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NCP1252 Boost and CAT4026 LED Driver Board

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APPLICATION NOTE

Introduction

This document describes the NCP1252 Boost and CAT4026 LED Driver board. This board includes a DC−DC boost converter and a linear driver for driving up to 6 strings of LEDs at 100 mA from a regulated 24 V supply. The LED channel current is regulated using the ON Semiconductor CAT4026 LED controller in conjunction with the NCP1252 PWM controller operating in Continuous Conduction Mode (CCM). The boost stage converts the 24 V into an output voltage of up to 130 V for driving long strings of LEDs.

Figure 1 shows a simplified block diagram of the NCP1252 Boost and CAT4026 LED Driver board.

Board Description

The board is configured for driving LED strings at variable currents up to 100 mA maximum.

In order to support high supply voltage of the LED anode, each LED string cathode is connected to an external power transistor. The LED current is set independently for each channel by an external resistor connected between the regulated RSET pin (1 V nominal) and ground.

A PWM logic input (active high) allows to turn on all 6 channels together. The PWM can be used to control the brightness of the LEDs by using a PWM signal where the duty cycle sets the brightness. A frequency of 300 Hz is recommended to get the best dimming resolution. The analog dimming (ANLG input) is an optional feature that can be left unconnected.

The board supports both open cathode−anode and short cathode−anode fault protections which respectively outputs an active−low signal $\overline{\text{FLT−OCA}}$ and $\overline{\text{FLT−SCA}}$ when a fault condition occurs.

Figures 2 and 3 show pictures of the actual board. To be in line with the requested SLIM design, the board has been designed to be less than 8 mm on top of the PCB (12.5 mm overall).

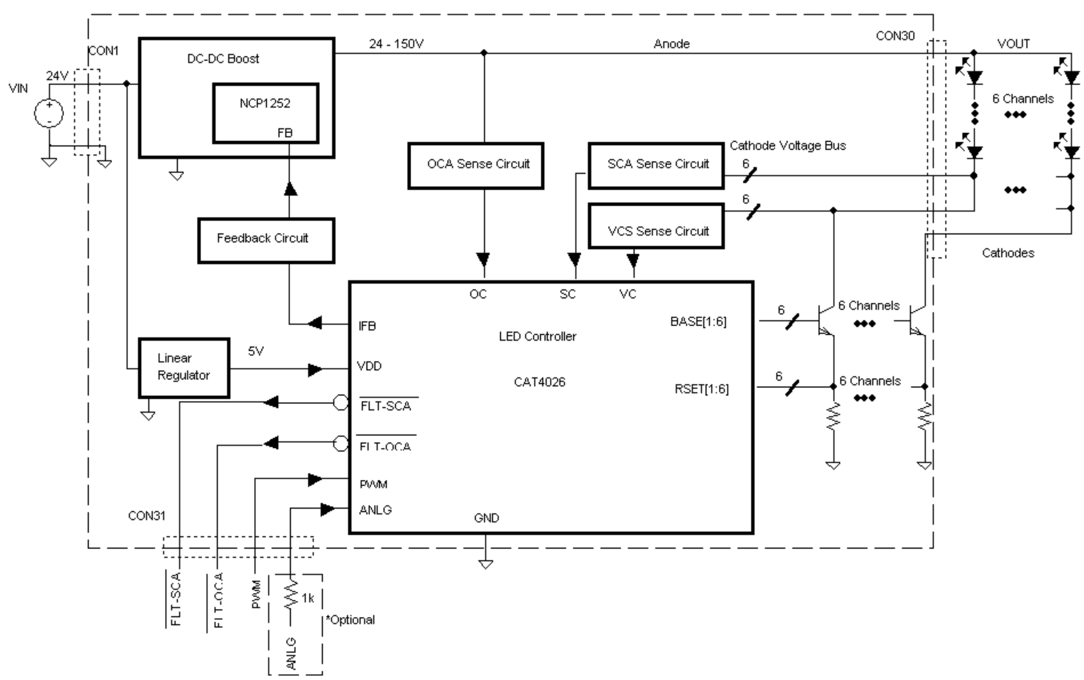

Figure 1. Board Block Diagram

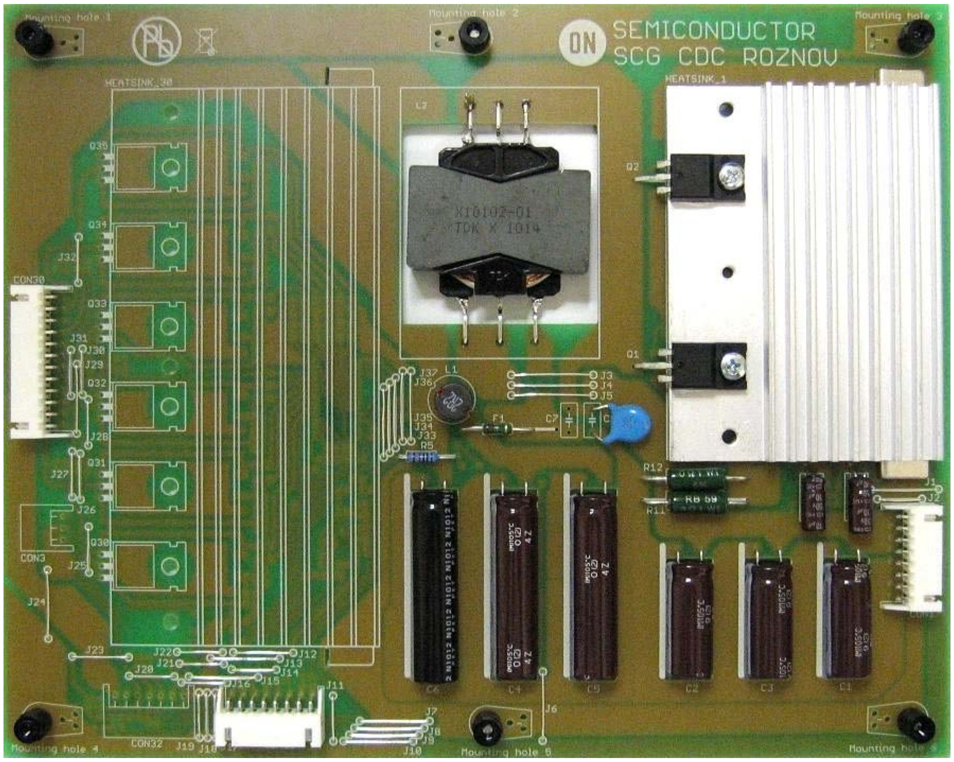

Figure 2. NCP1252 Boost and CAT4026 LED Driver Board (Top Side)

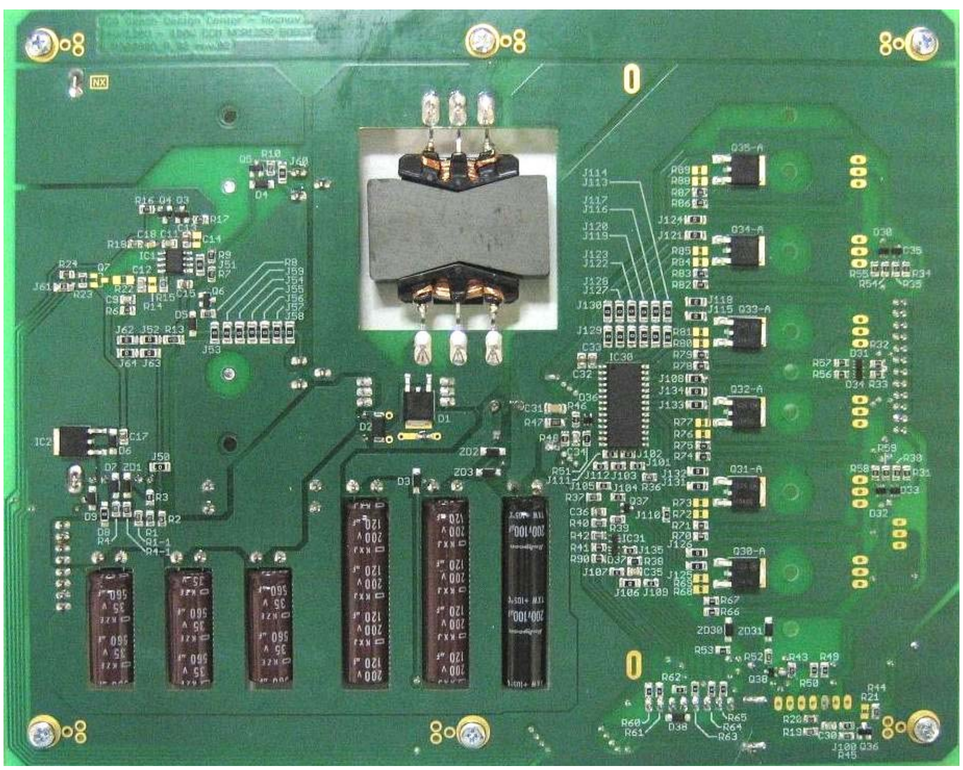

Figure 3. NCP1252 Boost and CAT4026 LED Driver (Bottom Side)

Detailed Operation

The board includes a boost converter and an LED driver section. Each section is described below.

