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AN-4188

Guidance of Using LED Direct-AC Driver Design Tool for FL77904/FL77944/FL77905

Overview

This application note provides a step-by-step guide for using the LED Direct-AC Driver Design Tool (DACD Design Tool).

Design Flow

The flow of using the DACD design tool is drawn in Figure 1. Based on requested system specification and selected LED part number, the design tool helps users to design LED-string configuration and driving currents of the driver IC. You may refer to AN-5088 [1] for detailed explanation for operating principle of the driver IC.

The design tool's appearance is like Figure 2. It can be separated into five sections with assistive figures. How to use these five sections are explained step-by-step in the following paragraphs.

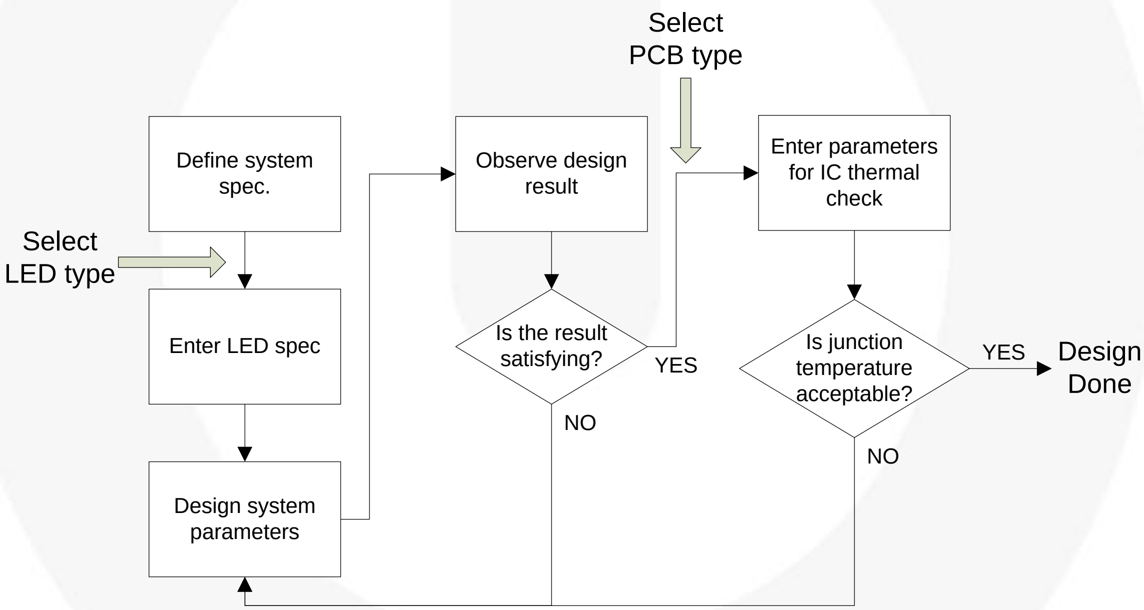


Figure 1. Flow Chart of Using DACD Design Tool

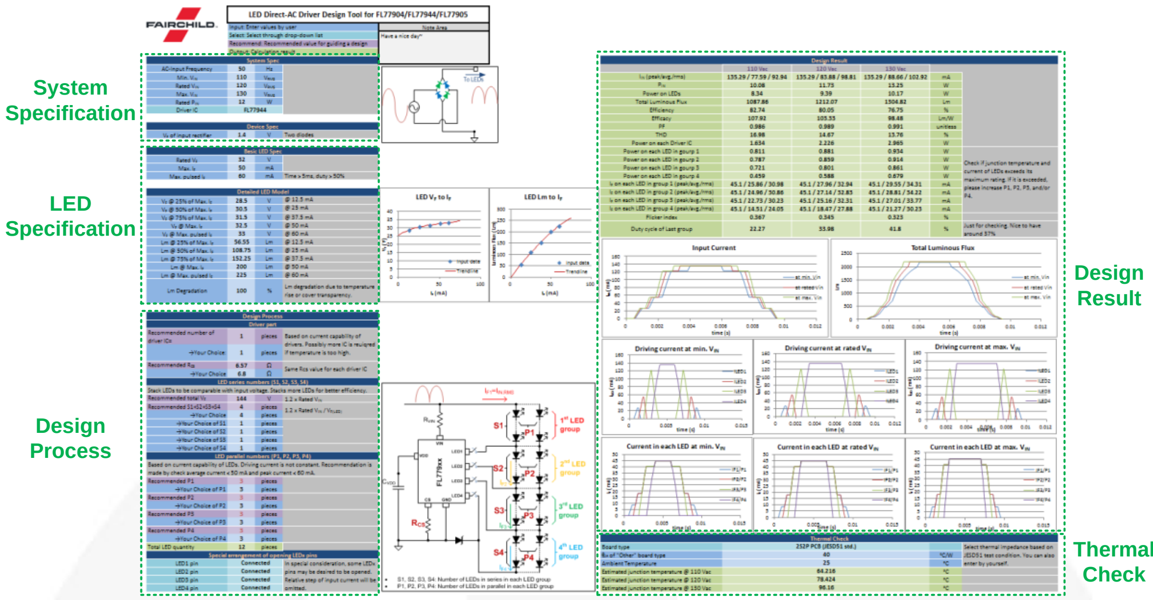


Figure 2. Appearance of the DACD Design Tool

Step 1: Entering Defined System Specification

In the System Spec section, rated input voltage and input power need to be entered. The Driver IC grid is a drop-down list. You can choose which driver IC you want to design with. Forward-voltage drop of input bridge rectifier also needs to be filled in the design tool.

Instead of starting a design with rated input power, you may want to start the design process with a targeted luminous flux (light output). In that case, you can roughly predict input power by Equation (1) in which the driver efficiency can be set as 80% at start. LED efficacy can be obtained from the LED data sheet.

