# FEB157-001 User's Guide
## Offline High Brightness
## LED Driver Evaluation Board

### Featured Fairchild Product: FAN7554

## Contents

# 1. Introduction

## 1.1 Product Description

A high brightness LED evaluation board has been developed using the Fairchild Semiconductor FAN7554D PWM controller. The board has the capability of driving one, two or three Lumiled, or similar LEDs. The output current is user selectable at 350mA, 700mA, or 1A. The current is selectable by inserting or removing jumpers JP1 and JP2 on the evaluation board. The board is designed to operate over the universal AC line range of 90Vac to 270Vac. A picture of the board is shown in Figure 1.

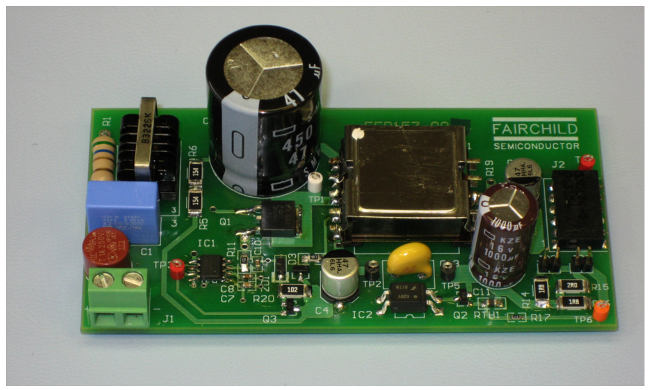


**Figure 1: Offline High Brightness LED Driver Board**

## 1.2 Circuit Description

The FEB157 evaluation board is an offline flyback converter utilizing the PWM controller, FAN7554D. Rather than controlling the output voltage, it is designed to control the LED load current. This is the preferred technique to drive high brightness LEDs. Controlling the LED current allows for a constant brightness as well as long life of the LEDs. The schematic of the FEB157 is shown in Figure 3 below.

Referring to Figure 3, the input AC line voltage comes in through J1. Capacitor C1, and common mode line choke, LF1, form the conducted EMI filter. The dc resistance of LF1 and R1 limit the inrush current at turn on. Diode bridge BD1 and filter capacitor C2 convert the ac voltage to an unregulated dc voltage. Resistors R5 and R6 provide the initial startup current for the FAN7554D. Capacitor C8 off of pin 2 of the FAN7554D provides for soft start in that the pulse width will gradually increase slowly at turn on thereby decreasing the stress on Q1. Once the converter is up and running the operating bias voltage will come from the auxiliary winding (pins 4–5) on transformer T1.

The oscillator frequency of the FAN7554D is set by an RC network, R10 and C9. In this board the frequency is set to 100kHz. However, the FAN7554D can be operated as high as 500kHz.

The FAN7554D is a current mode PWM controller. Current mode operation implies that there are two control loops. An inside loop that controls the current through the primary winding of the transformer and an outer loop that controls the output voltage. However, as previously stated, in this application the outer loop will actually provide feedback information regarding the LED load current instead of the output voltage.

Since the output current is being controlled instead of the output voltage, the output voltage will actually vary with the number of LEDs on the output. The same applies to the auxiliary winding that provides the bias supply to the FAN7554D. Consequently, the transformer had to be designed to provide enough bias when powering one LED. Then when powering three LEDs, the bias voltage is significantly higher. In order to maintain reliable operation, a regulator circuit consisting of R20, ZD1 and Q3 is implemented. This circuit will regulate the voltage to the Vcc pin of the FAN7554 to 18V when there are multiple LEDs on the output. Please note that this circuit would not be needed in a conventional application where the number of LEDs on the output is known and fixed. In such an application, the transformer would then be designed to provide the required Vcc voltage for that particular number of LEDs.

The FAN7554D will take feedback information from the sense resistor, R12, and from the feedback pin, pin 1, and generate a PWM signal that is applied to the FET at location Q1. This FET, FDQ2N80, is a 2A, 800V, N-channel MOSFET in a DPAK package. As with any flyback converter, energy is stored in the transformer while the FET is on, and released to the secondary when the FET is turned off. Since no transformer can be constructed with perfect coupling, the network consisting of resistors R2, R3, R4, diode D1 and capacitor C3 clamp the resulting leakage inductance spike so that it does not endanger Q1.

The transformer, T1, is constructed on an EFD20 core/bobbin. The energy stored in the transformer during the on time of Q1 is delivered to the secondary during the off time of Q1. Diode D4, and C11 rectify and filter the resulting secondary waveform to form a dc voltage. Inductor L1 and capacitor C12 provide additional attenuation of any residual switching spikes on the output voltage. Connector J2 is a Tyco six position connector (p/n 535676-5) that will mate with Future Electronics LED "Emitter" boards to carry the dc power to the LEDs. A picture of a three LED assembly is shown in Figure 2.