Boost Converter Operation

Most of the LCD conventional Switching Mode Power Supplies (SMPS) provide 24 V for the CCFL backlight. In order to reuse the same existing SMPS and allow for faster design introduction, the new LED backlight can be designed for 24 V supply.

If for direct LED backlight, the 24 V could be sufficient to drive limited diodes segments, the higher numbers of LEDs used for Edge solutions requires much higher voltage. The LED string voltage in the backlight application is typically between 100 V and 150 V.

Boost Concept

As there is no need of main isolation already provided by the 24 V SMPS, a conventional Boost or Step Up is capable to provide the requested higher voltage.

When the Power MOS turns ON, the supply voltage is applied on the Boost coil and the current ramps up.

When the switch turns OFF, the voltage rises up such that current flows to the output cap through rectifier diode. The inductor current ramps down until the Power MOS is switch ON again. If the switch OFF time is long enough, the current may go to zero with complete discharge of the inductor.

$$\Delta I = \left(\frac{Vin}{L}\right)ton = \left(\frac{Vout - Vin}{L}\right)toff \qquad \text{(eq. 1)}$$

Working with high voltage ratio: 120 / 24 = 5, we have 80% typical on time duty cycle (ton./ ton + toff).

Considering possible lower supply and higher output voltages, ton may go up to 90% which is very critical for the controller, not allowing high switching frequency and decreasing the efficiency.

To solve that, the boost is designed with tapped coil allowing for smaller duty cycle despite high voltage ratio.

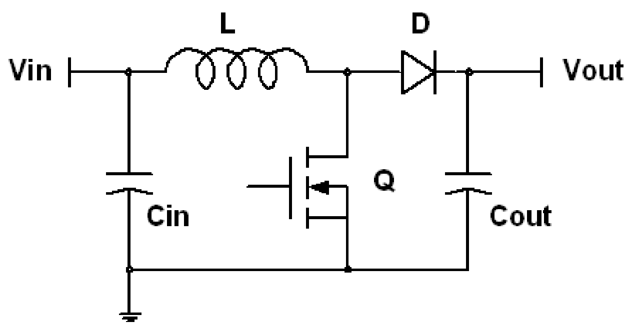

Figure 4. Conventional Boost Solution Schematic

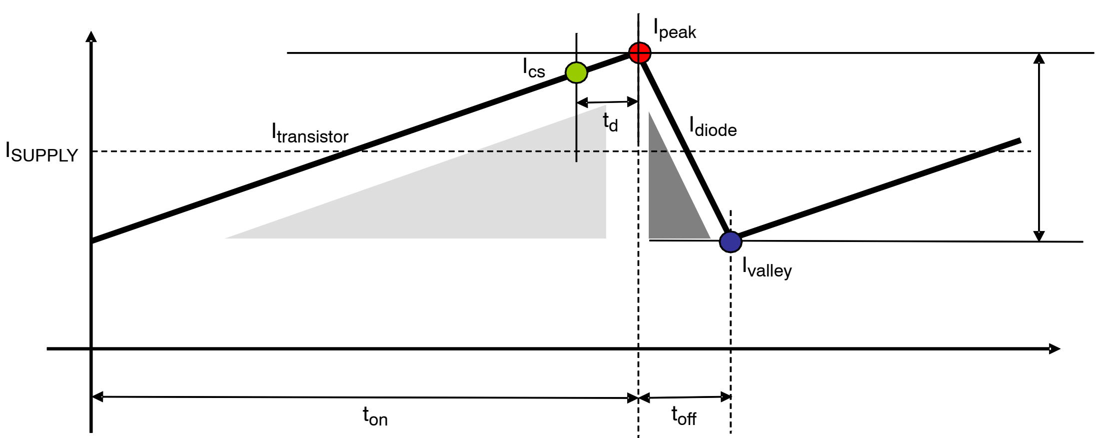

Figure 5. Conventional Boost Current in the Coil

Tapped Coil Boost Concept

The coil has an added connection point allowing the solution to work like a transformer but without the drawback of poor coupling.

$$\Delta I = \left(\frac{Vin}{Lp}\right)ton = \left(\frac{Vout - Vin}{Lp + Ls}\right)toff \qquad \text{(eq. 2)}$$

$$\frac{ton}{toff} = \left(\frac{Np}{Np + Ns}\right)\left(\frac{Vout - Vin}{Vin}\right) \qquad \text{(eq. 3)}$$

With $N_s = 3.3\ N_p$, for 24 Vin and 120 Vout, we are getting $t_{on} \approx t_{off}$ (about 50% duty cycle).

Tapped Coil Boost Design Consideration

With correct turn's ratio, the boost coil allows to get down to 50% duty cycle despite high boost voltage ratio (V_{out} / V_{in}). The larger t_{off} allows a reduction of rms current in both output diode and capacitor.

The shorter ton for the Power MOS switch, working with lower inductance, asks for a larger peak and rms current, requesting for low Rds−on to avoid over power dissipation and temperature.

The high secondary inductance Ls will limit the di/dt such that an added diode D2 should be connected from the switch to the output capacitor to avoid overvoltage on the Power MOS. This diode D2 can be small thanks to the very short conduction time.

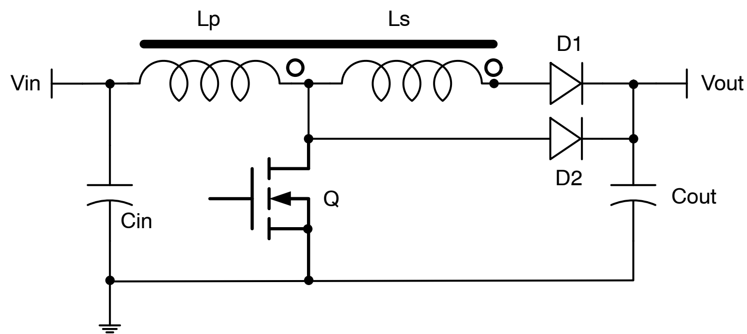

Figure 6. Tapped Coil Boost Solution Schematic

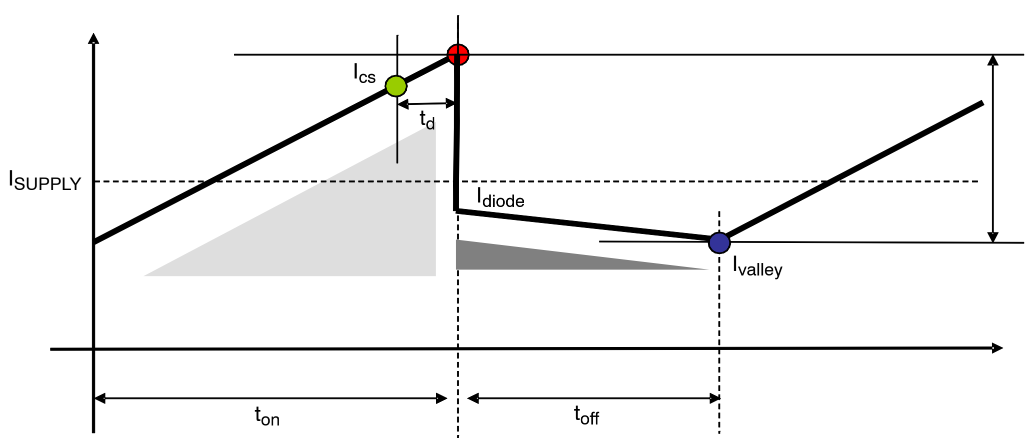

Figure 7. Tapped Coil Boost Current in the Coil

NCP1252B Controller

The NCP1252 controller is an improved UC384X previous solution. With more features and much reduced number of external surrounding parts, it offers everything needed to build cost−effective and reliable switching supplies or Boost converter.

Thanks to the use of an internally 10 ms fixed timer, NCP1252 detects an output overload without relying on the auxiliary V_{CC}. A Brown−Out input offers protection against low input voltages and improves the converter reliability and safety. The switching frequency is adjustable with an external resistance to provide highest design flexibility. The version B allows up to 80% duty cycle avoiding too short t_{off} or diode conduction time. The Internal 160 ns Leading Edge Blanking avoids possible issues with Continuous Conduction Mode and peak current by switch ON of Power MOS. An external capacitor defines the soft start. The wide range of V_{CC} allows easy supply from the 24 V input voltage with auto−recovery UVLO by 9 V.

Finally a SOIC8 package saves PCB space and represents a solution of choice in cost sensitive project.

ICs Supply

The CAT4026 is supplied through a 5 V linear regulator IC2/MC78M05CDTG (up to 35 V input capable) connected directly to the 24 V input voltage. Thanks to the limited current consumption, the regulator is in a DPAK without power dissipation issues.

Despite the NCP1252 could be directly supplied from the 24 V, we use 1 KΩ serial resistance (R1 + R1−1) and 15 V zener ZD1 to avoid too high V_{CC}, reducing the power dissipation in the controller and avoiding Over Voltage transients issues (V_{CC} should not exceeds 28 V).

An additional diode D3 is connected from V_{CC} to the output voltage avoiding NCP1252 to start with output short circuit to GND. To avoid safety issues if the 24 V power supply is not capable to detect this short circuit, the added fuse F1, in series with the output, will open−up and so disconnect the output from the 24 V supply.

Power Stage

To reduce power dissipation, two power MOS transistors (Q1 and Q2) are used in parallel such that R_{ds-on} is reduced by half. For reduced power application, one of the MOS can easily be disconnected to reduce the size of the special low profile heat sink.