$$P_{IN}\,(\mathrm{W}) = \frac{\text{Luminous Flux (Lm)}}{\text{LED Efficacy (Lm/W)} \times \text{Driver Efficiency (W/W)}} \quad (1)$$

System Spec		
AC-Input Frequency	50	Hz
Min. V_{IN}	110	V_{RMS}
Rated V_{IN}	120	V_{RMS}
Max. V_{IN}	130	V_{RMS}
Rated P_{IN}	12	W
Driver IC	FL77944	
Device Spec		
V_F of input rectifier	1.4	V	Two diodes

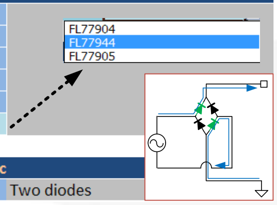


Figure 3. System-Specification Section

Step 2: Entering Specification of Chosen LED

There are two sections for LED spec, a "basic" section and a "detailed" section. Inputs in the basic section are used in the design-process section, which guides users to decide how many LEDs need to be used. The detailed section is for generating a much realistic LED model for calculating predicted outcome in design-result section.

You may already have the LED part number that you are going to implement. In a DACD system, total forward voltage of the LED string needs to be comparable with the peak value of input voltage. High-voltage type LEDs could be favored when design a low-wattage system with small area constrain.

Basic LED Spec			
Rated V_F	32	V	
Max. I_F	50	mA	
Max. pulsed I_F	60	mA	Time > 5ms, duty > 50%
Detailed LED Model			
V_F @ 25% of Max. I_F	28.5	V	@ 12.5 mA
V_F @ 50% of Max. I_F	30.5	V	@ 25 mA
V_F @ 75% of Max. I_F	31.5	V	@ 37.5 mA
V_F @ Max. I_F	32.5	V	@ 50 mA
V_F @ Max. pulsed I_F	33	V	@ 60 mA
Lm @ 25% of Max. I_F	56.55	Lm	@ 12.5 mA
Lm @ 50% of Max. I_F	108.75	Lm	@ 25 mA
Lm @ 75% of Max. I_F	152.25	Lm	@ 37.5 mA
Lm @ Max. I_F	200	Lm	@ 50 mA
Lm @ Max. pulsed I_F	225	Lm	@ 60 mA
Lm Degradation	100	%	Lm degradation due to temperature rise or cover transparency.

