LM3466
Dynamic Current Equalizer for Multi-String LED Lighting Systems

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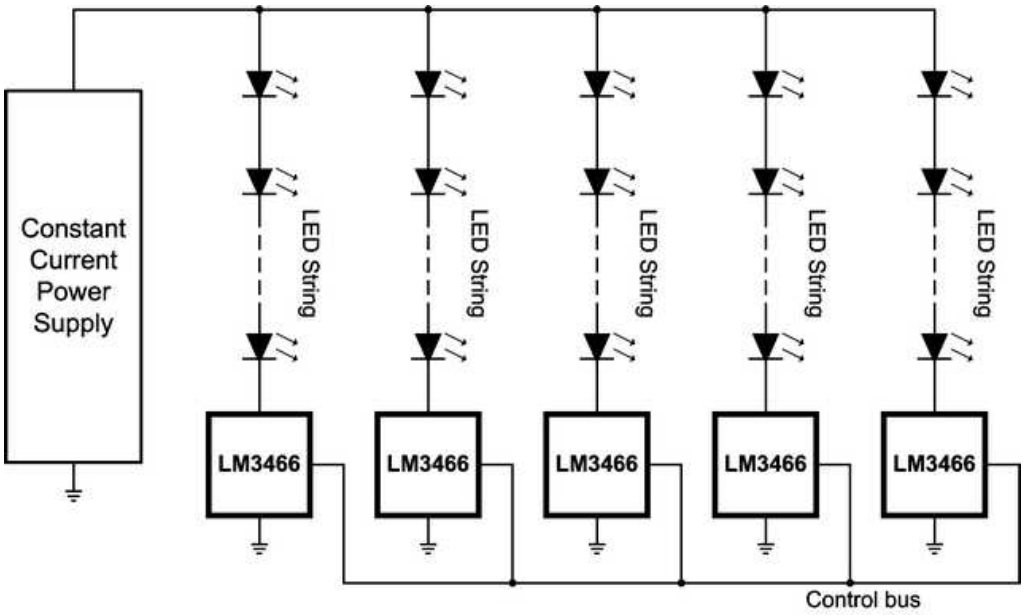
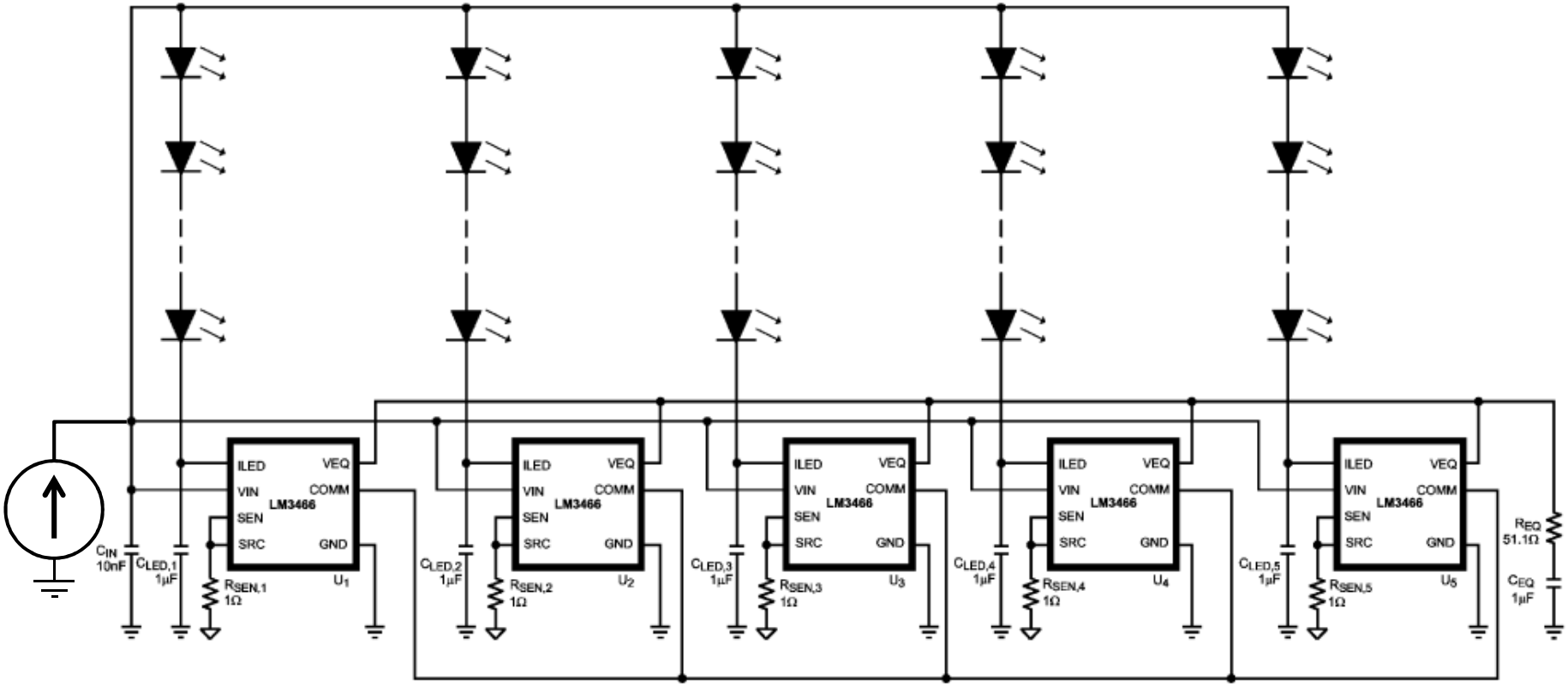
Hong Kong Design Center, Lighting Power Products,
PSS, Power Management