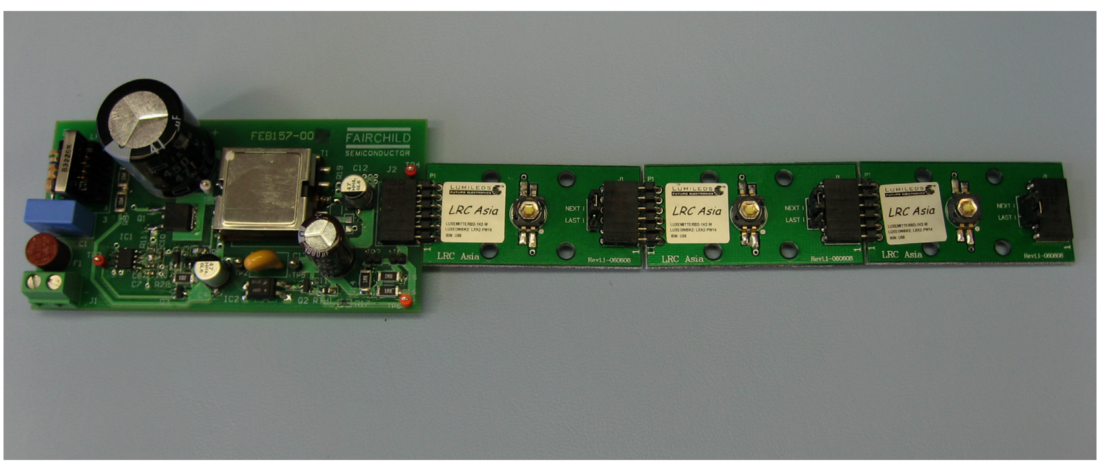



**Figure 2: Offline LED Driver and LED Assembly**

As previously mentioned, when driving high brightness LEDs the objective is to control the LED current. There are different ways of controlling the current. In this evaluation board a method utilizing sense resistors and an NPN transistor is used. Referring to the schematic in Figure 3, resistors R14, R15, and R16 are the resistors that sense the return current from the LED load. Jumpers JP1 and JP2 allow the selection of the output current. Table 1 describes the jumper status for particular output currents.

**Table 1: Jumper JP1/JP2 Status and LED Current**

| LED Current | JP1 Status | JP2 Status |
|---|---|---|
| 350mA | Out | Out |
| 700mA | In | Out |
| 1A | In | In |

Refer to the schematic in Figure 3. As the LED current returns back to the power supply, it develops a voltage across the sense resistor(s). Once this voltage reaches the base-emitter junction voltage of the NPN Q2, typically about 650mV, the transistor will conduct collector current. This current also flows through the photodiode inside the optocoupler, IC2. The optocoupler will transfer this feedback information optically across the primary-secondary boundary to the primary side of the supply thereby maintaining the necessary isolation. Thermistor RTH1, is a negative temperature coefficient device and compensates for changes in base-emitter voltage due to temperature change.

# 2. Electrical Requirements

## 2.1 Input Requirements

Voltage range: 90Vrms to 270Vrms

Frequency: 47Hz to 63Hz

## 2.2 Output Requirements

The FEB157 board will power one, two, or three high brightness LEDs (Lumiled or similar) at user selectable load currents of 350mA, 700mA, or 1A.

