EMC and Circuit Protection Solution
For LED Driver Circuit

- Jun 7th, 2011
1. **Requirement of components in LED driver circuit**
2. **EMC and circuit protection solution for LED driver circuit**
3. **Sunlord related product presentation**
   - Chip Varistor
   - Chip NTC thermistor
   - Chip ferrite bead
   - Chip power inductor
   - Chip solid tantalum capacitor
Requirement of Components in LED Driver Circuit

LED Driver circuit
- Large Power
- High Efficient
- Low Ripple
- High Reliability
- EMC Capability
- Low Profile

Components
- Large Current
- Low DCR
- Large Inductance
- High Reliability
- EMC/ESD Capability
- Small size
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Sunlord
EXPERT IN PASSIVE PARTS

EMC and Circuit Protection Solution

<table>
<thead>
<tr>
<th>No.</th>
<th>Function</th>
<th>Series</th>
<th>P/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rv</td>
<td>Surge Protection</td>
<td>Varistor for Surge Protection</td>
<td>SDVL/SDV Series</td>
</tr>
<tr>
<td>Rt1</td>
<td>Surge Protection</td>
<td>Power NTC Thermistor</td>
<td>SPNT</td>
</tr>
<tr>
<td>L1, L2, L3</td>
<td>Filtering</td>
<td>Bead/Power inductor</td>
<td>Bead/SWPA</td>
</tr>
<tr>
<td>L4</td>
<td>Energy Storing</td>
<td>Power Inductor</td>
<td>SWPA</td>
</tr>
<tr>
<td>Rt2</td>
<td>Temp. Sensing</td>
<td>NTC Thermistor</td>
<td>SDNT</td>
</tr>
<tr>
<td>C1</td>
<td>Energy Storing</td>
<td>Tantalum Capacitor</td>
<td>TC211/212</td>
</tr>
</tbody>
</table>
1. Requirement of components in LED driver circuit
2. EMC and circuit protection solution for LED driver circuit
3. Sunlord related product presentation
   - Chip Varistor
   - Chip NTC Thermistor
   - Chip Ferrite Bead
   - Chip Power Inductor
   - Chip Solid Tantalum Capacitor
Varistor is made of ZnO ceramics which have good performance of fast response time (less than 0.5ns), transmit energy absorbing and transferring to ground with millions of series-parallel P-N junctions.

**Features:**
- Fast response time: < 0.5nS
- High surge current capability
- Low leakage current
- Low clamping voltage
- Bidirectional V/I characteristic
Lightning discharges generate a wide range of electromagnetic radiations. The equipments will be damaged due to high transient voltage by induction or conduction.
### Applications of Varistor for LED Driver

#### Function
- **Primary protection:** suppress induced over-voltage caused by power and lightning.
- **Secondary protection:** suppress induced & switching over-voltage, protecting DC-DC Module and driver IC (good replacement of SMAJ/SMBJ TVS).
- **ESD protection for LEDs**

#### Primary Electrical Parameter
- **SDVL5650KA301PTF**
  - $V_c=775\,\text{V}$
  - $I_p=400\,\text{A}$
  - $E_t=13.4\,\text{J}$

- **SDV3216/3225**
  - $V_c=40\,\text{V}$
  - $I_p=120\sim400\,\text{A}$
  - $E_t=0.4\sim2.3\,\text{J}$

- **SDV1005/1608/2012**
  - $C_p=10\sim360\,\text{pf}$
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**Chip NTC Thermistor**

**NTC Thermistor:** Resistance decreases with temperature increasing;

**B Constant:**

\[
B = \frac{T_1 T_2}{T_2 - T_1} \ln \frac{R_{T1}}{R_{T2}}
\]

Generally, \(T_2=323.15K\) (50 °C), \(T_1=298.15K\) (25 °C)

Larger B constant for higher temperature sensing capability

**Types:**
- Chip power NTC Thermistor
- Chip temperature sensor NTC Thermistor
The inrush current occurs in power supply circuits (LED driver board, inverter fluorescent lamps, heaters, etc.) when electric equipment switches on. It will be hundred times higher than normal operating current.