LM3466, the Dynamic Current Equalizer

- Target for multi-channel LED systems
- Work with a constant current power supply
- Involve only linear circuitry



LM3466 Typical Application Circuit



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LM3466 Overview

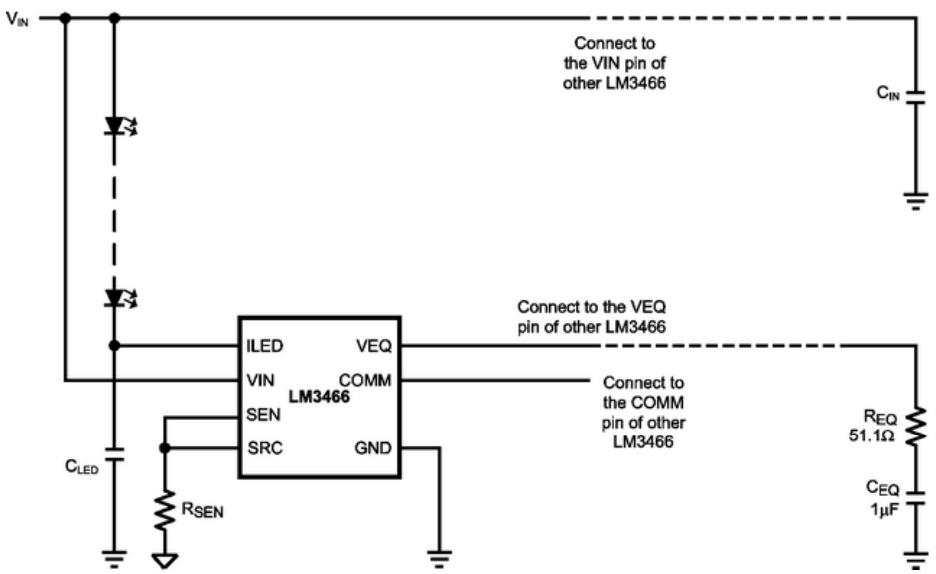
- Easy to design and use for lighting systems consisting of multiple LED strings (support modular design)
- **Automatically equalizes the current of every active LED string**, even the forward voltage of each string is different
- **Easy to pre-set and fine-tune current ratio among LED strings (e.g. color temperature adjustment or CRI enhancement)**
- Can achieve ±1% current accuracy at room temperature and ±1.5% over temperature
- Maintains constant output power if some strings open (inactive) by automatically equalizing the current of remaining active LED strings
- Works with a constant current power supply (ac/dc or dc/dc), and no communication to/from the constant current power supply is required

LM3466 Overview

- Operates with minimum voltage overhead to maximize power efficiency
- Wide input voltage range from 6V to 70V
- Fault status output
- Thermal shutdown
- Integrated 70V 1.5A MOSFET with 2.06A current limit
- Maximum 70V per LED string, 20 LEDs
- Linear circuitry does not deteriorate EMI
- Package: PSOP8, TO-220
- Target application : Any multiple current channel applications

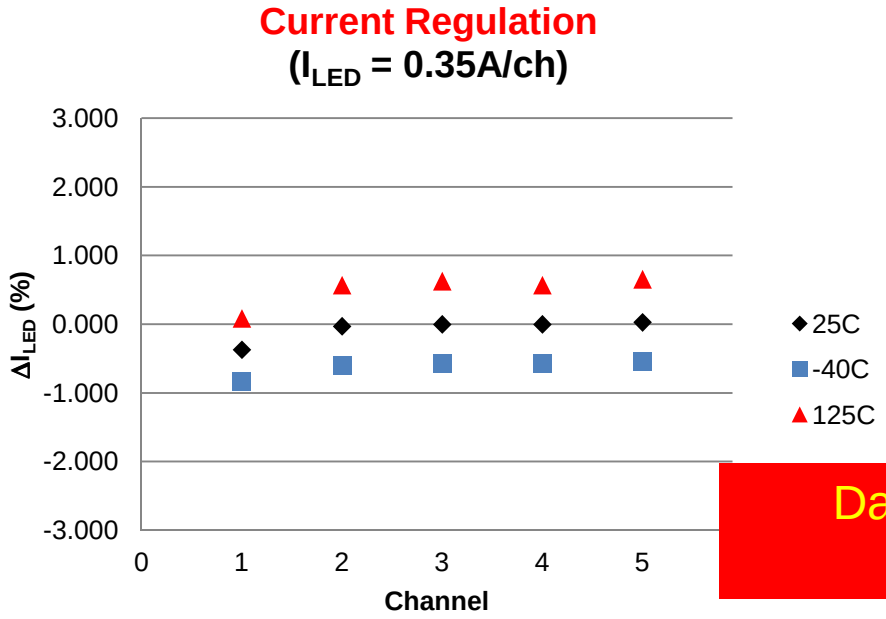
Modular Design

- To add one channel, just add an LM3466, a resistor and a capacitor
- The newly added channel will work with other channels to equalize the current from the power supply