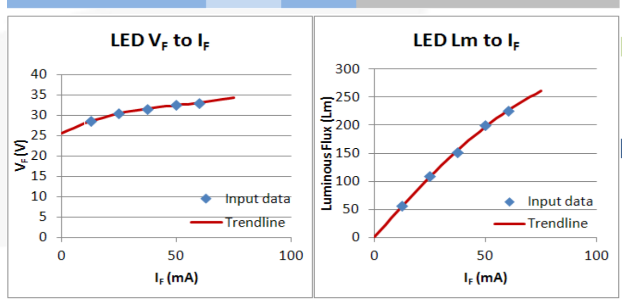


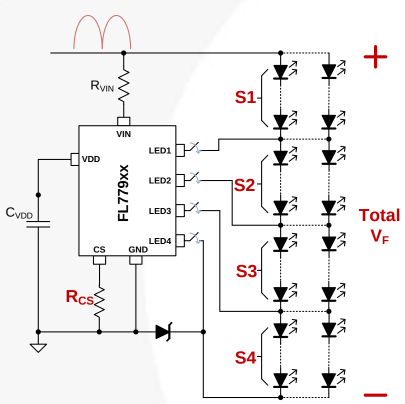
Figure 4. LED-Specification Section

Step 3: Design System Parameters

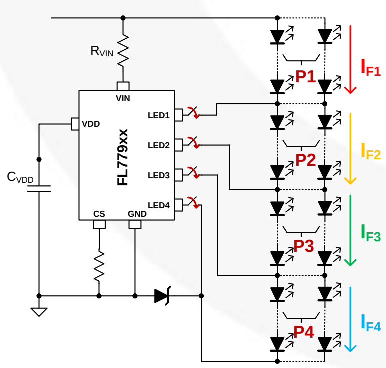
The design process section of the tool guides user to decide;

1. How many driver IC need to be applied
2. Resistance value of current-sensing resistor (R_{CS})
3. How many LEDs need to be put in series (S1, S2, S3, S4)
4. How many LEDs need to be put in parallel for each LED group (P1, P2, P3, P4)

The first and second items are about the driver, and the third and fourth items are for LED-string configuration. The driver part considers driver IC's current capability, not thermal constrain, and the rated input power in system-specification section. The series quantity considers peak value of input voltage since the DACD system requires total forward voltage of the LED string to be comparable with the input voltage. The LED string is then separated into several groups. The parallel quantity of each LED group considers peak and average current that will flow through the LED group.



(a) Total Series Quantity



***(b)* Parallel Quantity of each LED Group**

Figure 5. Considerations of Designing LED String

The design tool provides recommended value of these quantities. But, you still need to enter the value that you want to select. If the value that you input is not proper, a warning message will be shown. You can also ignore the warning if you insist on your input and think that the outcome in design-result section is acceptable. Note that you have to decide yourself how to separate the total series quantity into each LED group. Start with evenly-separated design if you have no special idea about it.

Design Process			
Driver part			
Recommended number of driver IC=	1	pieces	Based on current capability of drivers. Possibly more IC is reuiqred if temperature is too high.
→Your Choice:	1	pieces	
Recommended R_{CS}	6.57	Ω	Same Rcs value for each driver IC
→Your Choice	6.8	Ω	
LED series numbers (S1, S2, S3, S4)			
Stack LEDs to be comparable with input voltage. Stacks more LEDs for better efficiency.			
Recommended total V_F	144	V	1.2 x Rated V_{IN}
Recommended S1+S2+S3+S4	4	pieces	1.2 x Rated V_{IN} / $V_{F(LED)}$
→Your Choice	4	pieces	
→Your Choice of S1	1	pieces	
→Your Choice of S2	1	pieces	
→Your Choice of S3	1	pieces	
→Your Choice of S4	1	pieces	
LED parallel numbers (P1, P2, P3, P4)			
Based on current capability of LEDs. Driving current is not constant. Recommendation is made by check average current < 50 mA and peak current < 60 mA.			
Recommended P1	3	pieces	
→Your Choice of P1	3	pieces	
Recommended P2	3	pieces	
→Your Choice of P2	3	pieces	
Recommended P3	3	pieces	
→Your Choice of P3	3	pieces	
Recommended P4	3	pieces	
→Your Choice of P4	3	pieces	
Total LED quantity	12	pieces	
Special arrangement of opening LEDx pins			
LED1 pin	Connected		In special consideration, some LEDx pins may be desired to be opened. Relative step of input current will be omitted.
LED2 pin	Connected		
LED3 pin	Connected		
LED4 pin	Connected		

Figure 6. Design-Process Section

Both FL77904 and FL77944 have four LED driving pins, so a total of four LED groups can be assigned. There are only three LED driving pins in FL77905, so S4 and P4 need to be zero when applying FL77905.

