectifying and buffering the DC-DC output. This ensures maximum LED brightness.



Materials list

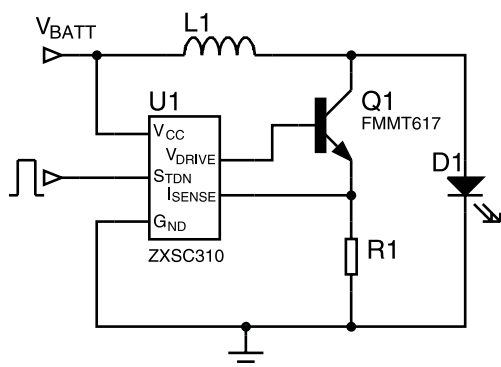
| Ref | Value | Part Number | Manufacture | Comments |
|-----|--------------------------|-------------|-------------|--------------------------------|
| U1 | N/A | ZXSC310E5 | Zetex Plc | Single cell converter, SOT23-5 |
| Q1 | N/A | FMMT617 | Zetex Plc | Low $V_{CE(sat)}$ NPN, SOT23 |
| D1 | 1A | ZHCS1000 | Zetex Plc | 1A Schottky diode, SOT23 |
| R1 | 100m Ω | Generic | Various | 0805 Size |
| C1 | 2.2 μ F | Generic | Various | Low ESR ceramic capacitor |
| L1 | 100 μ H ⁸ | | | Surface mount inductor |

⁸See Application section.

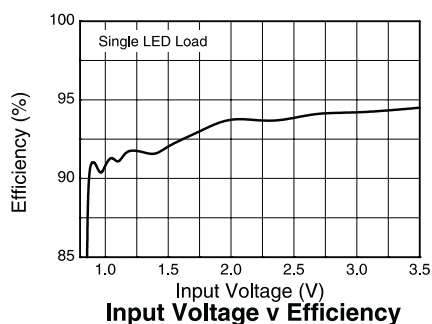
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(Notes)

Maximum battery life solution



To ensure optimum efficiency, and therefore maximum battery life, the LED is supplied with a pulsed current. Maximum efficiency is ensured with the removal of rectifier losses experienced in the maximum brightness solution.



Materials list

| Ref | Value | Part Number | Manufacture | Comments |
|-----|--------------------------|-------------|-------------|--------------------------------|
| U1 | N/A | ZXSC310E5 | Zetex Plc | Single cell converter, SOT23-5 |
| Q1 | N/A | FM6T617 | Zetex Plc | Low $V_{CE(SAT)}$ NPN, SOT23 |
| R1 | 330m Ω | Generic | Various | 0805 Size |
| L1 | 100 μ H ⁸ | | | Surface mount inductor |

⁸See Application section.

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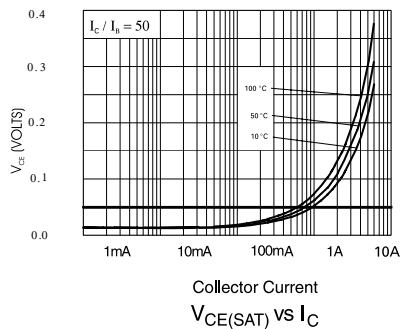
APPLICATIONS INFORMATION

The following section is a design guide for optimum converter performance.

Switching transistor selection

The choice of switching transistor has a major impact on the converter efficiency. For optimum performance, a bipolar transistor with low $V_{CE(SAT)}$ and high gain is required.

The Zetex FMMT618 is an ideal choice of transistor, having a low saturation voltage. A data sheet for the FMMT618 is available on Zetex web site or through your local Zetex sales office. Outline information is included in the characteristics section of this data sheet.



Schottky diode selection

For the maximum battery life solution a Schottky rectifier diode is not required. As with the switching transistor the Schottky rectifier diode has a major impact on the converter efficiency. A Schottky diode with a low forward voltage and fast recovery time should be used for this application.

The diode should be selected so that the maximum forward current is greater or equal to the maximum peak current in the inductor, and the maximum reverse voltage is greater or equal to the output voltage.

The Zetex ZHCS1000 meets these needs. Datasheets for the ZHCS Series are available on Zetex web site or through your local Zetex sales office. Outline information is included in the characteristics section of this data sheet.

For the maximum brightness solution a pulsed current is supplied to the LED and thus a Schottky rectifier diode is required.