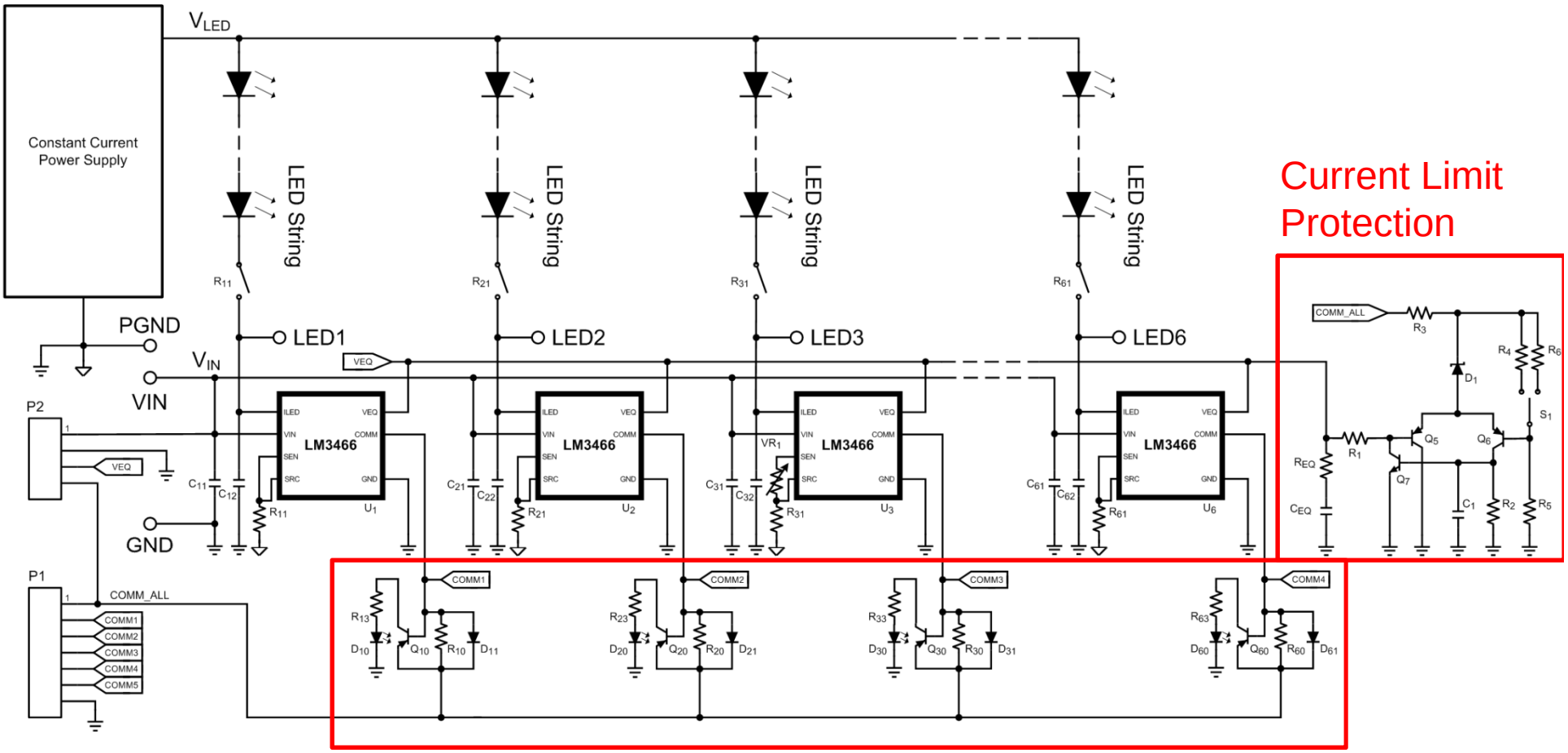
Dynamic Current Equalization

- Each LM3466 communicates with others in the same lighting system
- The LED current of each channel divides the current of the power supply equally (or in a ratio preset by a single resistor)
- Very easy to construct a high power lighting fixture by combining an off-the-shelf constant current power supply and LM3466's