Despite the output voltage limit to 130 V, 200 V power MOS should be used due to the overvoltage generated by the tapped boost coil construction.

Additional PNP transistors Q5 and Q6 allow faster Power MOS switch OFF with reduced impedance.

The boost diode D1 is an Ultra fast 5 A / 600 V diode MURHD560T4G allowing Continuous Conduction Mode with limited switching losses thanks to the low t_{rr}. The reversed voltage applied by the tapped coil asks for a voltage much higher than output voltage (classical boost).

To reduce peak voltage on the Power MOS switches, an additional diode D2 is added. Thanks to the limited conduction time, a 1 A / 200 V MURA120T3 is enough.

Tapped Boost Coil

To allow SLIM design below 8 mm height on top of the PCB, the coil has been design on special bobbin to be inserted within a PCB hole. Designed with PQ3811, the primary inductance of 30 μH is able to support up to 12 A without saturation while the secondary inductance with 270 μH allows to work with 50% duty cycle.

The 65 kHz switching frequency provides a good compromise between switching losses, efficiency and boost coil size.

Electrolytic Capacitors

To allow low profile design, all electrolytic capacitors are 10 mm diameter type, solder flat on the board with open holes allowing the parts to be partially below the PCB. The high RMS currents require using multiple capacitors in parallel for both the input and output of boost converter.