Inductor selection

The inductor value must be chosen to satisfy performance, cost and size requirements of the overall solution. For the LCD backlight reference design we recommend an inductor value of 68 μ H with a core saturation current rating greater than the converter peak current value and low series resistance.

Inductor selection has a significant impact on the converter performance. For applications where efficiency is critical, an inductor with a series resistance of 500m Ω or less should be used.

A list of recommended inductors is shown in the table below:

| Part No. | Manufacture | L | I_{PK} | R_{DC} |
|-----------------|-------------|------------|----------|----------------|
| DO1608C-683 | Coilcraft | 68 μ H | 0.4A | 0.86 Ω |
| CR54-680 | Sumida | 68 μ H | 0.61A | 0.46 Ω |
| P1174.683 | Pulse | 68 μ H | 0.4A | 0.37 Ω |
| SFOP5845-R61680 | Samwha | 68 μ H | 0.61A | 0.46 Ω |
| SIS43-680 | Delta | 68 μ H | 0.4 | 1.125 Ω |

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Peak current definition

The peak current rating is a design parameter whose value is dependent upon the overall application. For the high brightness reference designs, a peak current of was chosen to ensure that the converter could provide the required output power to the LED.

In general, the I_{PK} value must be chosen to ensure that the switching transistor, Q1, is in full saturation with maximum output power conditions, assuming worse-case input voltage and transistor gain under all operating temperature extremes.

Once I_{PK} is decided the value of R_{SENSE} can be determined by:

$$R_{SENSE} = \frac{V_{ISENSE}}{I_{PK}}$$

A selection guide of sense resistor and inductor values for given input voltages, output currents and number of LED connected in series is provided in the table below.

| Input Voltage (V) | LED current (mA) | No. of LED's | R_{SENSE} (m Ω) | Inductor (μ H) | Efficiency (%) |
|-------------------|------------------|--------------|---------------------------|---------------------|----------------|
| 3.3V | 10 | 3 | 510 | 68 | 80 |
| 3.3V | 10 | 4 | 330 | 68 | 81 |
| 3.3V | 10 | 6 | 150 | 68 | 79 |
| 3.3V | 20 | 3 | 220 | 68 | 84 |
| 3.3V | 20 | 4 | 150 | 68 | 93 |
| 3.3V | 20 | 6 | 77 | 68 | 79 |
| 3.3V | 30 | 3 | 170 | 68 | 84 |
| 3.3V | 30 | 4 | 100 | 68 | 84 |
| 3.3V | 30 | 6 | 47 | 68 | 77 |
| 5V | 10 | 3 | 750 | 68 | 83 |
| 5V | 10 | 4 | 510 | 68 | 84 |
| 5V | 10 | 6 | 330 | 68 | 79 |
| 5V | 20 | 3 | 440 | 68 | 85 |
| 5V | 20 | 4 | 250 | 68 | 85 |
| 5V | 20 | 6 | 150 | 68 | 82 |
| 5V | 30 | 3 | 330 | 68 | 86 |
| 5V | 30 | 4 | 170 | 68 | 85 |
| 5V | 30 | 6 | 100 | 68 | 83 |

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Output Power Calculation

By making the above assumptions for inductance and peak current the output power can be determined by:

$$P_{OUT} = (V_{OUT} - V_{IN}) \times I_{AV} \times \frac{T_{OFF}}{T_{ON} + T_{OFF}}$$

Note: V_{OUT} = output voltage + Schottky rectifier voltage drop.

Where

$T_{OFF} \approx 1.7 \mu s$ (internally set by ZXSC310)

and

$$T_{ON} = \frac{T_{OFF}(V_{OUT} - V_{IN})}{V_{IN}}$$

and

$$I_{AV} = \frac{I_{PK} + I_{MIN}}{2}$$

Where

$$I_{MIN} = I_{PK} - \frac{(V_{OUT} - V_{IN}) \times T_{OFF}}{L}$$

Operating frequency can be derived by:

$$F = \frac{1}{(T_{ON} + T_{OFF})}$$

Capacitor selection

For pulsed operation, as in the maximum battery life solution, no capacitors are required at the output to the LED. For rectified operation, as in the maximum brightness solution, a small value ceramic capacitor is required, typically 2.2uF.

Generally an input capacitor is not required, but a small ceramic capacitor may be added to aid EMC, typically 470nF to 1uF.