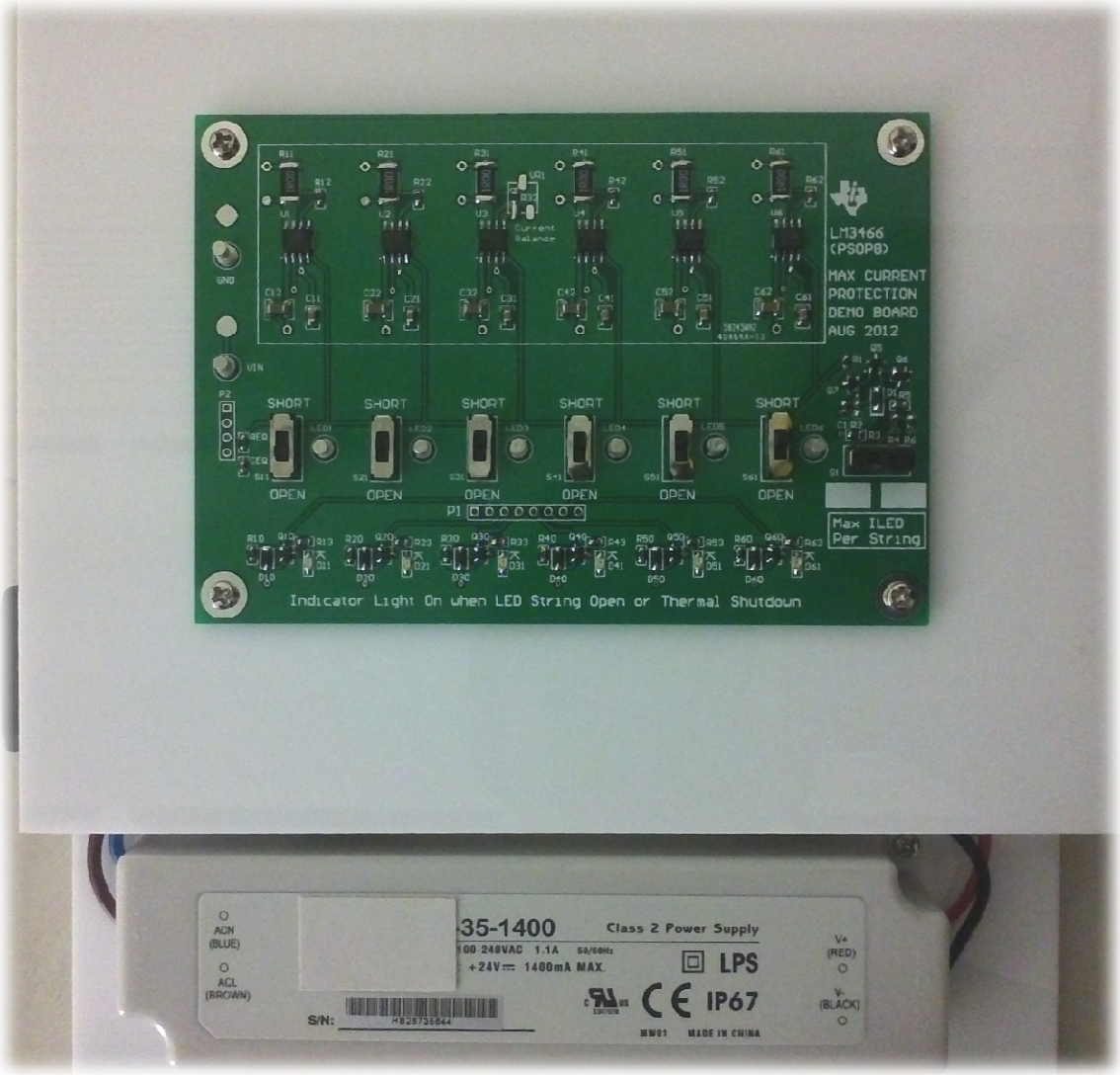


Data from a design example

LM3466 System with Current Limit Protection & Fault Indicator



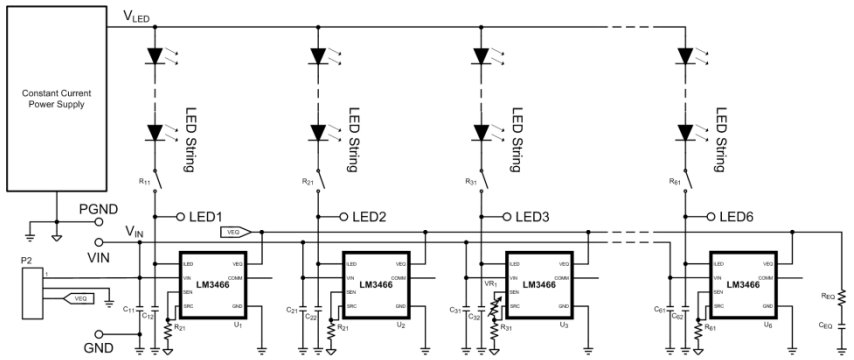
System Outlook



Concept of Current Limit Protection

- We know that LM3466 would automatically equalize the power supply current to every active LED string. What would happen if the LED string is disconnected?
- For example, constant current power supply is 1400mA; 6 LED strings

No. of strings OPEN	Current of each string
0	233mA
1	280mA
2	350mA
3	467mA
4	700mA
5	1400mA

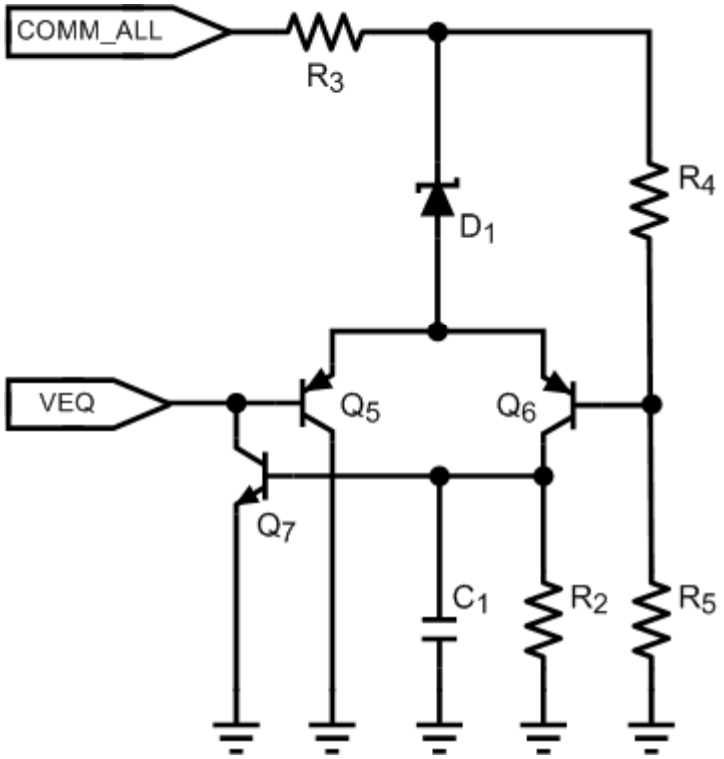


It's good. We share the current, output power does not change, the brightness is no change either

More strings open, active LED strings' conduction current might exceed the max rating.
We require the current limit of LED string while three or more strings open.