# 3. Designed Solution

## 3.1 Schematic

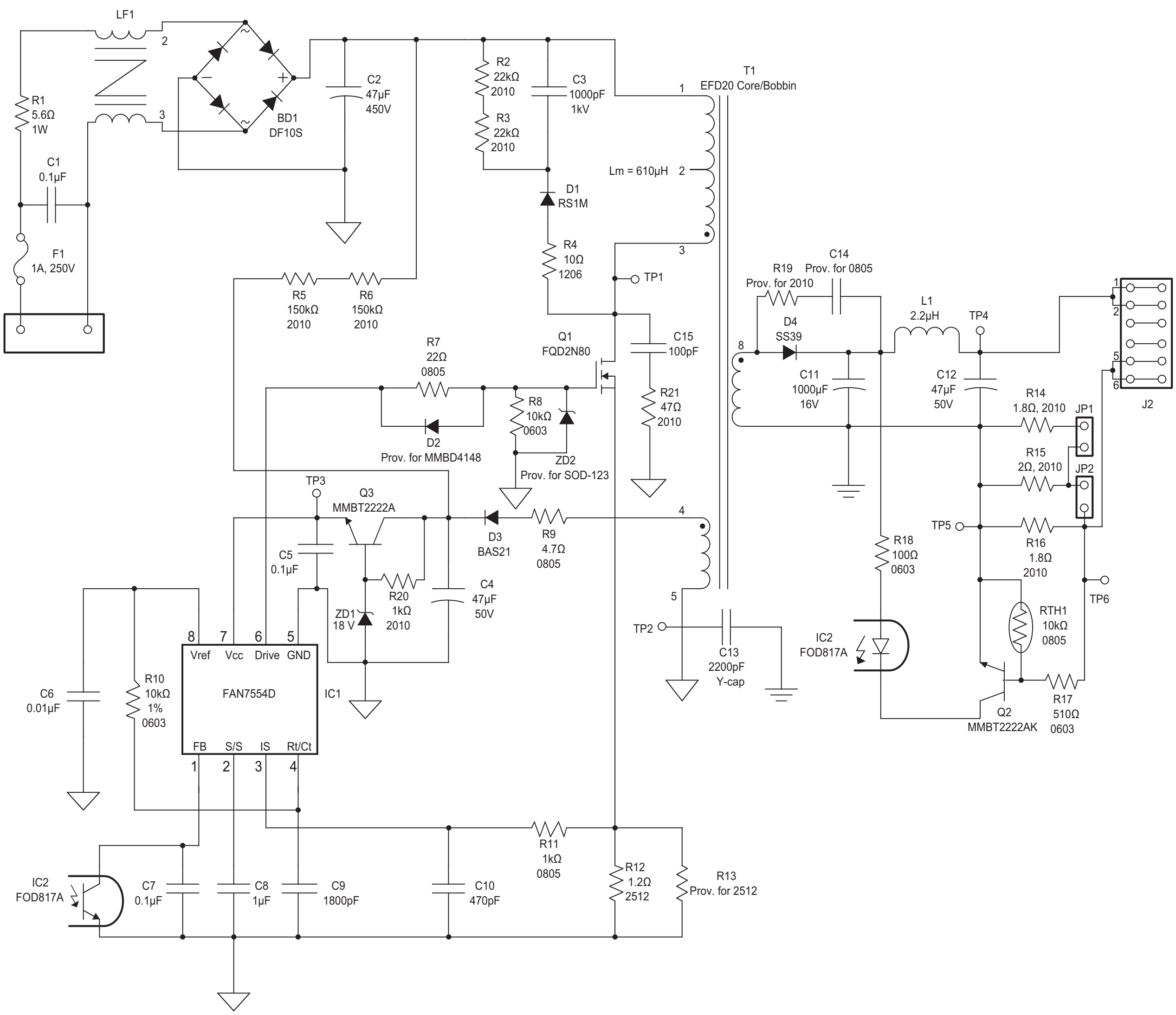


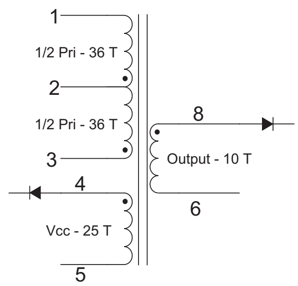

**Figure 3: Schematic of the FEB157 Offline High Brightness LED Driver Board**

## 3.2 Transformer

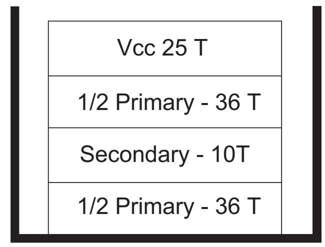
**Required Components**

Core = EFD20
Bobbin = 10 pin; SMD; Horizontal

**Schematic**




**Winding Stackup**




**Electrical Specifications**

| | Pin | Spec. | Remarks |
|---|---|---|---|
| Inductance | 1 - 3 | 537.0 - 656.0 uH | 100 kHz, 0.10 Vrms |
| Leakage | 1 - 3 | | All other windings shorted |

## 3.3 Bill of Materials

| Sch Ref | Vendor | Part Number | Description |
|---|---|---|---|
| BD1 | Fairchild | DF10S | 1.5A, 1000 V Bridge |
| C1 | NIC Components or Equivalent | NPX104M275VX2M | 0.1μF, X2 cap |
| C2 | NIC Components | NREH470M450V18X36F | 47μF, 450V |
| | UCC | ESMH451ESN470MN25S | 47μF, 450V |
| C3 | TDK | C4520X7R3A102KT | 1000 pF, 1kV, SMD |
| C4 | NIC Components or Equivalent | NACK470M50V6.3X8TR | 47μF, 50V, SMD |
| C5 | NIC Components or Equivalent | NMC0603X7R104K50TRP | 0.1μF, 50V, 0603 |
| C6 | NIC Components or Equivalent | NMC0603X7R103K50TRP | 0.01μF, 50V, 0603 |
| C7 | NIC Components or Equivalent | NMC0603X7R104K50TRP | 0.1μF, 50V, 0603 |
| C8 | NIC Components or Equivalent | NMC0603X7R105K16TRP | 1.0μF, 16V, 0603 |
| C9 | NIC Components or Equivalent | NMC0603NPO182F25TRP | 1800 pF, 25V, 0603, NPO |
| C10 | NIC Components or Equivalent | NMC0603X7R471K50TRP | 470 pF, 50V, 0603 |
| C11 | NIC Components or Equivalent | NRSJ102M16V10X16TB | 1000μF, 16V, Leaded |
| C12 | NIC Components or Equivalent | NACK470M50V6.3X8TR | 47μF, 50V, SMD |
| C13 | Panasonic | ECK-NVS222ME | 2200pF, Y-rated cap |
| C14 | | | Prov. for 0805 |
| C15 | TDK | C4520CH3F101K | 100 pF, 3kV, SMD |