(notes)

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Shutdown Control

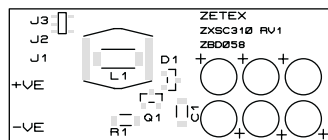
The ZXSC310 offers a shutdown mode that produces a standby current of less than 5uA when in operation. When the voltage at the S_{TDN} pin is 0.7V or higher the ZXSC310 is enabled, hence the driver is in normal operation. When the voltage at the S_{TDN} pin is 0.1V or lower the ZXSC310 is disabled, hence the driver is in shutdown mode. If the S_{TDN} pin is open circuit the ZXSC310 is also enabled.

Demonstration board

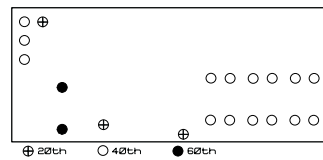
A demonstration board for the LCD backlighting solution, is available upon request. These can be obtained through your local Zetex office or through Zetex web pages. For all reference designs Gerber files and bill of materials can be supplied.

Layout of LCD backlighting solution

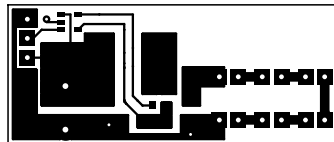
Top Silk



Drill File



Top Copper

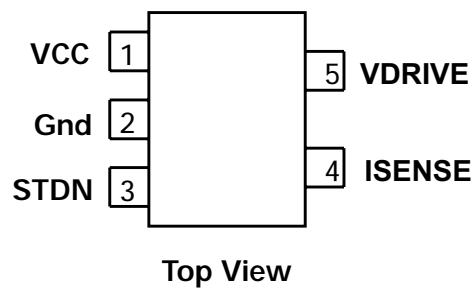


Bottom Copper



ZXSC310

PINOUT DIAGRAM



PIN DESCRIPTIONS

| Pin No. | Name | Description |
|---------|-------------|---|
| 1 | V_{CC} | Supply voltage, generally Alkaline, NiMH or NiCd single cell |
| 2 | G_{nd} | Ground |
| 3 | S_{TDN} | Shutdown |
| 4 | I_{SENSE} | Inductor current sense input. Internal threshold voltage set to 19mV. Connect external sense resistor |
| 5 | V_{DRIVE} | Drive output for external switching transistor. Connect to base of external switching transistor. |

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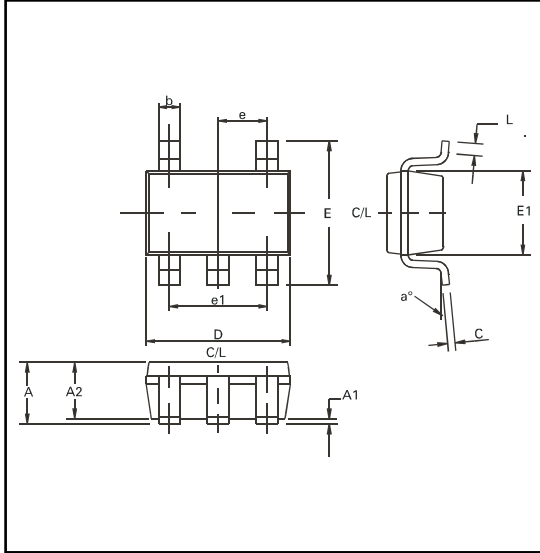
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SOT23-5 PACKAGE OUTLINE



SOT23-5 PACKAGE DIMENSIONS

| DIM | Millimetres | | Inches | |
|-----|-------------|------|-----------|-------|
| | MIN | MAX | MIN | MAX |
| A | 0.90 | 1.45 | 0.035 | 0.057 |
| A1 | 0.00 | 0.15 | 0.00 | 0.006 |
| A2 | 0.90 | 1.3 | 0.035 | 0.051 |
| b | 0.35 | 0.50 | 0.014 | 0.020 |
| C | 0.09 | 0.20 | 0.0035 | 0.008 |
| D | 2.80 | 3.00 | 0.110 | 0.118 |
| E | 2.60 | 3.00 | 0.102 | 0.118 |
| E1 | 1.50 | 1.75 | 0.059 | 0.069 |
| e | 0.95 REF | | 0.037 REF | |
| e1 | 1.90 REF | | 0.075 REF | |
| L | 0.10 | 0.60 | 0.004 | 0.024 |
| a° | 0 | 10 | 0 | 10 |

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