Current Limit Protection Circuitry

$$I_{LED}max = \frac{(V_Z + V_{BE})R_5}{R_{SNS} * R_4}$$



Current Limit Protection Circuitry

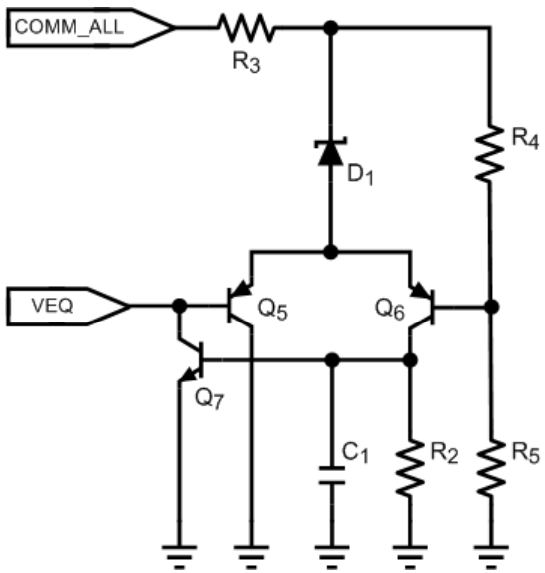
- In practical,

  V_Z = 2.7V, R_3 = 5.23k, R_5 = 10k,

  R_{11},R_{21}…R_n = 1Ω

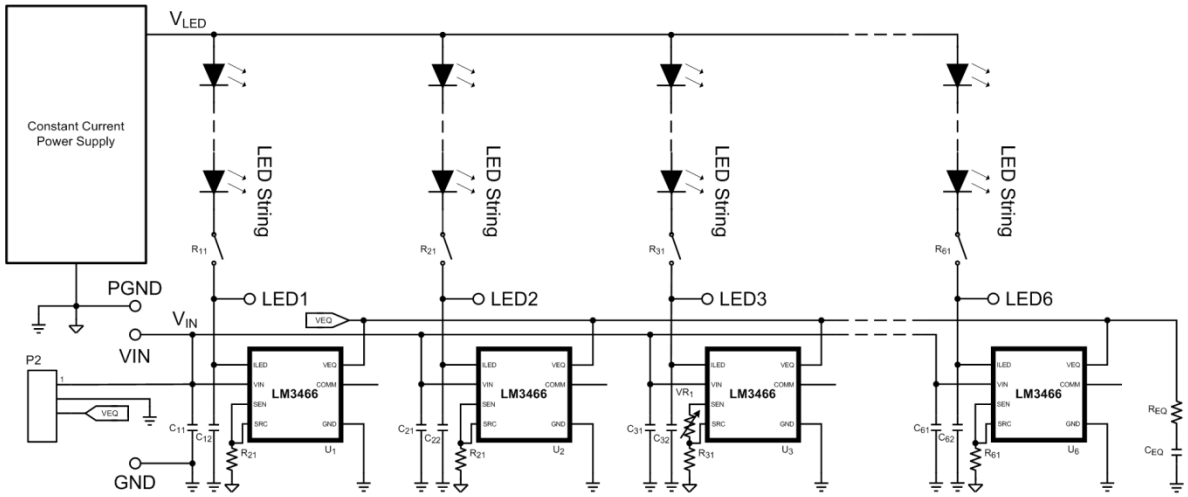
Use $$I_{LED}\max(\text{mA}) = \frac{29088}{R_4(\text{kohm})} - 10.42$$

for 300mA to 600mA current limit



Evaluation Setup

- Supply: Constant current source – max. 24VDC, 1400mA
- Output: 6 Channels (6 LEDs per channel)
- Normal operation: 1400mA supply current for 6 channels (~233mA for each channel)
- Current limit level:
  - 380mA (per channel)
  - 500mA (per channel)



Remark: If current limit protection is active, the supply will go into constant voltage (CV) mode. (e.g. the supply voltage is max. 24V.)

Evaluation Results

- Current Limit: 380mA(per channel)

No. of strings OPEN	Current of each string
0	233mA±1mA
1	280mA±1mA
2	351mA±1mA
3	377mA±2mA
4	377mA±2mA
5	377mA±2mA

Current Limiting Circuit operated.