Boost Oscillograms

Brown Out: Vstart = 21.1 V & Vstop = 19.4 V

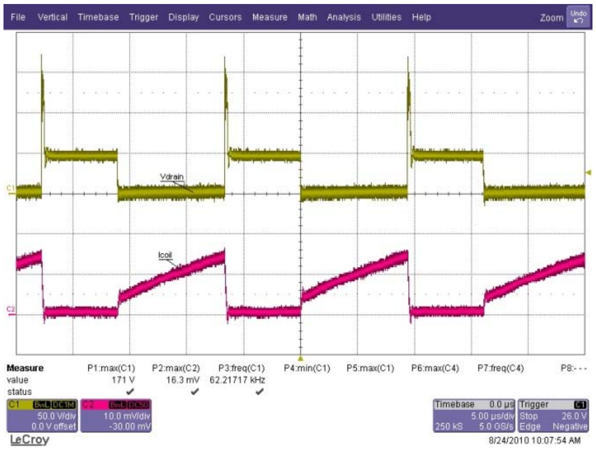

Figure 8. Boost Coil Current Waveform

For Vin = 24 V – 10%, Vout = 125 V, Pout = 73 W

Power MOS Q1 & Q2 Drain Voltage

50 V/div $\quad V_{Drain\ Max} = 171$ V

Boost coil input current

5 A/div $\quad I_{coilMax} = 8.1$ A

5 µs/div $\quad$ 62.2 kHz

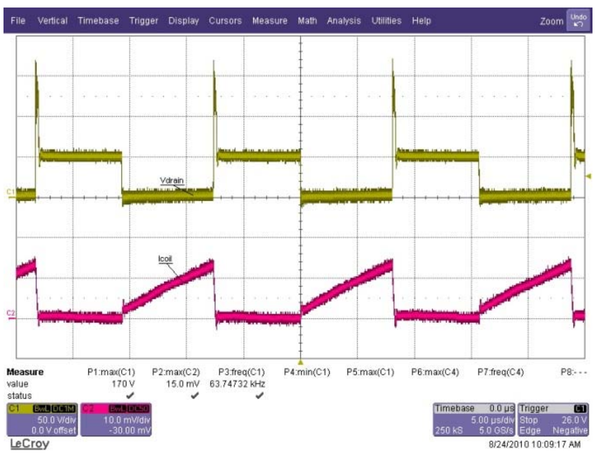

Figure 9. Boost Coil Current Waveform

For Vin = 24 V + 10%, Vout = 125 V, Pout = 73 W

Power MOS Q1 & Q2 Drain Voltage

50 V/div $\quad V_{Drain\ Max} = 170$ V

Boost coil input current

5 A/div $\quad I_{coilMax} = 7.5$ A

5 µs/div $\quad$ 63.7 kHz

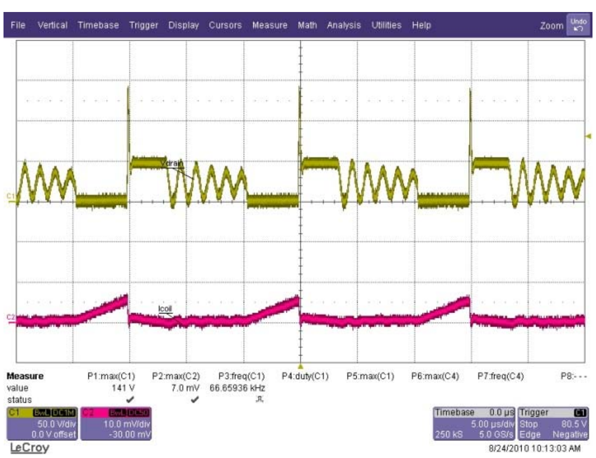

Figure 10. Boost Coil Current Waveform

For Vin = 24 V – 10%, Vout = 125 V, Pout = 10 W

Power MOS Q1 & Q2 Drain Voltage

50 V/div $\quad V_{Drain\ Max} = 141$ V

Boost coil input current

5 A/div $\quad I_{coilMax} = 3.5$ A

5 µs/div $\quad$ 66.7 kHz

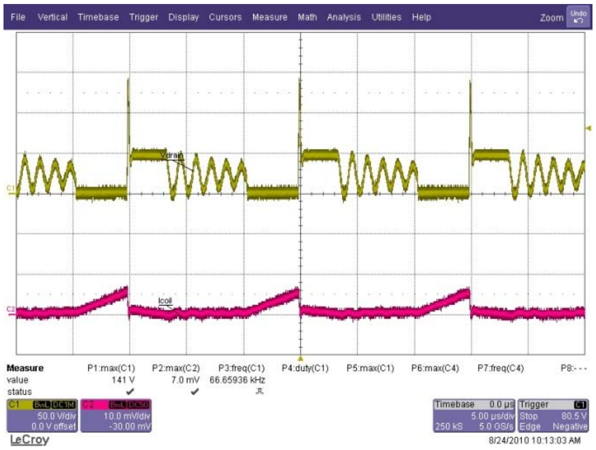

Figure 11. Boost Coil Current Waveform

For Vin = 24 V + 10%, Vout = 125 V, Pout = 10 W

Power MOS Q1 & Q2 Drain Voltage
50 V/div $V_{Drain\ Max}$ = 141 V

Boost coil input current
5 A/div $I_{coilMax}$ = 3 A
5 μs/div 62.3 kHz

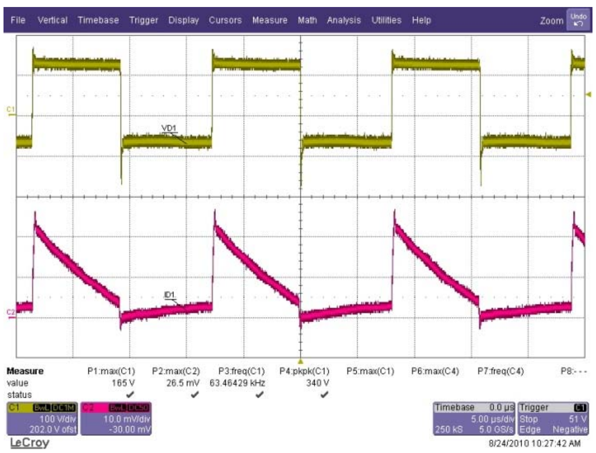

Figure 12. Boost Diode D1 Current Waveform

For Vin = 24 V + 10%, Vout = 125 V, Pout = 73 W

Boost diode D1 reversed Voltage
100 V/div $V_{DiodeMax}$ = 340 V

Boost diode D1 current
1 A/div $I_{DiodeMax}$ = 2.6 A
5 μs/div 63.5 kHz

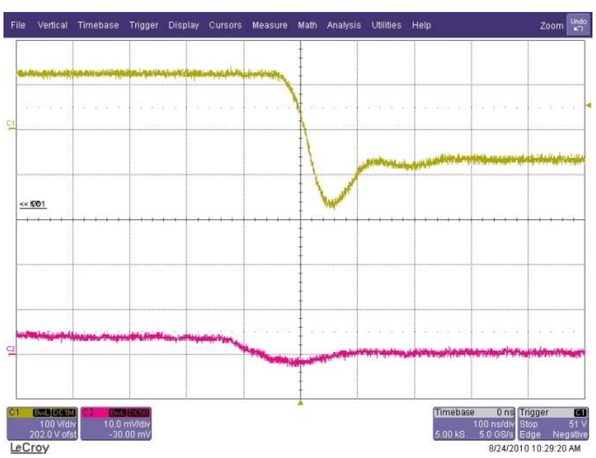

Figure 13. Boost Diode D1 Switch OFF Waveform Expend of Figure 12

For Vin = 24 V + 10%, Vout = 125 V, Pout = 73 W

Boost diode D1 reversed Voltage
100 V/div $V_{diodeMax}$ = 340 V

Boost diode D1 current
1 A/div $I_{DiodeMax}$ = 2.6 A
100 ns/div 63.5 kHz

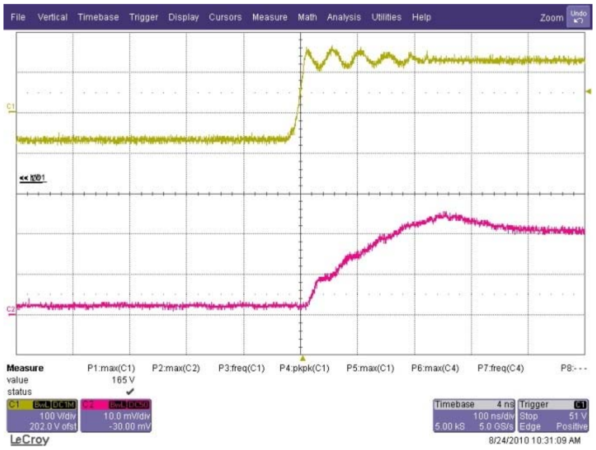

Figure 14. Boost Diode D1 Switch ON Expend of Figure 12

For Vin = 24 V + 10%, Vout = 125 V, Pout = 73 W

Boost diode D1 reversed Voltage
100 V/div $V_{diodeMax} = 165$ V

Boost diode D1 current
1 A/div $I_{DiodeMax} = 2.6$ A
100 ns/div 63.5 kHz

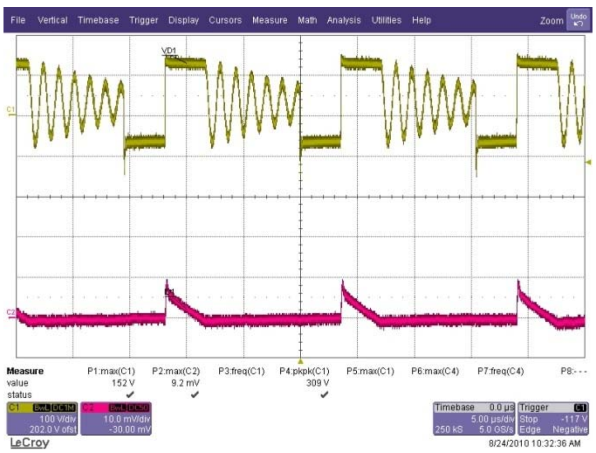

Figure 15. Current in the Boost Diode D1

For Vin = 24 V + 10%, Vout = 125 V, Pout = 10 W

Boost diode D1 reversed Voltage
100 V/div $V_{DiodeMax} = 309$ V

Boost diode D1 current
1 A/div $I_{DiodeMax} = 0.92$ A
5 µs/div 63 kHz

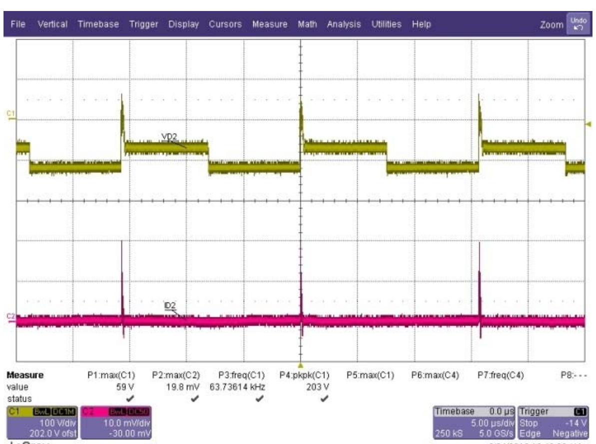

Figure 16. Current in the Tapped Boost Diode D2

For Vin = 24 V + 10%, Vout = 125 V, Pout = 73 W

Tapped Boost diode D2 reversed Voltage
100 V/div $V_{DiodeMax} = 203$ V

Boost diode D1 current
5 A/div $I_{DiodeMax} = 9.9$ A
5 µs/div 63.7 kHz

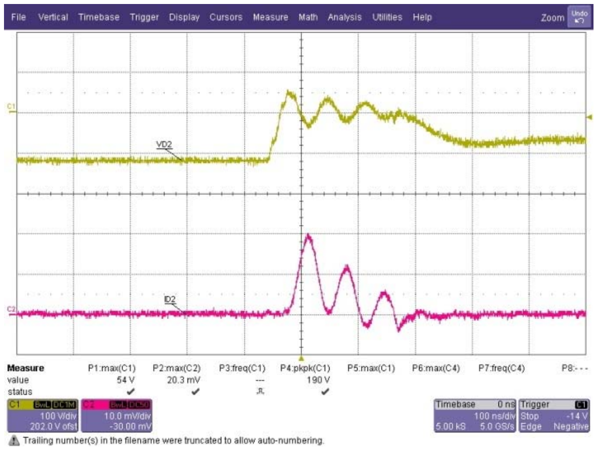

Figure 17. Current in the Tapped Boost Diode D2 Expend of Figure 16

For Vin = 24 V + 10%, Vout = 125 V, Pout = 73 W

Tapped Boost diode D2 reversed Voltage
100 V/div $V_{DiodeMax}$ = 203 V

Boost diode D1 current
5 A/div $I_{DiodeMax}$ = 9.9 A
100 ns/div 63.7 kHz

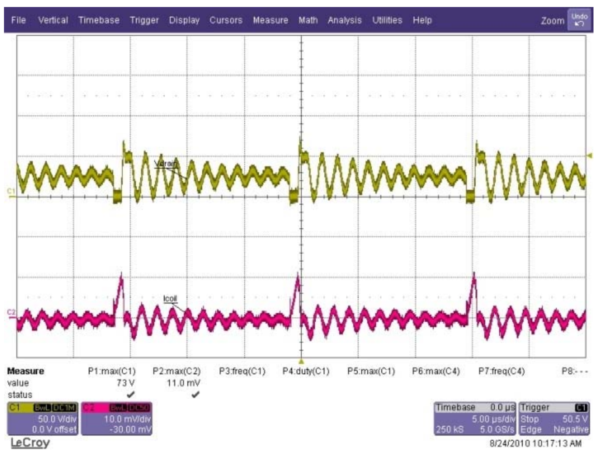

Figure 18. Current in the Boost Coil

For Vin = 24 V, Vout = 125 V, Pout = 0 W = No load

Power MOS Q1 & Q2 Drain Voltage
50 V/div $V_{Drain\ Max}$ = 73 V

Boost coil input current
0.5 A/div $I_{coilMax}$ = 0.55 A
5 µs/div 62.2 kHz

Boost Efficiency

For nominal 24 V input and 123 V output, the DC−DC boost efficiency performance is as follows.

- For 10 W load, the efficiency = 100 x Pout / Pin = 100 x (V_{OUT} x I_{OUT}) / (V_{IN} x I_{IN}) = 82.5%.
- For 73 W load, the efficiency = 87%.

LED Driver Operation

The CAT4026 controller regulates the current independently in the 6 LED strings by using external NPN power transistors and monitoring the voltage across the sense resistors tied to ground. Accurate constant current is guaranteed in each string so that the device is ideal for large LCD backlight applications. The controller senses each cathode string voltage and provides an output current feedback (IFB pin) to be interfaced to a DC/DC converter for automatically adjusting the anode voltage to the lowest level and therefore maximizes the power supply efficiency. The CAT4026 also detects shorted LEDs within a string or an open LED string fault condition. Both PWM and analog voltage inputs are available for dimming control.

LED Current Setting

The LED current is set to 100 mA independently in each of the six channels by using 10 Ω resistors connected between the CAT4026 RSET[1−7] pins and ground. For setting the LED current to another value, the following equation can be used to calculate the RSET resistor value.

$$RSET[\Omega] = 1\ V\ /\ LED\ Current\ [A]$$

The LEDs can be dimmed dynamically by applying a 300 Hz PWM signal to the PWM input. Figure 19 shows the variation of the LED current versus the PWM duty cycle.

The PWM input voltage should not exceed 5 V maximum. The PWM logic high threshold is 2.5 V, so to enable the CAT4026 the PWM input should be above 2.5 V.

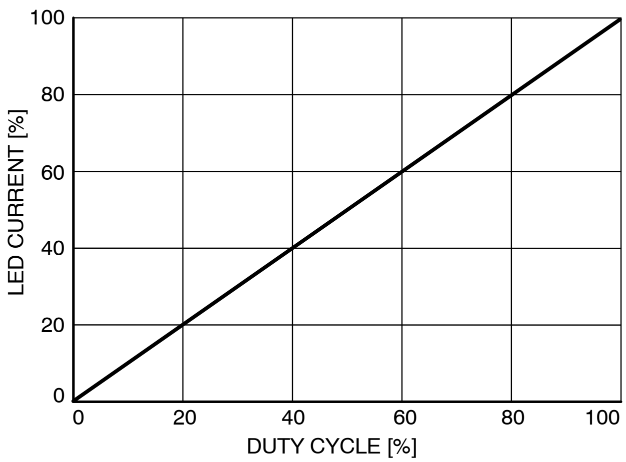

Figure 19. LED Current vs. Duty Cycle

In Figure 20 to Figure 24, the waveforms can be seen for duty cycles of 1, 50, and 95%.