## 3.3 Bill of Materials (Continued)

| Sch Ref | Vendor | Part Number | Description |
|---|---|---|---|
| Conn1 | Phoenix Contact | 1729018 | 2 position terminal block |
| Conn2 | Tyco | 535676-5 | 6 position connector |
| D1 | Fairchild | RS1M | 1A, 1000V, SMA |
| D2 | Fairchild | Prov. for MMBD4148 | |
| D3 | Fairchild | BAS21 | 0.2A, 250V, SOT-23 |
| D4 | Fairchild | SS39 | 3A, 90V, SMC |
| F1 | Littlefuse | 3721100 | 1A, 250V, Slo-Blo |
| IC1 | Fairchild | FAN7554D | PWM Controller, SO-8 |
| IC2 | Fairchild | FOD817A | Optocoupler |
| JP1 | Sullins | PRPN021PAEN-RC | 2 pin header (2mm) |
| JP2 | Sullins | PRPN021PAEN-RC | 2 pin header (2mm) |
| JP1 | Sullins | STN02SYBN-RC | 2 pin shunt |
| JP2 | Sullins | STN02SYBN-RC | 2 pin shunt |
| L1 | Coilcraft | DO1608C-222 | 2.2µH |
| LF1 | Sumida | UU9LFBNP-B322 | 3.2mH |
| Q1 | Fairchild | FQD2N80 | 2A, 800V, N-channel, DPAK |
| Q2 | Fairchild | MMBT2222AK | 0.6A, 40V, NPN |
| Q3 | Fairchild | MMBT2222AK | 0.6A, 40V, NPN |
| R1 | NIC Components or Equivalent | NCF100J5R6TR | 5.6Ω, 1 W |
| R2 | NIC Components or Equivalent | NRC50J223TR | 22kΩ, 1/2 W, 2010 |
| R3 | NIC Components or Equivalent | NRC50J223TR | 22kΩ, 1/2 W, 2010 |
| R4 | NIC Components or Equivalent | NRC12J100TR | 10Ω, 1/4 W, 1206 |
| R5 | NIC Components or Equivalent | NRC50J154TR | 150kΩ, 1/2 W, 2010 |
| R6 | NIC Components or Equivalent | NRC50J154TR | 150kΩ, 1/2 W, 2010 |
| R7 | NIC Components or Equivalent | NRC10J220TR | 22Ω, 1/8 W, 0805 |
| R8 | NIC Components or Equivalent | NRC06J103TR | 10kΩ, 1/10 W, 0603 |
| R9 | NIC Components or Equivalent | NRC10J4R7TR | 4.7Ω, 1/8 W, 0805 |
| R10 | NIC Components or Equivalent | NRC06F1002TR | 10kΩ, 1/10 W, 1%, 0603 |
| R11 | NIC Components or Equivalent | NRC10J102TR | 1kΩ, 1/8 W, 0805 |
| R12 | NIC Components or Equivalent | NRC100J1R2TR | 1.2Ω, 1 W, 2512 |
| R13 | | | Prov. for 2512 |
| R14 | NIC Components or Equivalent | NRC50J1R8TR | 1.8Ω, 3/4 W, 2010 |
| R15 | NIC Components or Equivalent | NRC50J2R0TR | 2.0Ω, 3/4 W, 2010 |
| R16 | NIC Components or Equivalent | NRC50J1R8TR | 1.8Ω, 3/4 W, 2010 |

## 3.3 Bill of Materials (Continued)

| Sch Ref | Vendor | Part Number | Description |
|---|---|---|---|
| R17 | NIC Components or Equivalent | NRC06J511TR | 510Ω, 1/10 W, 0603 |
| R18 | NIC Components or Equivalent | NRC06J101TR | 100Ω, 1/10 W, 0603 |
| R19 | | | Prov. for 2010 |
| R20 | NIC Components or Equivalent | NRC50J102TR | 1kΩ, 3/4 W, 2010 |
| R21 | NIC Components or Equivalent | NRC50J470TR | 47Ω, 3/4 W, 2010 |
| RTH1 | NIC Components or Equivalent | NCT08AJ104334TR | 10kΩ, NTC Thermistor, Beta = 3340 |
| T1 | Cooper | CTX0117893 | EFD20 Core/Bobbin Transformer |
| TP1 | Keystone | 5002 | PC Test Point-White |
| TP2 | Keystone | 5001 | PC Test Point-Black |
| TP3 | Keystone | 5000 | PC Test Point-Red |
| TP4 | Keystone | 5000 | PC Test Point-Red |
| TP5 | Keystone | 5001 | PC Test Point-Black |
| TP6 | Keystone | 5003 | PC Test Point-Orange |
| ZD1 | Fairchild | MMSZ5248B | 18V, 1/2W, SOD-123 |
| ZD2 | | | Prov. for SOD-123 |

## 3.4 Printed Circuit Board

The PCB is a double sided board made of FR4 with 1oz copper.