Evaluation Results

- Current Limit: 380mA(per channel)

Normal Operation

CH1	CH2	CH3	CH4	CH5	CH6
234mA	234mA	233mA	234mA	234mA	234mA

1 LED String Open

CH1	CH2	CH3	CH4	CH5	CH6
OPEN	281mA	280mA	282mA	281mA	281mA
281mA	OPEN	280mA	281mA	281mA	281mA
281mA	281mA	OPEN	281mA	281mA	280mA
281mA	281mA	280mA	OPEN	281mA	281mA
281mA	281mA	280mA	281mA	OPEN	281mA
281mA	281mA	280mA	281mA	281mA	OPEN

2 LED Strings Open

CH1	CH2	CH3	CH4	CH5	CH6
OPEN	OPEN	350mA	352mA	352mA	351mA
OPEN	352mA	OPEN	352mA	352mA	350mA
OPEN	352mA	350mA	OPEN	352mA	352mA
OPEN	352mA	350mA	352mA	OPEN	352mA
OPEN	352mA	350mA	352mA	352mA	OPEN
352mA	OPEN	OPEN	352mA	352mA	351mA
352mA	OPEN	351mA	OPEN	352mA	352mA
352mA	OPEN	350mA	352mA	OPEN	352mA
352mA	OPEN	350mA	352mA	352mA	OPEN
352mA	352mA	OPEN	OPEN	352mA	351mA
352mA	352mA	OPEN	352mA	OPEN	351mA
351mA	352mA	OPEN	352mA	352mA	OPEN
352mA	352mA	351mA	OPEN	OPEN	352mA
352mA	352mA	351mA	OPEN	352mA	OPEN
352mA	352mA	350mA	352mA	OPEN	OPEN

3 LED Strings Open

CH1	CH2	CH3	CH4	CH5	CH6
OPEN	OPEN	OPEN	379mA	379mA	379mA
OPEN	OPEN	378mA	OPEN	378mA	379mA
OPEN	OPEN	378mA	378mA	OPEN	377mA
OPEN	OPEN	376mA	376mA	376mA	OPEN
OPEN	377mA	OPEN	OPEN	377mA	377mA
OPEN	376mA	OPEN	376mA	OPEN	376mA
OPEN	377mA	OPEN	377mA	377mA	OPEN
OPEN	377mA	377mA	OPEN	OPEN	377mA
OPEN	376mA	376mA	OPEN	377mA	OPEN
OPEN	376mA	376mA	376mA	OPEN	OPEN
377mA	OPEN	OPEN	OPEN	377mA	377mA
377mA	OPEN	OPEN	377mA	OPEN	377mA
376mA	OPEN	OPEN	376mA	376mA	OPEN
376mA	OPEN	376mA	OPEN	OPEN	376mA
376mA	OPEN	376mA	OPEN	376mA	OPEN
376mA	OPEN	376mA	376mA	OPEN	OPEN
376mA	376mA	OPEN	OPEN	OPEN	376mA
376mA	376mA	OPEN	OPEN	376mA	OPEN
376mA	376mA	OPEN	376mA	OPEN	OPEN
376mA	376mA	376mA	OPEN	OPEN	OPEN

4 LED Strings Open

CH1	CH2	CH3	CH4	CH5	CH6
376mA	376mA	OPEN	OPEN	OPEN	OPEN
376mA	OPEN	376mA	OPEN	OPEN	OPEN
376mA	OPEN	OPEN	377mA	OPEN	OPEN
377mA	OPEN	OPEN	OPEN	377mA	OPEN
377mA	OPEN	OPEN	OPEN	OPEN	377mA
OPEN	376mA	376mA	OPEN	OPEN	OPEN
OPEN	376mA	OPEN	376mA	OPEN	OPEN
OPEN	376mA	OPEN	OPEN	376mA	OPEN
OPEN	377mA	OPEN	OPEN	OPEN	376mA
OPEN	OPEN	376mA	376mA	OPEN	OPEN
OPEN	OPEN	375mA	OPEN	375mA	OPEN
OPEN	OPEN	376mA	OPEN	OPEN	376mA
OPEN	OPEN	OPEN	376mA	375mA	OPEN
OPEN	OPEN	OPEN	376mA	OPEN	376mA
OPEN	OPEN	OPEN	OPEN	376mA	376mA

5 LED Strings Open

CH1	CH2	CH3	CH4	CH5	CH6
OPEN	OPEN	OPEN	OPEN	OPEN	377mA
OPEN	OPEN	OPEN	OPEN	377mA	OPEN
OPEN	OPEN	OPEN	376mA	OPEN	OPEN
OPEN	OPEN	379mA	OPEN	OPEN	OPEN
OPEN	377mA	OPEN	OPEN	OPEN	OPEN
376mA	OPEN	OPEN	OPEN	OPEN	OPEN

Evaluation Results

- Current Limit: 500mA(per channel)

No. of strings OPEN	Current of each string
0	233mA±1mA
1	280mA±1mA
2	351mA±1mA
3	468mA±2mA
4	493mA±2mA
5	493mA±3mA

Current Limiting Circuit operated.

