PMP6023
TPS92210
Universal Input 0-10V Dimmable 25W LED Driver Reference Design

May, 2014
Universal Input 0-10V Dimmable 25W LED Driver

1 Introduction

This TPS92210 reference design presents the TPS92210 AC-DC controller driving a 50V string of LEDs at 500mA in an isolated flyback configuration with an isolated 0-10V dimmer interface. The 0-10V dimming ratio is approximately 9:1. This power supply is power factor corrected and has power factor up to 0.99. The TPS92210 is a natural power factor correction LED driver with advanced energy features to provide high efficiency control for LED lighting applications. The features of TPS92210 include Constant On-Time Enables Single Stage Power Factor Correction, Cascoded MOSFET for Fast and Easy Startup, Fully Integrated Current Control without Sense Resistor, Transformer Zero Energy Detection Enables Valley Switching Operation.

2 Description

This reference design provides a high-brightness LED driver based on the configured as an isolated flyback converter with nature power factor correction. This design is dimmable by 0-10V dimmers with a dimming ratio of 9:1. It is designed to operate with an input voltage in the range of 100VAC to 264VAC. This design is set up for a 500mA LED current with LED stack voltage range from 45 V to 55 V.

2.1 Flyback Power Supply Description

The TPS92210 has two control modes. They are constant-on time control and peak-current mode control. This design uses peak-current mode control to ensure proper operation over a wide range of input voltage and 9:1 LED current dimming range. At full load, the converter is operating in the Frequency Modulation mode with a switching frequency around 120KHz.

In order for the converter to operate with a relatively constant switching frequency over the input voltage range, the switching on time needs to be adjusted according to the input voltage. This on time adjustment is achieved by injecting a current to the OTM resistor R19 through PNP transistor Q4. The injection current is controlled by the Q4 base voltage which is the divided average input voltage. At low line, the Q4 base voltage is low which decreases the injection current and leads to shorter on time. At high line, the Q4 base voltage is high which increases the injection current and leads to longer on time.

At low dimming level, the converter goes from the Frequency Modulation (FM) mode to the Amplitude Modulation (AM) mode. In AM mode, the peak primary current is programmed by the PCL resistor R19. This peak current needs to be set just above the actual peak current during full load operation to ensure smooth transition from FM mode to AM mode.
2.2 **0-10V Dimmer Interface Daughter Board Description**

The 0-10V dimmer interface circuit is located on the daughter board. It has a separated ground which is isolated from both primary and secondary grounds of the flyback power supply. It is powered by a 24V bias supply from the transformer winding (9-10). The dimming interface circuit takes the 0-10V dimming signal from the dimmer and compares it to a sawtooth waveform generated by a Programmable Unijunction Transistor (PUT) based oscillator. The comparator output, which is a square wave, drives an opto coupler. The duty cycle of the square wave is proportional to the 0-10V dimming signal. The opto coupler transfers this square wave signal to the flyback power supply secondary side. It is averaged by a RC filter to generate the LED current reference voltage for the power supply secondary control.

The 0-10V dimmer interface daughter board also provides a 1.5 mA current source to power the dimmer.

2.3 **Features**

2.3.1 **Connector Description**

This section describes the connectors of the reference design board.

2.3.1.1 **J5**

This connector is for the AC input to the board. Use the screw down terminal to connect Line and Neutral to the circuit.

2.3.1.2 **J3 & J4**

Connect J3 to the LED anode and J4 to the LED cathode.

2.3.1.3 **TP1, TP2, TP3, TP4 on the daughter board**

TP1 is internally connected to the 24V bias supply
Connect TP2 to the 0-10V dimmer output negative
Connect TP3 to the 0-10V dimmer output positive
Connect TP4 to the 0-10V dimmer supply (For most dimmers this is the same as output positive)
### Electrical Performance Specifications