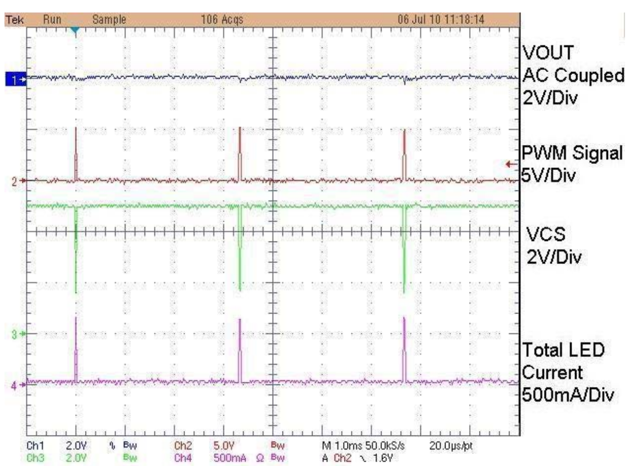

Figure 20. PWM Waveforms 1% Duty Cycle

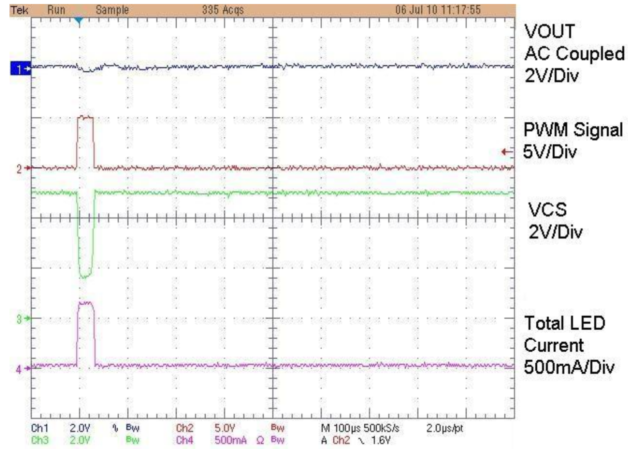

Figure 21. PWM Waveforms 1% Duty Cycle Zoomed

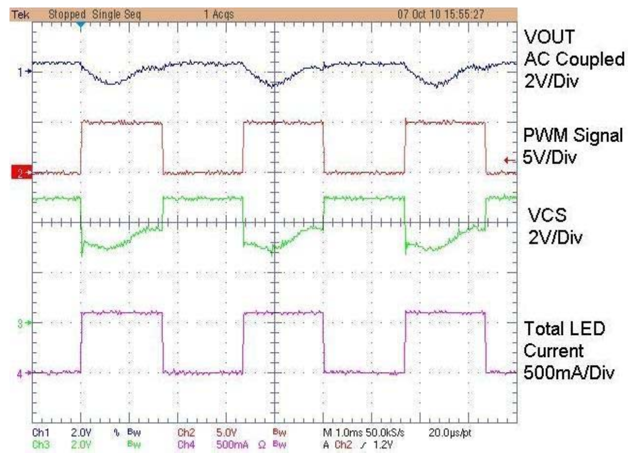

Figure 22. PWM Waveforms 50% Duty Cycle

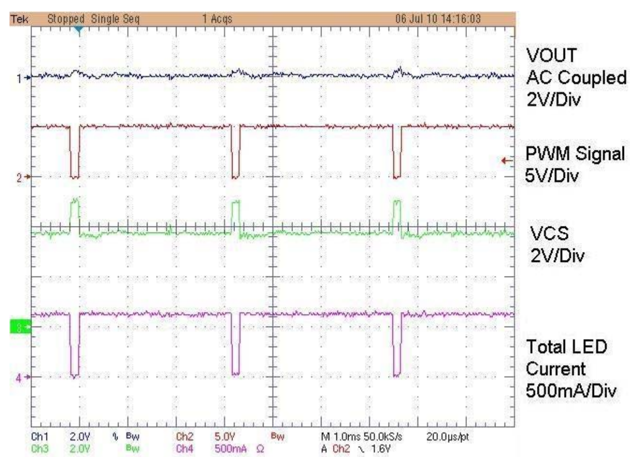

Figure 23. PWM Waveforms 95% Duty Cycle

To use the ANLG input for analog dimming, an external 1 kΩ resistor is needed to provide current limiting when an SCA fault occurs, otherwise leave the pin unconnected. The LED brightness versus ANLG input pin voltage is shown in Figure 24.

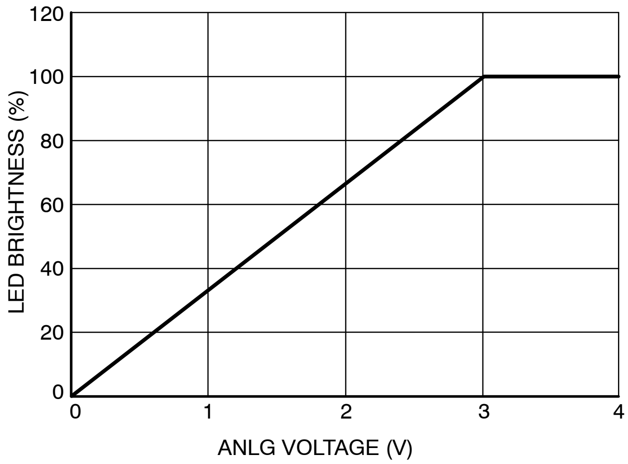

Figure 24. LED Brightness vs. ANLG Pin Voltage

Normal Operation

Figure 25 shows a power−up waveform once the PWM is enabled for a nominal 100 V anode voltage VOUT.

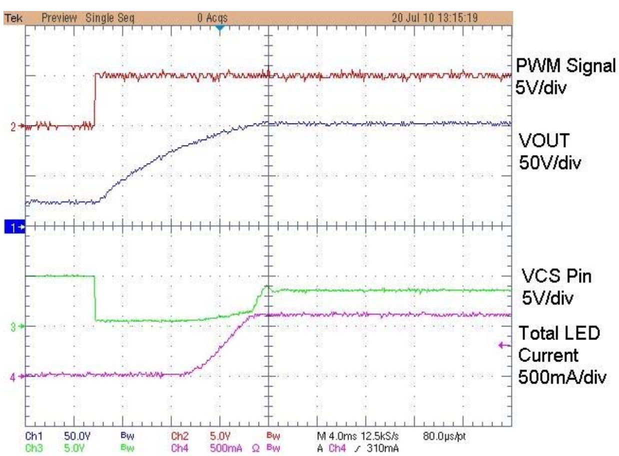

Figure 25. Normal Power Up

Fault Protection (Open LED, Short LED)

The board supports two fault detection open−drain output signals $\overline{\text{FLT−OCA}}$ and $\overline{\text{FLT−SCA}}$ which are pulled low when a fault condition occurs respectively open−LED or shorted−LED. In normal operation, when the faults are not present, these two signals are pulled high to the 5 V VDD rail.

Open Cathode−Anode (OCA) Fault Protection

The CAT4026 OCA input is used to detect and protect against abnormally high LED Anode condition. An external resistive divider connected between the LED anode and the OCA pin will trigger a fault FLT−OCA condition once the OCA pin voltage exceeds 1.0 V. Any open−LED channel will automatically be disabled and removed from the feedback loop when OCA is triggered. This method provides an auto−recovery feature for the system to resume normal operation by ensuring only the ‘good’ LED channels are included in the feedback loop. A latched OCA fault condition (FLT−OCA active low) will be set on the connector CON31 pin P2 when the OCA threshold has been reached.

Figure 26 shows the operation of the OCA fault occurrence during power−up.

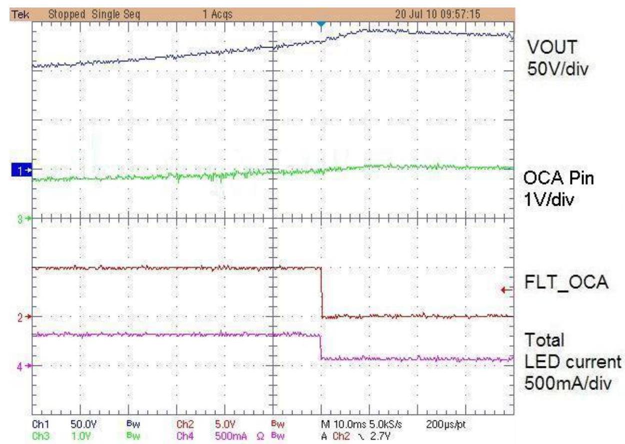

Figure 26. OCA Fault During Power Up

Figure 27 shows the operation of the OCA fault occurrence in live operation.