NTC resistance at room temperature is big enough to suppress inrush current when the equipment switches on. After that, as the body temperature of NTC rising, its resistance becomes smaller, and thus the power consumption of NTC is negligible to ensure electric equipment working normally.
- Improved reliability and lower R25 due to use of internal electrodes
- Developed material (large resistivity and B constant) provides low residual resistance and high permissible current
- SMD type designed for high density
- Available in a standard EIA compatible case size
- Excellent long time aging stability
The material resistivity of Pin-type is very low (50-200\(\text{m} \cdot \text{m} \ \Omega\)) which results in low B constant and high Residual Resistance.

Chip power NTC adopts innovative materials with high resistivity (5000\(\text{m} \cdot \text{m} \ \Omega\) or so) and internal electrode structure, and thus provides high B constant (4000K or more) and low Residual Resistance.

<table>
<thead>
<tr>
<th>Size</th>
<th>B constant (K)</th>
<th>Residual Resistance ((\Omega))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin-type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(diameter)</td>
<td>Chip (L×W)</td>
<td>Pin-type</td>
</tr>
<tr>
<td>Φ5</td>
<td>4516</td>
<td>2500-3300</td>
</tr>
<tr>
<td>Φ7</td>
<td>4532</td>
<td>2500-3300</td>
</tr>
<tr>
<td>Φ9</td>
<td>4532/5056</td>
<td>2500-3300</td>
</tr>
<tr>
<td>Φ11</td>
<td>5056</td>
<td>2500-3300</td>
</tr>
<tr>
<td>Φ13</td>
<td>5056/8063</td>
<td>2500-3300</td>
</tr>
<tr>
<td>Φ15</td>
<td>8063</td>
<td>2500-3000</td>
</tr>
<tr>
<td>Φ20</td>
<td>10080</td>
<td>2500-3000</td>
</tr>
<tr>
<td>SUNLORD Chip NTC</td>
<td>R25 (Ω)</td>
<td>B Constant (K)</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
<td>----------------</td>
</tr>
<tr>
<td>SPNT4516</td>
<td>5-200</td>
<td>3500-4000</td>
</tr>
<tr>
<td>SPNT4532</td>
<td>5-200</td>
<td>3500-4000</td>
</tr>
<tr>
<td>SPNT4532/5056</td>
<td>5-400</td>
<td>3500-4000</td>
</tr>
<tr>
<td>SPNT5056</td>
<td>5-120</td>
<td>3500-4000</td>
</tr>
<tr>
<td>SPNT5056/8063</td>
<td>5-120</td>
<td>3500-4000</td>
</tr>
<tr>
<td>SPNT8063</td>
<td>5-120</td>
<td>3500-4000</td>
</tr>
<tr>
<td>SPNT10080</td>
<td>5-50</td>
<td>3500-4000</td>
</tr>
</tbody>
</table>
Temperature Sensor NTC

- Large B constant for higher temperature sensing capability
- Designed for high density
- Available in a standard EIA compatible case size
- Excellent long time aging stability

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Resistance at 25°C (KΩ)</th>
<th>B constant (k)</th>
<th>Max. permissive Operating Current (mA)</th>
<th>Dissipation Factor (mW/°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDNT1005</td>
<td>0.022~680</td>
<td>3380~4400</td>
<td>0.03~6.7</td>
<td>1.0</td>
</tr>
<tr>
<td>SDNT1608</td>
<td>0.1~680</td>
<td>3380~4500</td>
<td>0.03~3.1</td>
<td>1.0</td>
</tr>
<tr>
<td>SDNT2012</td>
<td>0.1~680</td>
<td>3380~4500</td>
<td>0.04~4.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>
1. Requirement of components in LED driver circuit