#### Table 1: TPS92210 Universal Input 0-10V dimmable LED Driver Electrical Performance Specifications

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
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<tbody>
<tr>
<td><strong>Input Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage range</td>
<td>Normal operation</td>
<td>100</td>
<td>120/230</td>
<td>264</td>
<td>VAC</td>
</tr>
<tr>
<td>Maximum input current</td>
<td>At 120VAC 60Hz input voltage</td>
<td>0.05</td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td><strong>Output Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output voltage, VOUT</td>
<td></td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>V</td>
</tr>
<tr>
<td>Output load current, IOUT</td>
<td>Input voltage = 120V 60Hz, Load = 50V LED</td>
<td>480</td>
<td>500</td>
<td>520</td>
<td>mA</td>
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<tr>
<td></td>
<td>Input voltage = 230V 50Hz, Load = 50V LED</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output current regulation</td>
<td>Input voltage = 120V 60Hz, Load = 50V LED</td>
<td></td>
<td></td>
<td>&lt;±4</td>
<td>%</td>
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<tr>
<td></td>
<td>Input voltage = 230V 50Hz, Load = 50V LED</td>
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<td></td>
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<td></td>
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<tr>
<td>Output current ripple</td>
<td>Input voltage = 120V 60Hz, Load = 50V LED</td>
<td></td>
<td></td>
<td>&lt;170</td>
<td>mApp</td>
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<td></td>
<td>Input voltage = 230V 50Hz, Load = 50V LED</td>
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<td></td>
<td>&lt;200</td>
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</tr>
<tr>
<td><strong>Systems Characteristics</strong></td>
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<tr>
<td>Switching frequency</td>
<td>Input voltage = 120V 60Hz, Load = 50V LED</td>
<td>120</td>
<td>120</td>
<td></td>
<td>kHz</td>
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<tr>
<td></td>
<td>Input voltage = 230V 50Hz, Load = 50V LED</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Factor</td>
<td>Input voltage = 120V 60Hz, Load = 50V LED</td>
<td></td>
<td></td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Input voltage = 230V 50Hz, Load = 50V LED</td>
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<td></td>
<td>0.96</td>
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<tr>
<td>Efficiency</td>
<td>Input voltage = 120V 60Hz, Load = 50V LED</td>
<td></td>
<td></td>
<td>86</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>Input voltage = 230V 50Hz, Load = 50V LED</td>
<td></td>
<td></td>
<td>86</td>
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</tr>
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</table>
Figure 1: TPS92210 Universal Input 0-10V Dimmable LED Driver Main Board Schematic
Figure 2: TPS92210 Universal Input 0-10V Dimmable LED Driver Daughter Board Schematic
Performance Data and Typical Characteristic Curves

Figures 3 through 13 present typical performance curves for TPS92210 Universal Input 0-10 V dimmable LED Driver

4.1 Efficiency

![Efficiency Graph]

*Figure 3: Efficiency*

4.2 Line Regulation

![Line Regulation Graph]

*Figure 4: Line Regulation*
4.3 Power Factor

Figure 5: Power Factor 60Hz

Figure 6: Power Factor 50Hz
4.4 *Dimming Curve*

![Graph showing LED Current vs. Dimming Voltage](image)

*Figure 7: LED Current vs. Dimming Voltage*
4.5 Start Up

Figure 8: Start Up Waveforms at 120Vac 60Hz Ch1: Rectified AC Input Ch4: LED current

Figure 9: Start Up Waveforms at 230Vac 50Hz Ch1: Rectified AC Input Ch4: LED current
4.6  Input Current

Figure 10: Input Current at 120V 60Hz Ch1: Input Voltage Ch4: Input Current

Figure 11: Input Current at 230V 50Hz Ch1: Input Voltage Ch4: Input Current
4.7 Switch Waveforms

Figure 12: Switch Node at 120V 60Hz Ch1: MOSFET Q6 Drain

Figure 13: Switch Node at 230V 50Hz Ch1: MOSFET Q6 Drain
4.8 EMI Performance

Figure 14: 120VAC Conducted EMI Scan
Figure 15: 230VAC Conducted EMI Scan
The following figures (Figure 16 through Figure 19) show the design of the printed circuit board.