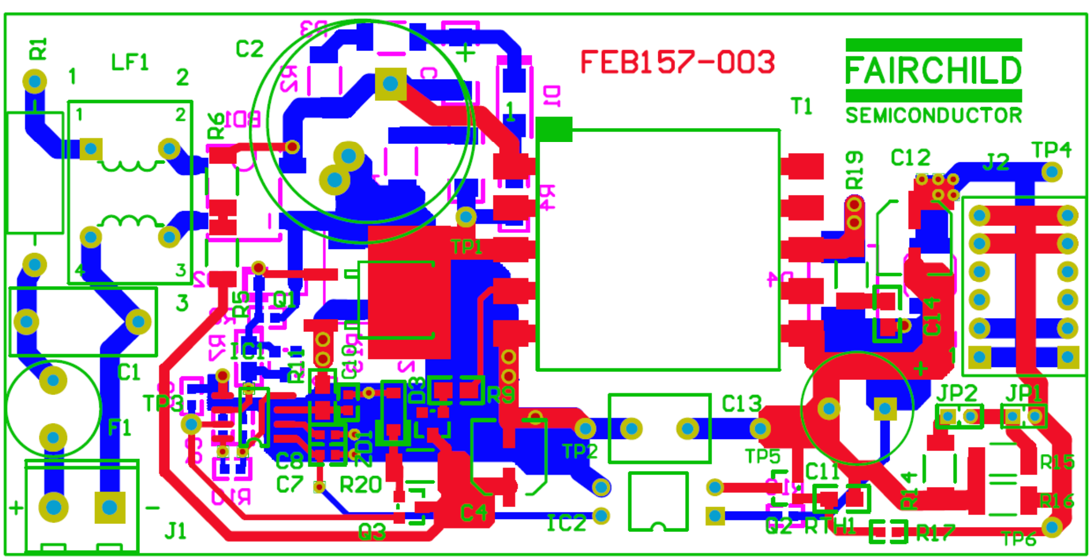



**Figure 4: Silkscreen/Component Placement of PCB Layout**

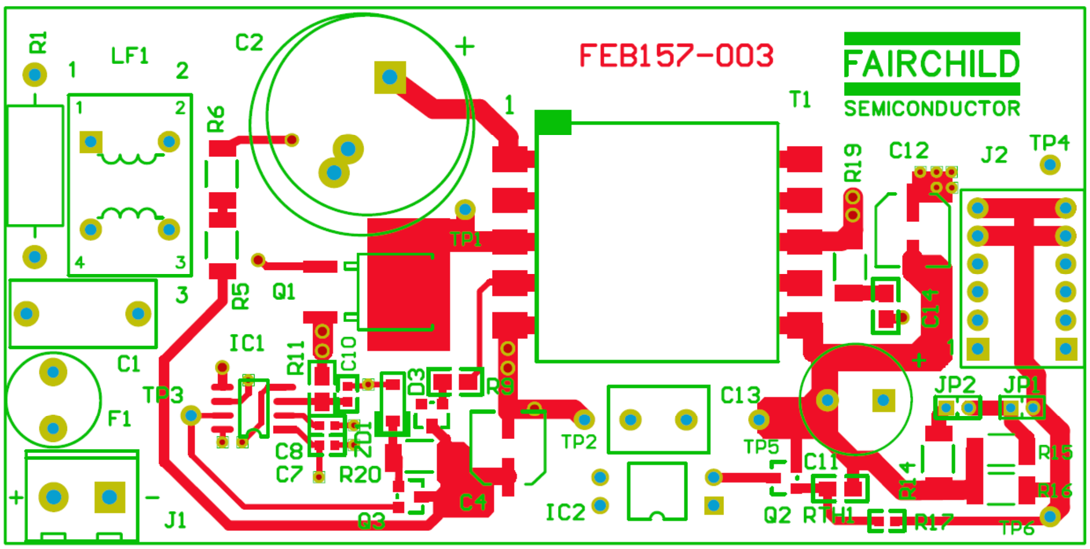



Figure 5: Silkscreen/Component Placement of Top Side Layer

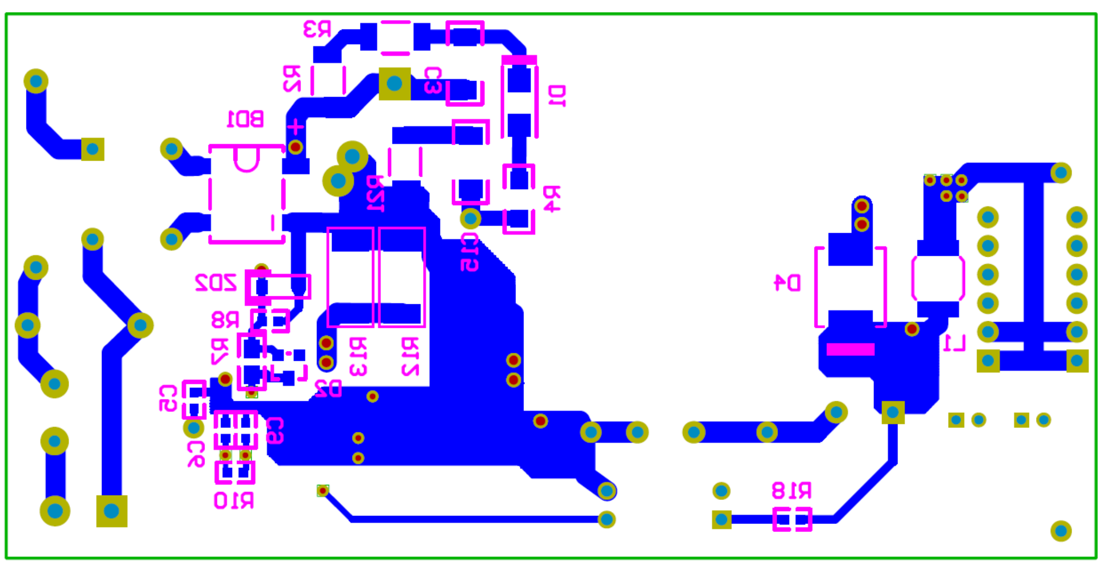


Figure 6: Silkscreen/Component Placement of Bottom Side Layer