In some special design consideration, you may want to use less driving pins than provided. For example, you may want to bypass LED1 to have a higher minimum conducting current, or the LED you chose has a forward voltage spec that is too high for connecting four of them in series. In such cases, the special-arrangement section has drop-down list that you can indicated that you want some LED driving pins to be opened.

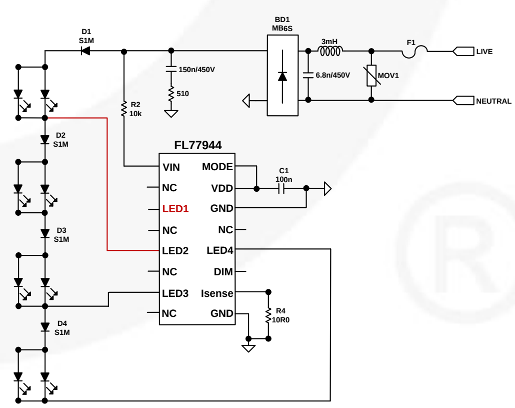


Figure 7. An Example that LED1 Pin is Opened

Step 4: Check Design Result

Through previous steps, we come to a complete design of driver and LED-string configuration. Based on the design, the design tool calculates outcomes like luminous flux, Total Harmonic Distortion (THD), and power dissipated on driver and LEDs. Now, you check if all these values fulfill system requirement. If not, you need to change the designed parameters in previous steps. For example,

- Luminous flux is too high/low → Decrease/increase input power (P_{IN}) and increase/decrease current-sensing resistor (R_{CS}).
- Efficacy is too low → Increase LED parallel quantity P1~P4 or switch to LED part number with better efficacy.
- Power or current on each LED is too high → Increase LED parallel quantity P1~P4
- Duty cycle of last LED group is too low → Decrease S1+S2+S3+S4.
- THD is not good → Adjust S1~S4 while keep summation of them unchanged.

The design outcome is also presented as waveforms shown in Figure 9. When more than one driver IC is implemented, the driving current figures stand for summed driving current of all the drivers.

Design Result					
	110 Vac	120 Vac	130 Vac		
I_{IN} (peak/avg./rms)	135.29 / 77.59 / 92.94	135.29 / 83.88 / 98.81	135.29 / 88.66 / 102.92	mA	
P_{IN}	10.08	11.73	13.25	W	
Power on LEDs	8.34	9.39	10.17	W	
Total Luminous Flux	1087.86	1212.07	1304.82	Lm	
Efficiency	82.74	80.05	76.75	%	
Efficacy	107.92	103.33	98.48	Lm/W	
PF	0.986	0.989	0.991	unitless	
THD	16.98	14.67	13.76	%	
Power on each Driver IC	1.634	2.226	2.965	W	
Power on each LED in gourp 1	0.811	0.881	0.934	W	Check if junction temperature and current of LEDs exceeds its maximum rating. If it is exceeded, please increase P1, P2, P3, and/or P4.
Power on each LED in gourp 2	0.787	0.859	0.914	W	
Power on each LED in gourp 3	0.721	0.801	0.861	W	
Power on each LED in gourp 4	0.459	0.588	0.679	W	
I_F on each LED in group 1 (peak/avg./rms)	45.1 / 25.86 / 30.98	45.1 / 27.96 / 32.94	45.1 / 29.55 / 34.31	mA	
I_F on each LED in group 2 (peak/avg./rms)	45.1 / 24.96 / 30.86	45.1 / 27.14 / 32.83	45.1 / 28.81 / 34.22	mA	
I_F on each LED in group 3 (peak/avg./rms)	45.1 / 22.73 / 30.23	45.1 / 25.16 / 32.31	45.1 / 27.01 / 33.77	mA	
I_F on each LED in group 4 (peak/avg./rms)	45.1 / 14.51 / 24.05	45.1 / 18.47 / 27.88	45.1 / 21.27 / 30.23	mA	
Flicker index	0.367	0.345	0.323	%	
Duty cycle of Last group	22.27	33.98	41.8	%	Just for checking. Nice to have around 37%