Figure 16: Top Layer and Top Overlay Main Board (Top view)

Figure 17: Bottom Layer and Bottom Overlay Main Board (Bottom view)
Figure 18: Top Layer and Top Overlay Daughter Board (Top view)

Figure 19: Bottom Layer and Bottom Overlay Daughter Board (Bottom view)
## 6 Bill of Materials

Table 1: The components list of the Main Board according to the schematic shown in Figure 1

<table>
<thead>
<tr>
<th>REFERENCE DESIGNATOR</th>
<th>QTY</th>
<th>VALUE</th>
<th>DESCRIPTION</th>
<th>SIZE</th>
<th>MFR</th>
<th>PART NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1</td>
<td>0.1 µF</td>
<td>CAP FILM, 0.1 µF, 630VDC RADIAL</td>
<td>13 x 6mm</td>
<td>EPCOS</td>
<td>B32921C3104M</td>
</tr>
<tr>
<td>C2,C3</td>
<td>2</td>
<td>0.22 µF</td>
<td>CAP FILM, 0.22 µF, 630VDC RADIAL</td>
<td>18 x 7mm</td>
<td>EPCOS</td>
<td>B32922C3224K</td>
</tr>
<tr>
<td>C4</td>
<td>1</td>
<td>0.01 µF</td>
<td>CAP, CERM, 0.01 µF, 1000V, X7R, 10%</td>
<td>1808</td>
<td>Vishay</td>
<td>VJ1808Y103KXGAT</td>
</tr>
<tr>
<td>C5,C13</td>
<td>2</td>
<td>4700 pF</td>
<td>CAP, CERM, 4700pF, 500VAC, Y1, 20%</td>
<td>10mm</td>
<td>Vishay</td>
<td>VY1472M635Y5U63V0</td>
</tr>
<tr>
<td>C6,C7</td>
<td>2</td>
<td>1 µF</td>
<td>CAP, CERM, 1 µF, 100V, +/-10%, X7R</td>
<td>1206</td>
<td>MuRata</td>
<td>GRM31CR72A105KA01L</td>
</tr>
<tr>
<td>C8</td>
<td>1</td>
<td>1000 µF</td>
<td>CAP, Aluminum, 1000 µF, 63V, +/-20%</td>
<td>16 x 35mm</td>
<td>Panasonic</td>
<td>UPW1J02MHD6</td>
</tr>
<tr>
<td>C9</td>
<td>1</td>
<td>47 µF</td>
<td>CAP, Aluminum, 47 µF, 25V, +/-20%</td>
<td>5 x 11mm</td>
<td>Panasonic</td>
<td>EEU-EB1E470S</td>
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<tr>
<td>C10,C11</td>
<td>2</td>
<td>0.1 µF</td>
<td>CAP, CERM, 0.1 µF, 25V, +/-10%, X7R</td>
<td>0603</td>
<td>MuRata</td>
<td>GRM188R71E104KA01D</td>
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<tr>
<td>C12</td>
<td>1</td>
<td>2.2 µF</td>
<td>CAP, CERM, 2.2 µF, 16V, +/-10%, X7R</td>
<td>0805</td>
<td>TDK</td>
<td>C2012X7R1C225K</td>
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<tr>
<td>C14</td>
<td>1</td>
<td>1 µF</td>
<td>CAP, CERM, 1 µF, 25V, +/-10%, X5R</td>
<td>0805</td>
<td>MuRata</td>
<td>GRM216R61E105KA12D</td>
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<tr>
<td>C15</td>
<td>1</td>
<td>0.33 µF</td>
<td>CAP, CERM, 0.33 µF, 16V, +/-10%, X7R</td>
<td>0603</td>
<td>Kemet</td>
<td>C0603C344K4RACUT</td>
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<tr>
<td>C16,C17,C18</td>
<td>3</td>
<td>0.01 µF</td>
<td>CAP, CERM, 0.01 µF, 100V, +/-10%, X7R</td>
<td>0603</td>
<td>AVX</td>
<td>06031C103KAT2A</td>
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<td>C19</td>
<td>1</td>
<td>10 µF</td>
<td>CAP, CERM, 10 µF, 35V, +/-20%, X7R</td>
<td>1210</td>
<td>Taiyo Yuden</td>
<td>GM5325AB7106MM-T</td>
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<tr>
<td>C20</td>
<td>1</td>
<td>330 pF</td>
<td>CAP, CERM, 330pF, 630V, +/-5%, C0G/NP0</td>
<td>1206</td>
<td>TDK</td>
<td>C3216C02J331J</td>
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<tr>
<td>D1</td>
<td>1</td>
<td>16V</td>
<td>Diode, Zener, 16V, 500mW</td>
<td>SOD-123</td>
<td>On Semi</td>
<td>MMSZ4703T1G</td>