# 4. Test Results

## 4.1 Regulation

### 4.1.1 Line Regulation

This graph illustrates the regulation of the output current over line voltage for the three possible settings, 350mA, 700mA, and 1A.

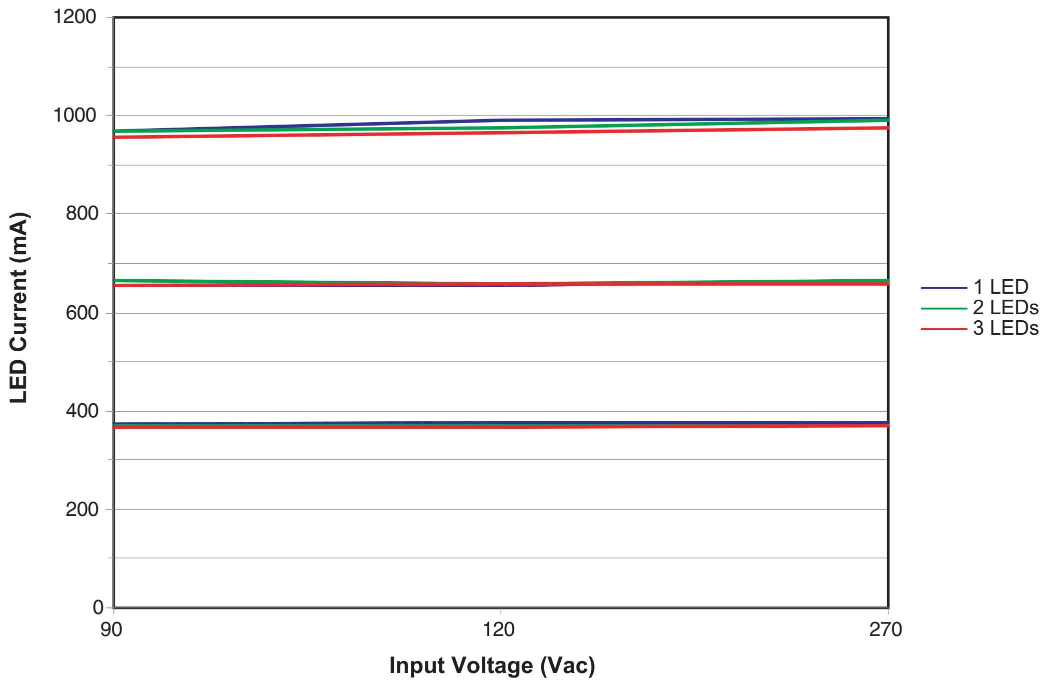



**Figure 7: LED Current vs. Line Voltage**

## 4.2 Efficiency

The efficiency data shown is for the converter with a load of one, two and three LEDs driven at 1A.