Evaluation Results

- Current Limit: 500mA(per channel)

Normal Operation

CH1	CH2	CH3	CH4	CH5	CH6
234mA	234mA	233mA	234mA	234mA	233mA

1 LED String Open

CH1	CH2	CH3	CH4	CH5	CH6
OPEN	281mA	280mA	282mA	281mA	280mA
281mA	OPEN	280mA	281mA	281mA	281mA
281mA	280mA	OPEN	281mA	281mA	280mA
281mA	281mA	281mA	OPEN	281mA	281mA
281mA	281mA	280mA	281mA	OPEN	281mA
281mA	281mA	280mA	281mA	281mA	OPEN

2 LED Strings Open

CH1	CH2	CH3	CH4	CH5	CH6
OPEN	OPEN	351mA	352mA	352mA	351mA
OPEN	352mA	OPEN	352mA	352mA	350mA
OPEN	352mA	350mA	OPEN	352mA	352mA
OPEN	352mA	350mA	352mA	OPEN	352mA
OPEN	352mA	351mA	352mA	352mA	OPEN
352mA	OPEN	OPEN	352mA	352mA	351mA
352mA	OPEN	351mA	OPEN	352mA	352mA
352mA	OPEN	350mA	352mA	OPEN	352mA
352mA	OPEN	350mA	352mA	352mA	OPEN
352mA	352mA	OPEN	OPEN	352mA	351mA
352mA	352mA	OPEN	352mA	OPEN	351mA
351mA	352mA	OPEN	352mA	352mA	OPEN
351mA	352mA	351mA	OPEN	OPEN	352mA
352mA	352mA	351mA	OPEN	352mA	OPEN
352mA	352mA	351mA	352mA	OPEN	OPEN

3 LED Strings Open

CH1	CH2	CH3	CH4	CH5	CH6
OPEN	OPEN	OPEN	469mA	468mA	467mA
OPEN	OPEN	468mA	OPEN	469mA	469mA
OPEN	OPEN	467mA	469mA	OPEN	469mA
OPEN	OPEN	468mA	469mA	469mA	OPEN
OPEN	469mA	OPEN	OPEN	469mA	468mA
OPEN	469mA	OPEN	469mA	OPEN	468mA
OPEN	469mA	OPEN	468mA	468mA	OPEN
OPEN	469mA	468mA	OPEN	OPEN	469mA
OPEN	469mA	468mA	OPEN	469mA	OPEN
OPEN	469mA	468mA	469mA	OPEN	OPEN
469mA	OPEN	OPEN	OPEN	469mA	467mA
469mA	OPEN	OPEN	469mA	OPEN	468mA
468mA	OPEN	OPEN	469mA	469mA	OPEN
469mA	OPEN	468mA	OPEN	OPEN	469mA
469mA	OPEN	468mA	OPEN	469mA	OPEN
468mA	OPEN	468mA	469mA	OPEN	OPEN
468mA	469mA	OPEN	OPEN	OPEN	468mA
468mA	469mA	OPEN	OPEN	469mA	OPEN
468mA	469mA	OPEN	469mA	OPEN	OPEN
469mA	469mA	468mA	OPEN	OPEN	OPEN

4 LED Strings Open

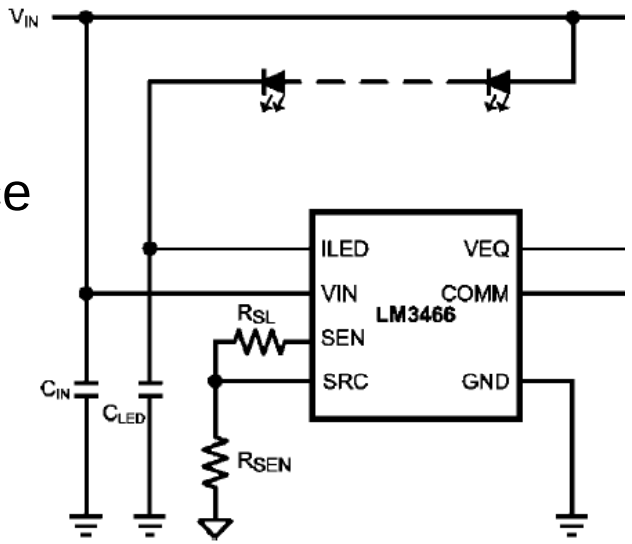
CH1	CH2	CH3	CH4	CH5	CH6
494mA	494mA	OPEN	OPEN	OPEN	OPEN
494mA	OPEN	495mA	OPEN	OPEN	OPEN
495mA	OPEN	OPEN	495mA	OPEN	OPEN
495mA	OPEN	OPEN	OPEN	495mA	OPEN
495mA	OPEN	OPEN	OPEN	OPEN	495mA
OPEN	493mA	493mA	OPEN	OPEN	OPEN
OPEN	494mA	OPEN	494mA	OPEN	OPEN
OPEN	494mA	OPEN	OPEN	494mA	OPEN
OPEN	495mA	OPEN	OPEN	OPEN	494mA
OPEN	OPEN	494mA	494mA	OPEN	OPEN
OPEN	OPEN	494mA	OPEN	494mA	OPEN
OPEN	OPEN	494mA	OPEN	OPEN	494mA
OPEN	OPEN	OPEN	495mA	495mA	OPEN
OPEN	OPEN	OPEN	495mA	OPEN	495mA
OPEN	OPEN	OPEN	OPEN	494mA	494mA

5 LED Strings Open

CH1	CH2	CH3	CH4	CH5	CH6
OPEN	OPEN	OPEN	OPEN	OPEN	491mA
OPEN	OPEN	OPEN	OPEN	491mA	OPEN
OPEN	OPEN	OPEN	490mA	OPEN	OPEN
OPEN	OPEN	493mA	OPEN	OPEN	OPEN
OPEN	492mA	OPEN	OPEN	OPEN	OPEN
490mA	OPEN	OPEN	OPEN	OPEN	OPEN