</tr>
<tr>
<td>D2</td>
<td>1</td>
<td>12V</td>
<td>Diode, Zener, 12V, 500mA</td>
<td>SOD-123</td>
<td>On Semi</td>
<td>MMSZ4999T1G</td>
</tr>
<tr>
<td>D3</td>
<td>1</td>
<td>800V</td>
<td>Diode, Bridge, 800V, 0.5A</td>
<td>4-SOC1</td>
<td>Fairchild</td>
<td>MB8S</td>
</tr>
<tr>
<td>D4</td>
<td>1</td>
<td>800V</td>
<td>Diode, Ultrafast, 800V, 1A</td>
<td>SMA</td>
<td>Vishay</td>
<td>US1K-E3/61T</td>
</tr>
<tr>
<td>D5</td>
<td>1</td>
<td>600V</td>
<td>DIODE ULT FAST 600V 3A</td>
<td>SMB</td>
<td>ST</td>
<td>STTH1R04U</td>
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<tr>
<td>D6</td>
<td>1</td>
<td>100V</td>
<td>Diode, Small Signal, 100V, 200mA</td>
<td>SOT-23</td>
<td>Fairchild</td>
<td>MM8D1204</td>
</tr>
<tr>
<td>D7,D8</td>
<td>2</td>
<td>24V</td>
<td>Diode, Zener, 24V, 500mA</td>
<td>SOD-123</td>
<td>On Semi</td>
<td>MMSZ4709T1G</td>
</tr>
<tr>
<td>D9</td>
<td>1</td>
<td>100V</td>
<td>Diode, Fast, 100V, 200mA</td>
<td>SOD-123</td>
<td>Diodes</td>
<td>BAV19W-7-F</td>
</tr>
<tr>
<td>F1</td>
<td>1</td>
<td>3A</td>
<td>Fuse, 3A, 350VAC,</td>
<td>10.92mm x 8.76mm x 3.91mm</td>
<td>Littelfuse</td>
<td>047003.YXP</td>
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<tr>
<td>L1</td>
<td>1</td>
<td>22 mH</td>
<td>Common Mode Choke,</td>
<td>17 x 22mm</td>
<td>Taiyo Yuden</td>
<td>TLF14CB2230R4K1</td>
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<tr>
<td>L2</td>
<td>1</td>
<td>2.2 mH</td>
<td>INDUCTOR 2200UH 0.62A</td>
<td>13 x 16mm</td>
<td>Colicraft</td>
<td>RFS1317-225KL</td>
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<tr>
<td>Q1</td>
<td>1</td>
<td>950V</td>
<td>MOSFET, N-CH, 950V, 12A</td>
<td>TO-220FP</td>
<td>ST</td>
<td>STF15N95K5</td>
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<tr>
<td>Q2,Q3</td>
<td>2</td>
<td>40V</td>
<td>Transistor, NPN, 40V, 0.2A,</td>
<td>SOT-23</td>
<td>Fairchild</td>
<td>MMBT3904</td>
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<tr>
<td>Q4</td>
<td>1</td>
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<td>PNP Transistor</td>
<td>SOT-23</td>
<td>Diodes</td>
<td>MMBT3906-7-F</td>
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<tr>
<td>R1,R2,R22,R23</td>
<td>4</td>
<td>549k Ω</td>
<td>Resistor, Chip, 1/4W, 1%</td>
<td>1206</td>
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<tr>
<td>R3</td>
<td>1</td>
<td>4.99 Ω</td>
<td>Resistor, Chip, 1/10W, 1%</td>
<td>0603</td>
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<td></td>
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<tr>
<td>R4</td>
<td>1</td>
<td>10k Ω</td>
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<tr>
<td>R5</td>
<td>1</td>
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<td>Resistor, Chip, 1/10W, 1%</td>
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<td>1</td>
<td>100 kΩ</td>
<td>Resistor, Chip, 1/10W, 1%</td>
<td>0603</td>
<td></td>
<td></td>
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<tr>
<td>R8</td>
<td>1</td>
<td>23.2 kΩ</td>
<td>Resistor, Chip, 1/10W, 1%</td>
<td>0603</td>
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### Table 2: The components list of the Daughter Board according to the schematic shown in Figure 2