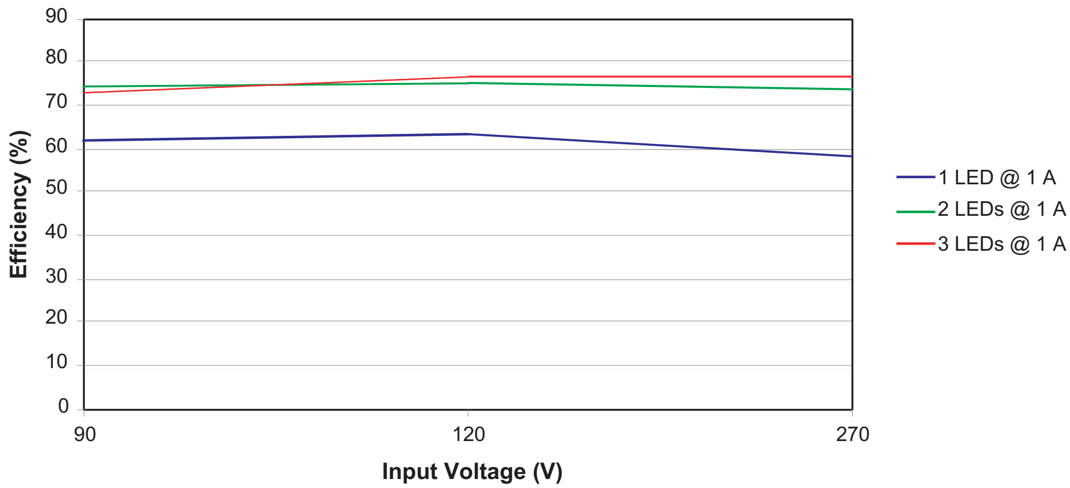



**Figure 8: Converter Efficiency Data Plotted Against Increasing Line Input for LED Current of 1A.**

## 4.3 Steady State Operation

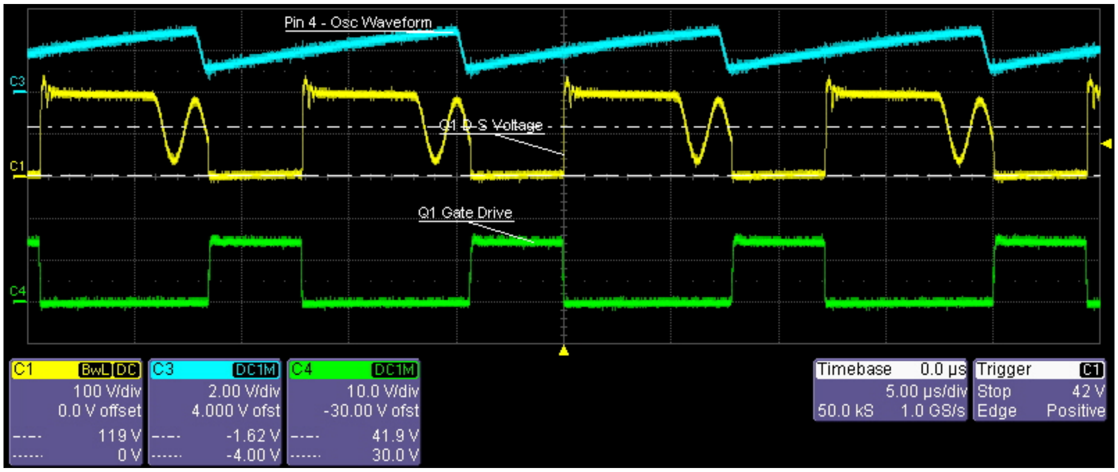



**Figure 9: Steady State Waveforms at 90Vac with Three LEDs at 1A**

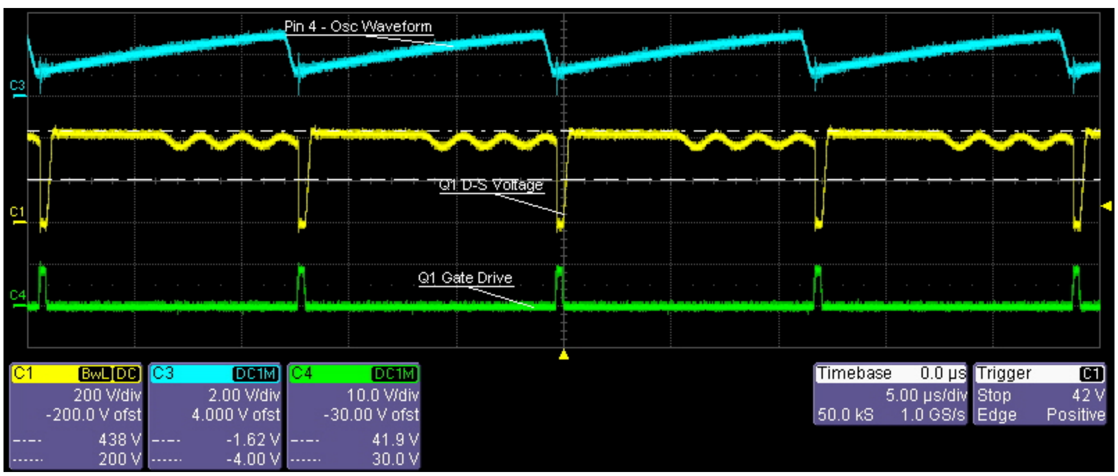



**Figure 10: Steady State Waveforms at 270Vac with One LED at 350mA**

## 4.4 Start up

The startup profile is captured at 90Vac and 270Vac with a load of three LEDs operating at a current of 1A.

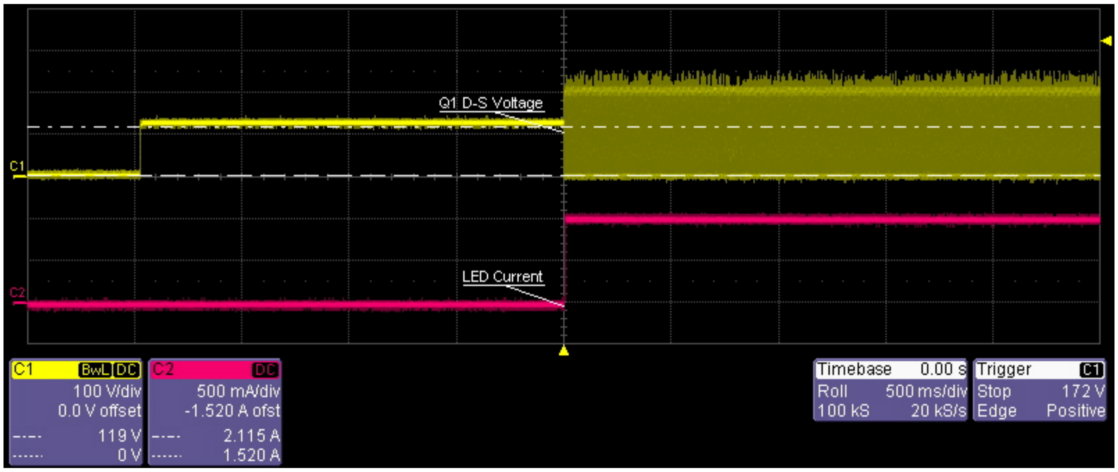