2. EMC and circuit protection solution for LED driver circuit

3. Sunlord related product presentation
   - Chip Varistor
   - Chip NTC Thermistor
   - **Chip Ferrite Bead**
   - Chip Power Inductor
   - Chip Solid Tantalum Capacitor
- Bead is connected in series in the circuit.
- Bead is a frequency dependent resistor.
- At low frequencies, inductive impedance is low.
- At higher frequencies, the impedance increases and becomes resistive function.
- The resistive loss attenuates the unwanted frequencies through heating of the bead’s ferrite material due to eddy currents.

\[ Z = R + jX \]
\[ Z^2 = R^2 + X^2 \]
**Development Plan**

**Miniaturization**

Smaller size beads are required due to limited surface of LED lightings

Main size: 2012/1608

Tendency: →1005 → 0603 →...

**Wide Frequency Range**

EMI tends to higher frequency with the development of high speed transmission. Good EMC capability in high frequency beads are needed. Sunlord HZ/HPZ series bead are effective in suppressing high frequency EMI in 30MHz~3GHz.

Development plan:
Bead for 6GHz and above EMI suppression

**High Impedance**

High impedance is also a tendency in order to achieve a better EMC performance.

The highest impedance bead nowadays of Sunlord’s is 2700 Ω @100MHz.

**Large Current**

Sunlord large current bead PZ/UPZ series which provide large rated current and low RDC achieve low heat loss in power supply circuit.

Development plan: large current of >10A
Sunlord’s Beads

GZ Series
Attenuation Frequency Range: 30~750MHz

SZ Series
Attenuation Frequency Range: 100~400MHz

PZ or UPZ Series
Attenuation Frequency Range: 30~750MHz

HZ or HPZ Series
Attenuation Frequency Range: 30~3000MHz
## Sunlord’s Beads

<table>
<thead>
<tr>
<th>Size</th>
<th>/</th>
<th>Property Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0603 (0201)</td>
<td>Impedance Range (Ω)</td>
<td>10 240</td>
</tr>
<tr>
<td></td>
<td>Ir Range (A)</td>
<td>0.1 1.0</td>
</tr>
<tr>
<td>1005 (0402)</td>
<td>Impedance Range (Ω)</td>
<td>10 1800</td>
</tr>
<tr>
<td></td>
<td>Ir Range (A)</td>
<td>0.1 2.0</td>
</tr>
<tr>
<td>1608 (0603)</td>
<td>Impedance Range (Ω)</td>
<td>10 2700</td>
</tr>
<tr>
<td></td>
<td>Ir Range (A)</td>
<td>0.1 6.0</td>
</tr>
<tr>
<td>2012 (0805)</td>
<td>Impedance Range (Ω)</td>
<td>10 2700</td>
</tr>
<tr>
<td></td>
<td>Ir Range (A)</td>
<td>0.2 6.0</td>
</tr>
<tr>
<td>3216 (1206)</td>
<td>Impedance Range (Ω)</td>
<td>10 1000</td>
</tr>
<tr>
<td></td>
<td>Ir Range (A)</td>
<td>0.3 6.0</td>
</tr>
<tr>
<td>4516 (1806)</td>
<td>Impedance Range (Ω)</td>
<td>60 470</td>
</tr>
<tr>
<td></td>
<td>Ir Range (A)</td>
<td>2.0 6.0</td>
</tr>
<tr>
<td>......</td>
<td>Impedance Range (Ω)</td>
<td>......</td>
</tr>
<tr>
<td></td>
<td>Ir Range (A)</td>
<td>......</td>
</tr>
</tbody>
</table>
Ferrite bead is one of the most important EMC components. Different type beads are recommended in different circuits:

- **Filtering in input circuit**
  PZ3216&PZ4516 Series

- **LED PWM mode dimming**
  PZ3216&PZ/UPZ2012&PZ/UPZ1608 Series

Bead size is a very important element which is related with price, property, lead time. Generally, smaller size bead has a lower price, thus, small size UPZ series bead is a good option for LED power supply circuit.