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<th>REFERENCE DESIGNATOR</th>
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<th>VALUE</th>
<th>DESCRIPTION</th>
<th>SIZE</th>
<th>MFR</th>
<th>PART NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1,C2</td>
<td>2</td>
<td>0.01 μF</td>
<td>CAP, CERM, 0.01μF, 100V, +10/%, X7R</td>
<td>0603</td>
<td>AVX</td>
<td>06031C103KAT2A</td>
</tr>
<tr>
<td>C3</td>
<td>1</td>
<td>22 μF</td>
<td>CAP, CERM, 22μF, 6.3V, +20/%, X5R</td>
<td>0805</td>
<td>Murata</td>
<td>GRM21BR60J226ME39L</td>
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<tr>
<td>D1</td>
<td>1</td>
<td>15V</td>
<td>Diode, Zener, 15V, 500mW</td>
<td>SOD-123</td>
<td>On Semi</td>
<td>MMSZ4702T1G</td>
</tr>
<tr>
<td>Q1</td>
<td>1</td>
<td>40V</td>
<td>Transistor, Programmable Unijunction 40V, 300mW</td>
<td>TO-92</td>
<td>On Semi</td>
<td>2N6027</td>
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<tr>
<td>Q2</td>
<td>1</td>
<td>40V</td>
<td>PNP Transistor</td>
<td>SOT-23</td>
<td>Diodes</td>
<td>MMBT3906-7-F</td>
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<tr>
<td>R1</td>
<td>1</td>
<td>1.0 MΩ</td>
<td>Resistor, Chip, 1/10W, 1%</td>
<td>0603</td>
<td>std</td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td>1</td>
<td>30.1 kΩ</td>
<td>Resistor, Chip, 1/10W, 1%</td>
<td>0603</td>
<td>std</td>
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<tr>
<td>R3</td>
<td>1</td>
<td>13.3 kΩ</td>
<td>Resistor, Chip, 1/10W, 1%</td>
<td>0603</td>
<td>std</td>
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<tr>
<td>R4,R7,R8</td>
<td>1</td>
<td>10.0 kΩ</td>
<td>Resistor, Chip, 1/10W, 1%</td>
<td>0603</td>
<td>std</td>
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<tr>
<td>R9</td>
<td>1</td>
<td>143 kΩ</td>
<td>Resistor, Chip, 1/10W, 1%</td>
<td>0603</td>
<td>std</td>
<td></td>
</tr>
<tr>
<td>R10</td>
<td>1</td>
<td>4.75 kΩ</td>
<td>Resistor, Chip, 1/10W, 1%</td>
<td>0603</td>
<td>std</td>
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<tr>
<td>R11</td>
<td>1</td>
<td>200 kΩ</td>
<td>Resistor, Chip, 1/10W, 1%</td>
<td>0603</td>
<td>std</td>
<td></td>
</tr>
<tr>
<td>U1</td>
<td>1</td>
<td>OptoCoupler</td>
<td>4-SMD</td>
<td>Fairchild</td>
<td>FOD817DS</td>
<td></td>
</tr>
<tr>
<td>U2</td>
<td>1</td>
<td>Low Power Low Offset Voltage Dual Comparator</td>
<td>8-SOIC</td>
<td>Texas Instruments</td>
<td>LM393M</td>
<td></td>
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</tbody>
</table>
EVALUATION BOARD/KIT/MODULE (REF DESIGN) WARNINGS, RESTRICTIONS AND DISCLAIMER

For Feasibility Evaluation Only, in Laboratory/Development Environments. The REF DESIGN is not a complete product. It is intended solely for use for preliminary feasibility evaluation in laboratory / development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical / mechanical components, systems and subsystems. It should not be used as all or part of a production unit.

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