**Figure 11: Startup Profile at 90 Vac with Three LEDs at 1A**

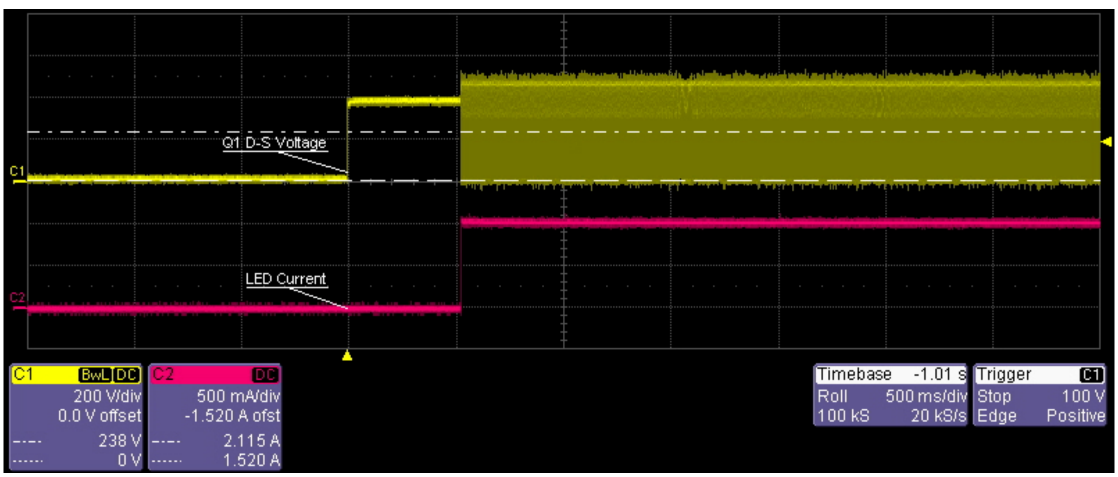



**Figure 12: Startup Profile at 270Vac with Three LEDs at 1A**

**Warning and Disclaimer:**

This Evaluation Board may employ high voltages so appropriate safety precautions should be used when operating this board. Replace components on the Evaluation Board only with those parts shown on the parts list in the User's Guide. Contact an authorized Fairchild representative with any questions.

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