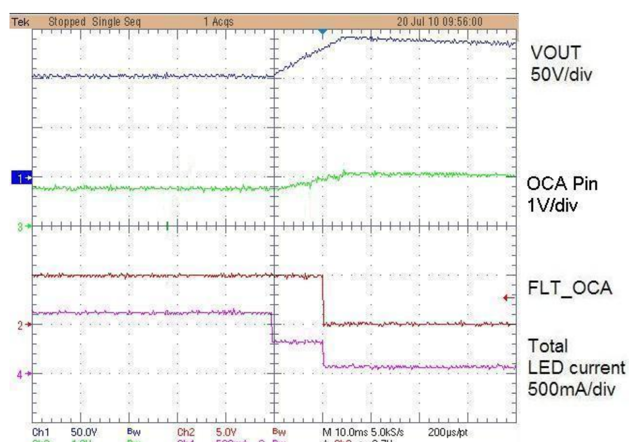

Figure 27. OCA Fault in Live Operation

Short Cathode−Anode (SCA) Fault Protection

The CAT4026 SCA pin is used to detect a severe mismatch in LED string voltage, such as the occurrence of a short between several LEDs (anode to cathode) within one string. The SCA pin is connected to each LED cathode via a diode array and a voltage level translator. The SCA threshold voltage of the detector is set and can be adjusted by using an external Zener diode (ZD31) nominally set to 25 V and a series resistor (R52) 3 kΩ. The SCA trigger voltage is set to about 30 V on the board. An unlatched signal will be produced by the FLT−SCA pin. The fault FLT−SCA output is connected to the ANLG pin through a diode and pulls the ANLG pin lower to 0.6 V when the SCA fault is present (FLT−SCA low), thereby limiting the current in each channel to 20 mA.

Figure 28 shows the operation of the SCA fault occurrence during power−up.

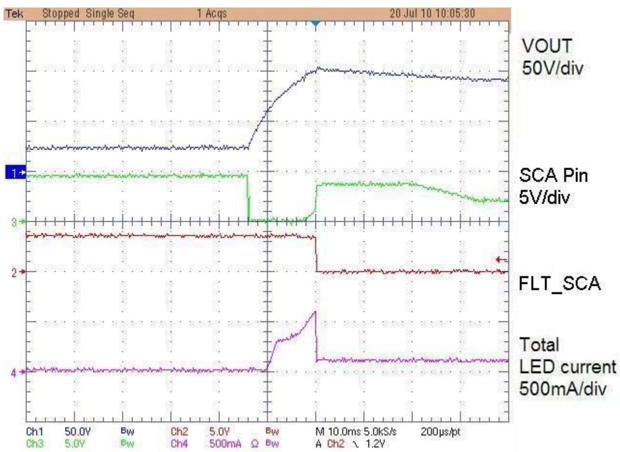

Figure 28. SCA Fault at Power Up

Figure 29 shows the operation of the SCA fault occurrence in live operation.

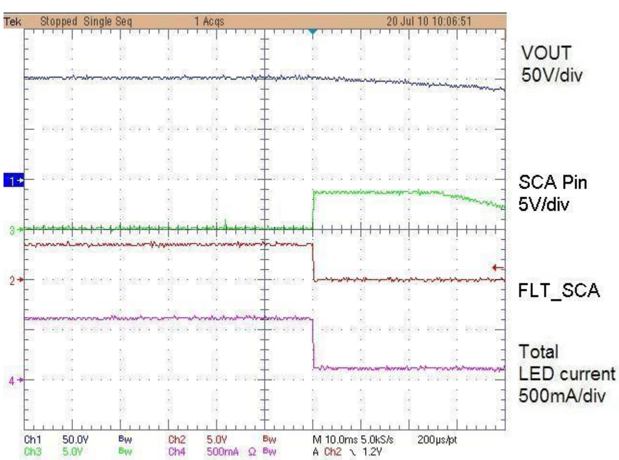

Figure 29. SCA Fault in Live Operation

Performance

Figure 30 shows the overall efficiency (power in LEDs divided by power in) versus VIN for a 100 V LED string at about 600 mA current. The average efficiency is about 87%.

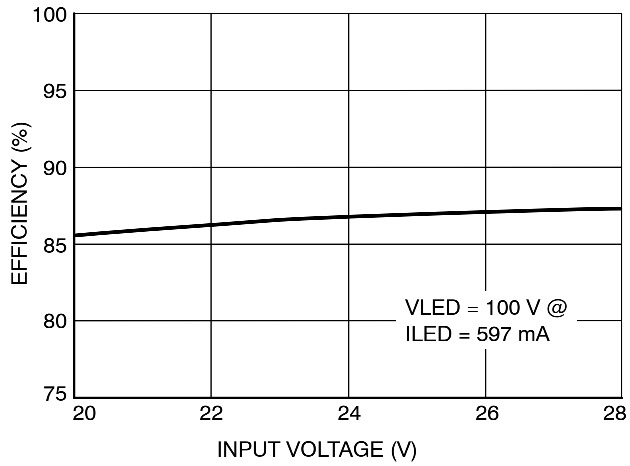

Figure 30. Efficiency vs. VIN

This board shows very tight voltage and current line regulation with an input voltage variation from 20 V to 28 V of about 0.80% and 0.03% respectively.

Feedback Loop Circuit

This feedback circuit shown in Figure 31 is driven by the CAT4026 IFB pin which is connected to the NCP1252 FB feedback pin via an inverting current amplifier circuit (current mirror). It also contains two 75 V zener diodes (ZD2 and ZD3) in series tied to VOUT to limit the output voltage to about 145 V max in case the CAT4026 IFB becomes disconnected.

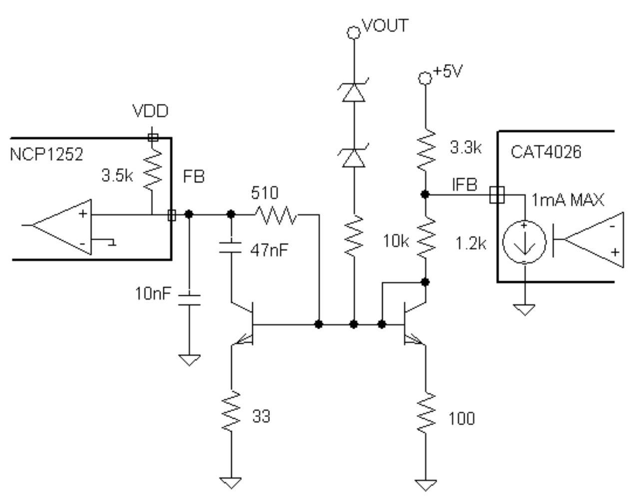

Figure 31. Feedback Circuit

Test Procedure

Warning: Due to the high−voltage (up to 150 V) present on the board and on the LED load, the test set−up should be handled with care.

The following steps are needed for the installation of the board together with the power supply and the load. The load consists of LED strings, or an equivalent resistive load, with a voltage drop of around 100 V when biased with a 100 mA current per string (600 mA total).

Connect the 24 V DC external supply with a current limit set to 4 A to the board connector CN01 P8 (VIN). Connect the external supply Ground to connector CN01 P1 (Gnd).

Connect the PWM input to the connector CN31 P8. The PWM input should never exceed 5 V.

Before powering−up the board, an LED load (or equivalent resistive load) should be connected to each of the six LED channels on connector CN30 or connect one load with all channels in parallel. The connector CN04 includes 6 LED cathode pins and 6 anode voltage pins connected together.

To use separate strings, connect the cathodes or one side of the 1.2 kΩ resistive loads rated at 25 W to each of the cathode pins CN04 P2, P4, P6, P8, P10, and P12 (LED1−6), and the anode or other side of the resistive loads to CN04 P1, P3, P5, P7, P9, and P11 (VIN).

To use one single load string, short CN04 P2, P4, P6, P8, P10, and P12 (LED1−6) together and connect to the cathode or one side of a 200 Ω load rated at 150 W, and connect CN04 P1, P3, P5, P7, P9, and P11 (VIN) to the anode or other end of the resistive load.

Set the DC power supply (VIN) to a low 18 V to test the under−voltage lockout (UVLO) functionality. Ensure the LEDs do not turn on, while the PWM input is at 5 V.

- Connect the PWM input to GND (logic low).
- Turn on the power supply VIN to 18 V.
- Set the PWM input to 5 V (logic high).
- Make sure the LEDs do *not* turn on.
- Set the PWM to GND and turn off the power supply VIN.
- Turn on the power supply VIN to 24 V.
- Set the PWM input to 5 V (logic high).

Make sure both the short and open cathode−anode fault pins ($\overline{\text{FLT−SCA}}$ on CN31 P4 and $\overline{\text{FLT−OCA}}$ on CN31 P2) are pulled high to 5 V VDD.

Measure the current in the LED string (or resistive load) with an ammeter, the average current should be around 100 mA.

On one string, short 10 LEDs or the equivalent to bring the cathode voltage to about 31 V, and verify that the SCA fault $\overline{\text{FLT−SCA}}$ pin is pulled low and the LED current is dropped down to around 20 mA per channel.

Unshort the load and verify that there once again is 100 mA of current and the SCA fault pin is not pulled to ground.

Open the load and verify that the OCA fault $\overline{\text{FLT−OCA}}$ pin is pulled low and stays low even after reconnecting the load.

Using a function generator, set the PWM signal for a 300 Hz frequency, 5 $V_{pk−pk}$ amplitude, 2.5 V offset, and 50% duty cycle pulse train. Measure the average current through the load which should be around 50 mA.