- Know frequency range of noise
- Know noise attenuation required
- Know system rated current
- Know allowable space on the PCB
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Power inductors are used in DC-DC converter circuit for energy storing, choke and smoothing. With inductors and output capacitors, DC-DC converter provide a steady output.
The inductor body temperature will increase under continual current. The Heat Rating Current is defined as the current that causes the body temperature rise 40°C from 20°C ambient.

The inductance will decrease under continual current. The Saturation Current is defined as the current at which the inductance drops by 30%.

**DCI1（Saturation Current）**

**DCI2（Heat Rating Current）**
SWPA structure makes the lowest profile power inductor possible, offers an excellent combination of high current, high inductance and low DC resistance.
SWPA: The air gaps between magnetic powders form uniform and multiple.

Sleeve type: The air gap between magnetic ring and core forms single and big.
Lower magnetic leakage

**SWPA Type**

**Sleeve Type**

magnetic leakage result in AC loss
SWPA series wire wound power inductor

Higher Saturation Current than conventional inductors of the same size

Lower AC Loss and Electro Magnetic Interference

- SWPA with a closed magnetic circuit minimizes AC loss;
- Sleeve Type inductors with an air gap leaks flux that results in the increase of AC loss
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High Performance, Space & Power Savings

◆ Sleeveless square-core winding makes full use of core space and thickens wires inside inductor to achieve lowest possible DC resistance

◆ Minimizes heat generation and maximizes efficient use of battery power

◆ 40% Higher current rating than conventional inductors of equal size, takes up less PCB real estate

◆ Metallization on Ferrite Core results in excellent shock resistance and damage-free durability

◆ Magnetic-resin shielded construction reduces buzz noise to ultra-low levels

◆ Closed magnetic circuit design reduces leakage flux and Electro Magnetic Interference (EMI)
## Property Range Table

<table>
<thead>
<tr>
<th>Series</th>
<th>Dimensions (L<em>W</em>H)</th>
<th>Inductance Range (uH)</th>
<th>Rated Current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWPA252012S</td>
<td>2.5*2.0[mm]</td>
<td>0.47~22</td>
<td>0.38~2.27</td>
</tr>
<tr>
<td>SWPA30S</td>
<td>3.0*3.0[mm]</td>
<td>0.82~100</td>
<td>0.21~2.1</td>
</tr>
<tr>
<td>SWPA40S</td>
<td>4.0*4.0[mm]</td>
<td>0.82~220</td>
<td>0.17~3.15</td>
</tr>
<tr>
<td>SWPA50S</td>
<td>5.0*5.0[mm]</td>
<td>1.0~100</td>
<td>0.49~4.45</td>
</tr>
<tr>
<td>SWPA60S</td>
<td>6.0*6.0[mm]</td>
<td>0.50~330</td>
<td>0.57~5.90</td>
</tr>
<tr>
<td>SWPA80S</td>
<td>8.0*8.0[mm]</td>
<td>0.82~330</td>
<td>0.64~6.30</td>
</tr>
</tbody>
</table>
★ Rated Current

- The inductance will drop greatly when the loop current increases more than saturation current, and thus the peak value of current ripple cannot be suppressed due to low inductance, which may cause damage to IC.

- The body temperature of inductors may rise sharply when the loop current increases more than heat rating current, which may cause the worse reliability of wire insulation material and even destroy inductors.