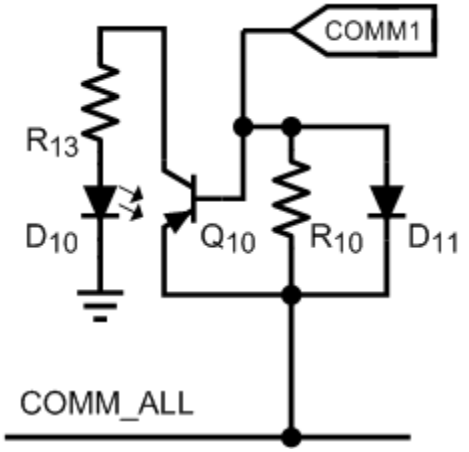
Color Temperature Adjustment

- An external resistor R_{SL} connecting between the SEN pin and R_{SEN} can be used to fine tune the LED current balance of the system for the purpose of color temperature adjustment
- Increasing the R_{SL} of a specific LM3466 can reduce its LED string current while other LED string will take up the delta current, and overall input current maintains the same
- For example, a LM3466 system consists of five white LED string and an amber LED string. R_{SL} of the LM3466 driving the amber string, hence its current, can be adjusted, so that the color temperature of the light output can be tuned

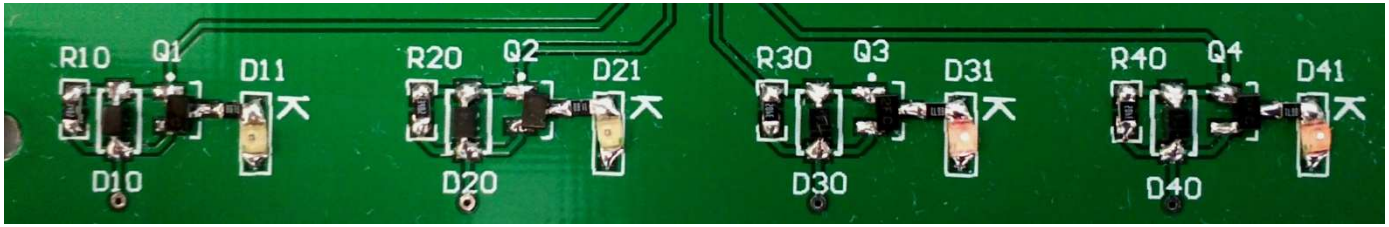


OPEN Fault

- To avoid falsely latch off the LED string, if a LM3466 in the system detected its string is open, the whole system will go into “reclaim” mode, the supply will go into voltage regulation (CV) mode or “OVP” mode, and the light will blink for couple of seconds. If the open condition persists, the string is confirmed open. Then the affected LM3466 is latched off, and system is back to normal, input current is shared between active strings

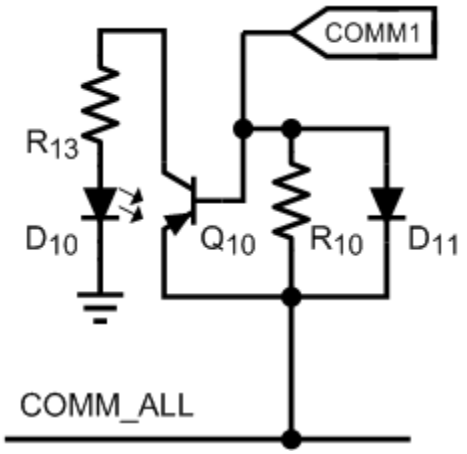


- With its LED string confirmed open, the affected LM3466’s COMM pin will pull low, and its fault indicator will be lit up

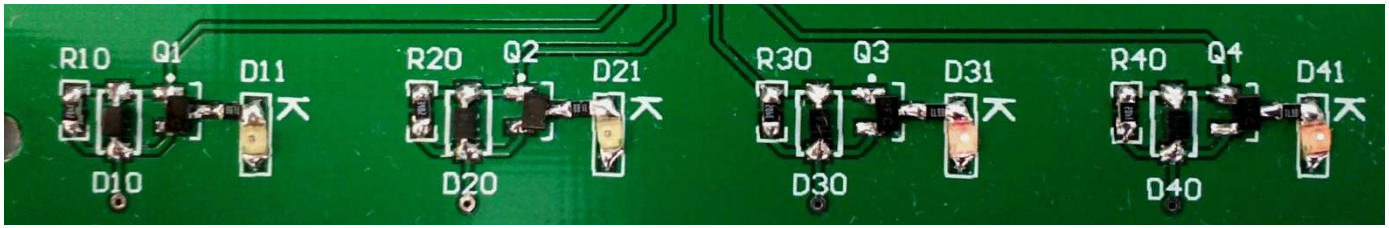


Thermal Protection

- If a LM3466 in the system is overheat to above 150deg.C (mainly because it has shorted LED in its string, then its LED pin voltage is high and causes high power dissipation), its powerFET will be turned off. Then its junction temperature (Tj) will drop. It will turn back on if its Tj goes below 140deg.C. But then, it might be overheat and turned off again. The light will blink. The system won't allow this happen forever. After 253 of this thermal cycle (typically, it lasts for several seconds to tens of second dependent on the ambient temperature and the heat sink design), the overheat LM3466 will be latched off, and system is back to normal, input current is shared between active strings



- During thermal cycling, the overheat LM3466's fault indicator will blink. After it is latched off, the fault indicator will be lit up steadily



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