Board Schematic

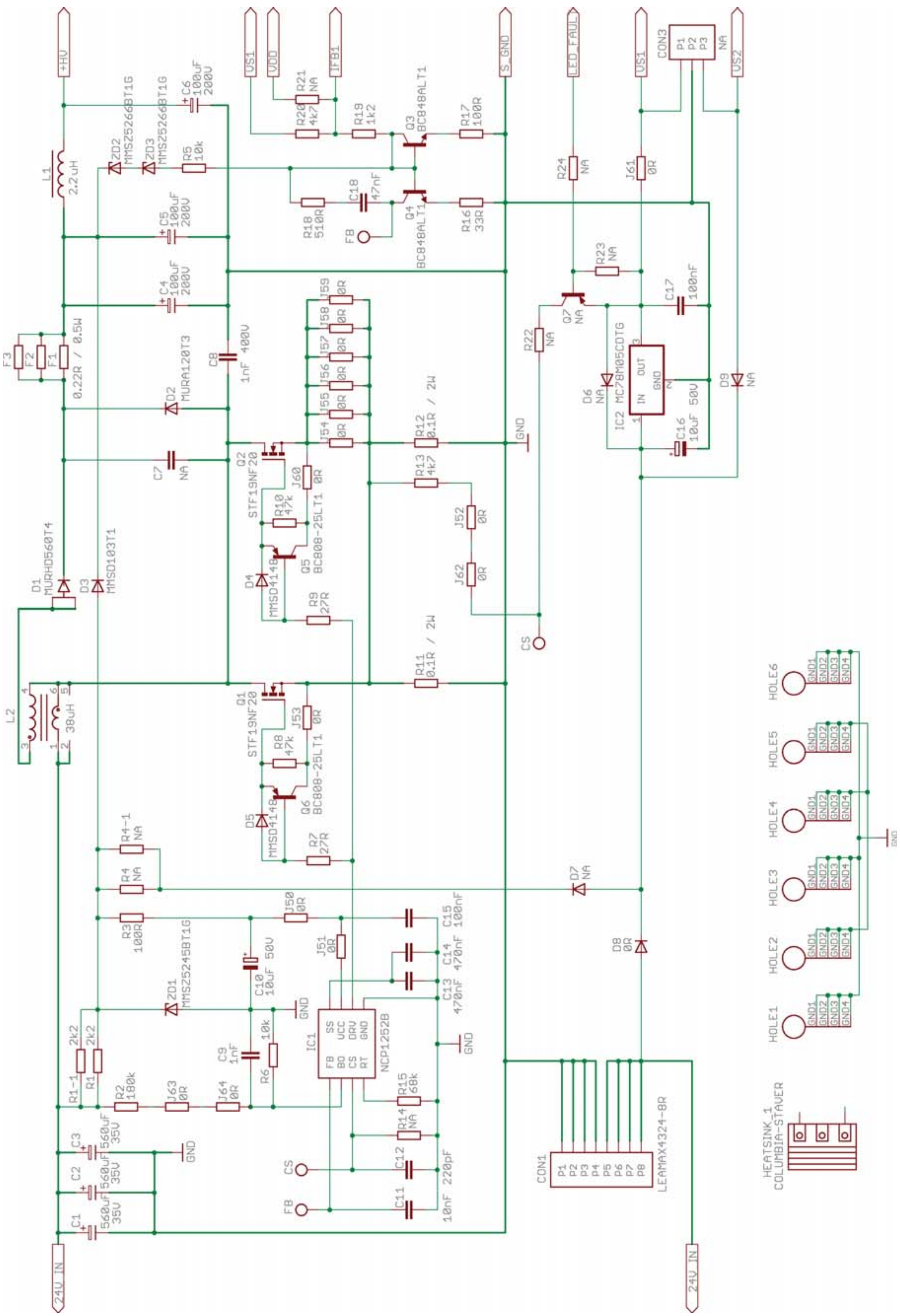

Figure 32. Board Schematic Part 1 of 2 (DC−DC NCP1252 Boost Section)

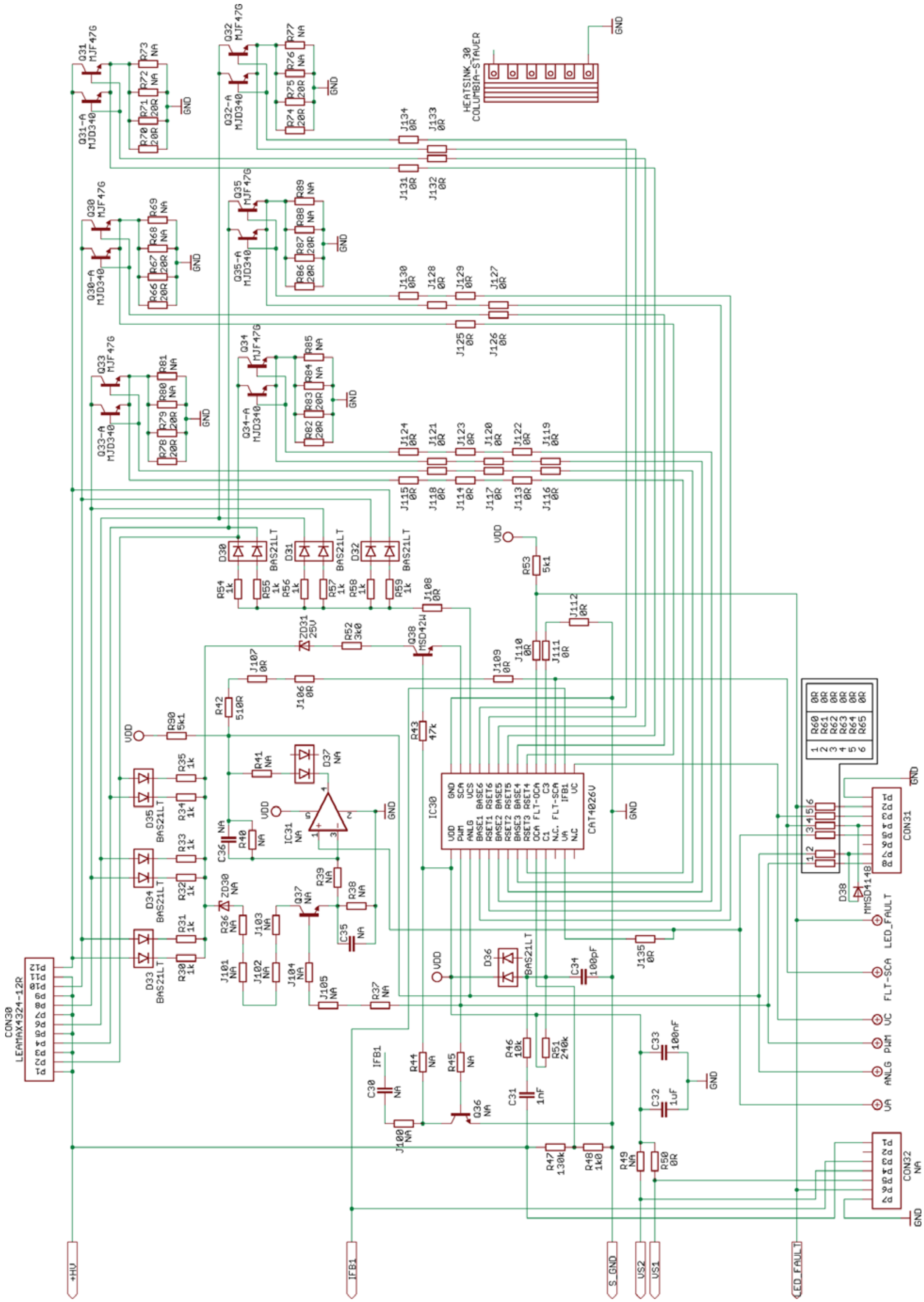

Figure 33. Board Schematic Part 2 of 2 (CAT4026 Linear LED Driver Section)