Generally, the smaller current is selected to set as rated current to suit the circuit.

eg: SWPA6045S100M:
DCI1=3.20 A
DCI2=2.45 A --->choose this current
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Features of tantalum capacitor

Solid chip tantalum capacitor provides excellent characteristics and can operate in a wide temperature range. It has unique features:

**Advantage**
- High specific capacity, good for smaller size
- Good capability of self-healing
- Can easily get large capacitance in a small size
- Brilliant stability in a wide temperature range
- Longevity of work and high reliability

**Disadvantage**
- Low rated voltage
- Polarity limited
- High price
# Features of tantalum capacitor

<table>
<thead>
<tr>
<th>Types</th>
<th>size</th>
<th>Capacitance</th>
<th>Rated voltage</th>
<th>Operating Temp.</th>
<th>Tem. Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLCC</td>
<td>0402 [01005] ~5750 [2220]</td>
<td>0.10pF ~47uF</td>
<td>2.5V~3150V</td>
<td>-55~ +85 °C</td>
<td>&gt; ± 10%</td>
</tr>
<tr>
<td>Film Cp.</td>
<td>3.3<em>1.6</em>1.1 ~41.5<em>42.5</em>28</td>
<td>680pF ~220uF</td>
<td>16V~630V</td>
<td>-55~ +125°C</td>
<td>&gt; ± 10%</td>
</tr>
<tr>
<td>Super Cp.</td>
<td>Φ 4.8<em>1.4 ~ Φ 35</em>60</td>
<td>0.1F~1000F</td>
<td>&lt;7.5V</td>
<td>-40~ +70°C</td>
<td>&gt; ± 30%</td>
</tr>
<tr>
<td>Ta Cp.</td>
<td>1106 [0402] ~7343 [2812]</td>
<td>0.22uF~ 2200uF</td>
<td>2.5V~50V</td>
<td>-55~ +125°C</td>
<td>&lt; ± 10%</td>
</tr>
</tbody>
</table>

In general, Ta capacitor present a good performance in capacitance, operating temperature, brilliant reliability. Therefore, Ta Capacitor is fairly suitable as output capacitor in DC-DC converter circuit.
<table>
<thead>
<tr>
<th>Size</th>
<th>Capacitance</th>
<th>Rated Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>P case (2012)</td>
<td>0.1~22uF</td>
<td>2.5~20V</td>
</tr>
<tr>
<td>A case (3216)</td>
<td>0.1~100uF</td>
<td>2.5~50V</td>
</tr>
<tr>
<td>B case (3528)</td>
<td>0.15~220uF</td>
<td>2.5~50V</td>
</tr>
<tr>
<td>C case (6032)</td>
<td>0.47~220uF</td>
<td>4~50V</td>
</tr>
<tr>
<td>D case (7343-28)</td>
<td>2.2~330uF</td>
<td>4~50V</td>
</tr>
<tr>
<td>E case (7343-41)</td>
<td>10~680uF</td>
<td>4~50V</td>
</tr>
</tbody>
</table>
1. The reliability of Ta capacitor is influenced by many ambient condition elements, such as temperature, humidity, application force etc. Enough parameters margin is necessary to considered to improve the reliability of Ta capacitor.

2. Take measures to make sure that Ta capacitors work in a Min. ripple current and voltage condition.

3. Ta capacitors are inherently polar devices and may be permanently damaged or destroyed if applied reverse voltage. But if reverse voltage can’t avoid, it must not exceed:

   1) 10% of $V_R$ or 1V at 25°C;
   2) 5% of $V_R$ or 0.5V at 85°C;
   3) 1% of $V_R$ or 0.1V at 125°C;
4. In order to achieve high reliability, working voltage should obey:

1) For general use, working voltage should derate to 70% of VR or below. For power lines or some low-impedance circuit, working voltage should derate to 30% of VR or below.

2) When operating temperature is above 85°C and below 125°C, voltage derating is necessary:

\[
V_{\text{max}} = (1 - \frac{T-85}{125})V_R
\]

\(T\): operating temperature; \(V_R\): rated voltage at 85°C

5. When Ta capacitor is used in circuit where surge current may occurred, a resistor is needed to connect in series with capacitor to prevent from damaging.

6. Margin designing is necessary to improve the reliability of Ta capacitor especially in some circuit that easily lead to short-circuit.
Thank You!