BOARD LIST OF COMPONENTS

Table 1. BOARD LIST OF COMPONENTS FOR THE NCP1252 SECTION

Name	Manufacturer	Description	Part Number	Units
C1, C2, C3	Rubycon Chemi−con	Electrolytic Capacitor 560 μF, 35 V, 20%	ZL 35V 560 μF 10x25 EKZE 35V 560 μF 10 x 25	3
C4, C5, C6	Rubycon Chemi−con	Electrolytic Capacitor 100 μF, 200 V, 20%	TXW 200V 100 μF 10x40 EKXJ 200V 120 μF 10 x 40	3
C7	Vishay Roederstein	Ceramic Capacitor 10 nF, 400 V, 5%	MKP18040310404M	0/NA
C8	Vishay	Ceramic Capacitor 1 nF, 400 V, 10%	BFC237051102	1
C9	Kemet	Ceramic Capacitor 1 nF, 50 V, 10%	C0805C102K5RACTU	1
C18	Kemet	Ceramic Capacitor 47 nF, 50 V, 10%	C0805C473K5RAC	1
C11	Kemet	Ceramic Capacitor 10 nF, 50 V, 10%	C0805C103K5RACTU	1
C10, C16	Rubycon Chemi−con	Electrolytic Capacitor 10 μF, 50 V, 20%	50MS510M6357 EKMG500ELL100ME11D	2
C12	Kemet	Ceramic Capacitor 220 pF, 50 V	C0805C221K5RACTU	1
C15, C17	Kemet	Ceramic Capacitor 100 nF, 50 V, 10%	C0805C104K5RACTU	2
C13, C14	Kemet	Ceramic Capacitor 470 nF, 50 V, 10%	C0805C474K5RACTU	2
CON1	LEAMAX Enterprise	Connector	4324−08R	1
CON3	LEAMAX Enterprise	Connector	4324−03R	0/NA
D1	ON Semiconductor	5 A, 600 V MEGAHERTZ™ Ultrafast Rectifier	MURHD560T4G	1
D2	ON Semiconductor	Ultrafast Power Rectifier	MURA120T3	1
D3	ON Semiconductor	Switching Diode, 250 V	MMSD103T1G	1
D4, D5	ON Semiconductor	Switching Diode, 100 V	MMSD4148T1G	2
D8	Vishay Dale	Zero Value Resistor 5%	CRCW12060000Z0EA	1
D6, D7, D9	ON Semiconductor	Switching Diode, 100 V	MMSD4148T1G	0/NA
F1	Vishay	Fuse Resistor 0.22 Ω, 0.5 W	NFR25H0002207JA100	1
Heatsink1	Columbia−Staver	Aluminum Heatsink	TP209ST, 80.0, 7.0, NA,−−, 02B	1
Hole 1 – Hole 6	Kang Yang	Ground Lugs	GND−15	6
IC1	ON Semiconductor	Current Mode PWM Controller	NCP1252BDR2G	1
IC2	ON Semiconductor	500 mA, 5 V Voltage Regulator 5%	MC78M05CDTG	1
J1 – J10	−	Wire Jumpers	−	10
J50 – J64	Vishay Dale	Zero Value Resistor 5%	CRCW12060000Z0EA	15
L1	Coilcraft	Inductor 2.2 μH, 5%	RFB0807−2R2L	1
L2	TDK	Tapped Boost Inductor	PFC3811QM−691K	1
Q1, Q2	STM	Power N−MOSFET 20 A, 200 V	STF19NF20	2
Q3, Q4	ON Semiconductor	NPN General Purpose Transistor	BC848ALT1G	2
Q5, Q6	ON Semiconductor	PNP General Purpose Transistor	BC808−25LT1G	2
Q7	ON Semiconductor	PNP General Purpose Transistor	BC858ALT1G	0/NA
R16	Vishay Draloric	Resistor SMD 33 Ω, 1%	CRCW0805133RFKEA	1
R1, R1−1	Vishay Draloric	Resistor SMD 2.2 kΩ, 1%	CRCW08052K20FKEA	2
R2	Vishay Draloric	Resistor SMD 180 kΩ, 1%	CRCW0805180KFKEA	1
R3, R17	Vishay Draloric	Resistor SMD 100 Ω, 1%	CRCW0805100RFKEA	2
R4, R4−1	Vishay Draloric	Resistor SMD 2.2 kΩ, 1%	CRCW08052K20FKEA	0/NA
R5	Vishay Dale	Resistor Through Hole 10 kΩ, 1%	CCF5510K0FKE36	1
R6	Vishay Draloric	Resistor SMD 10 kΩ, 1%	CRCW080510K0FKEA	1
R19	Vishay Draloric	Resistor SMD 1.2 kΩ, 1%	CRCW120611K2FKEA	1
R20	Vishay Draloric	Resistor SMD 3.3 kΩ, 1%	CRCW080513K3FKEA	1

Table 1. BOARD LIST OF COMPONENTS FOR THE NCP1252 SECTION

Name	Manufacturer	Description	Part Number	Units
R21	Vishay Draloric	Resistor SMD 4.7 kΩ, 1%	CRCW080514K7FKEA	0/NA
R13	Vishay Draloric	Resistor SMD 4.7 kΩ, 1%	CRCW120614K7FKEA	1
R7, R9	Vishay Draloric	Resistor SMD 27 Ω, 1%	CRCW0805127RFKEA	2
R11, R12	Welwyn	Resistor Through Hole 0.1 Ω, 5%, 2 W	WP2S−R1A25	2
R8, R10	Vishay Draloric	Resistor SMD 47 kΩ, 1%	CRCW0805147KFKEA	2
R18	Vishay Draloric	Resistor SMD 510 Ω, 1%	CRCW0805510RFKEA	1
R15	Vishay Draloric	Resistor SMD 68 kΩ, 1%	CRCW080568K0FKEA	1
R14	–	Resistor SMD	–	0/NA
R22	Vishay Draloric	Resistor SMD 1 kΩ, 1%	RC1206FR−071KL	0/NA
R23, R24	Vishay Draloric	Resistor SMD 10 kΩ, 1%	CRCW080510K0FKEA	0/NA
ZD2, ZD3	ON Semiconductor	68 V Zener Diode 500 mW 5%	MMSZ5266BT1G	2
ZD1	ON Semiconductor	15 V Zener Diode 500 mW 5%	MMSZ5245BT1G	1

Table 2. BOARD LIST OF COMPONENTS FOR THE CAT4026 SECTION

Name	Manufacturer	Description	Part Number	Units
C30	MULTICOMP	Ceramic Capacitor 1 nF, 50 V, 10%	MCCA000350	0/NA
C31	YAGEO	Ceramic Capacitor 1 nF, 200 V, 10%	CC1206KRX7RABB102	1
C32	KEMET	Ceramic Capacitor 1 μF, 10 V, 10%	C0805C105K8RACTU	1
C33	MULTICOMP	Ceramic Capacitor 100 nF, 16 V, 10%	MCCA000274	1
C34	MULTICOMP	Ceramic Capacitor 100 pF, 50 V, 10%	MCCA000330	1
C35	MULTICOMP	Ceramic Capacitor 10 nF, 50 V, 10%	MCCA000368	0/NA
C36	MULTICOMP	Ceramic Capacitor 100 nF, 16 V, 10%	MCCA000274	0/NA
CON30	LEAMAX Enterprise	Connector	4324−12R	1
CON31	LEAMAX Enterprise	Connector	4324−08R	1
CON32	LEAMAX Enterprise	Connector	4324−07R	0/NA
D30 – D37	ON Semiconductor	Switching Diode, 250 V	BAS21LT1G	8
D38	ON Semiconductor	Switching Diode, 100 V	MMSD4148T1G	1
ZD31	ON Semiconductor	25 V Zener Diode, 500 mW 5%	MMSZ5253BT1G	1
ZD30	ON Semiconductor	15 V Zener Diode, 500 mW 5%	MSZ5245BT1G	0/NA
Heatsink 30	Columbia−Staver	Aluminum Heatsink	TP209ST,120,7.0,NA,−−,02B	1
IC30	ON Semiconductor	6−Channel LED Controller	CAT4026V−T1	1
IC31	ON Semiconductor	Low Input Bias Current, 1.8 V OpAmp	LMV301SQ3T2G	0/NA
J11 – J37	–	Wire Jumpers	–	27
J100 – J135	Vishay Dale	Zero Value Resistors 1%	CRCW12060000Z0EA	36
Q30A – Q35A	ON Semiconductor	High Voltage Power Transistors NPN	MJD340G	6
Q30 – Q35	ON Semiconductor	Bipolar Power NPN	MJF47G	6
Q36	ON Semiconductor	NPN General Purpose Transistor	BC848ALT1G	0/NA
Q37	ON Semiconductor	General Purpose High Voltage Transistor NPN	MSD42WT1G	0/NA
Q38	ON Semiconductor	General Purpose High Voltage Transistor NPN	MSD42WT1G	1
R36	Vishay Draloric	Resistor SMD 18 kΩ, 1%	CRCW080518K0FKEA	0/NA
R46	Vishay Draloric	Resistor SMD 10 kΩ, 1%	CRCW080510K0FKEA	1
R37, R44, R45	Vishay Draloric	Resistor SMD 47 kΩ, 1%	CRCW0805147KFKEA	0/NA
R90, R53	Vishay Draloric	Resistor SMD 5.1 kΩ, 1%	CRCW080510K0FKEA	2
R49	Vishay Draloric	Resistor SMD 0 Ω, 1%	CRCW08050000Z0EA	0/NA
R50, R60 – R65	Vishay Draloric	Resistor SMD 0 Ω, 1%	CRCW08050000Z0EA	7

Table 2. BOARD LIST OF COMPONENTS FOR THE CAT4026 SECTION

Name	Manufacturer	Description	Part Number	Units
R43	Vishay Draloric	Resistor SMD 47 kΩ, 1%	CRCW0805147KFKEA	1
R41	Vishay Draloric	Resistor SMD 1 kΩ, 1%	CRCW08051K00FKEA	0/NA
R30 – R35, R54 – R59, R48	Vishay Draloric	Resistor SMD 1 kΩ, 1%	CRCW08051K00FKEA	16
R39, R40	Vishay Draloric	Resistor SMD 100 kΩ, 1%	CRCW0805100KFKEA	0/NA
R38	Vishay Draloric	Resistor SMD 1.8 kΩ, 1%	CRCW08051K80FKEA	0/NA
R42	Vishay Draloric	Resistor SMD 510 Ω, 1%	CRCW080510R0FKEA	1
R52	Vishay Draloric	Resistor SMD 3.0 kΩ, 1%	CRCW08053K00FKEA	1
R47	Vishay Dale	Resistor SMD 130 kΩ, 1%	CRCW1206130KFKEA	1
R51	Vishay Dale	Resistor SMD 240 kΩ, 1%	CRCW0805240KFKEA	1
R66, R67 R70, R71, R74, R75, R78, R79, R82, R83, R86, R87	Vishay Dale	Resistor SMD 20 Ω, 1%	CRCW080520R0FKEA	12
R68, R69, R72, R73, R76, R77, R80, R81, R84, R85, R88, R89	–	–	–	0/NA

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