Figure 8. Predicted Outcomes of the Design Result

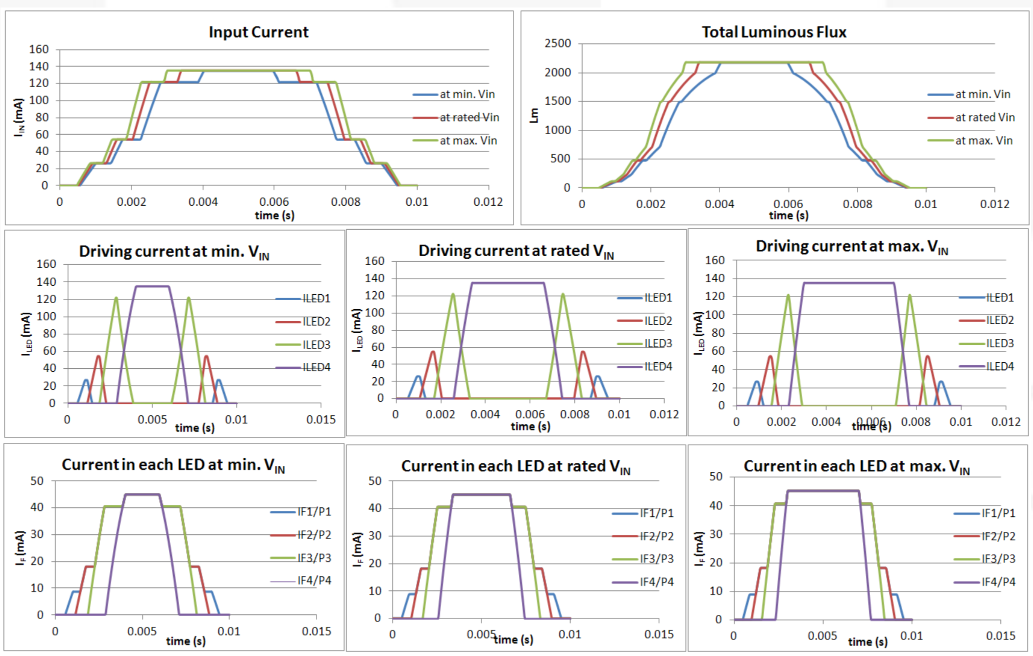


Figure 9. Predicted Waveforms of the Design Result

Step 5: Check Junction Temperature of the Driver ICs

The last step is to check junction temperature of the driver IC. There is a drop-down list for "board type" input. When "1S" or "2S2P" is chosen, the design tool uses junction-to-air thermal impedance (θ_{JA}) value on the datasheet of the picked driver IC to predict junction temperature. If "Other" is chosen, you can enter your own predicted θ_{JA} for calculating junction temperature. If the junction temperature is higher than recommended operating temperature range or threshold of over-temperature protection, there will be a warning message. When warning message appears, you may:

- Increase total LED forward voltage by increasing S1+S2+S3+S4.
- Or, you may also increase quantity of driver IC.

1S PCB (JESD51 std.)
2S2P PCB (JESD51 std.)
Other

Thermal Check			
Board type	2S2P PCB (JESD51 std.)		Select thermal impedance based on JESD51 test condition. You can also enter by yourself.
θ_{JA} of "Other" board type	40	°C/W	
Ambient Temperature	25	°C	
Estimated junction temperature @ 110 Vac	64.216	°C	
Estimated junction temperature @ 120 Vac	78.424	°C	
Estimated junction temperature @ 130 Vac	96.16	°C	

Figure 10. Thermal-check Section

References

[1] "AN-5088 Designing for High Performance Commercial and Industrial Lighting Solution Using FL77944 High Power LED Direct AC Driver," Fairchild Semiconductor, July 2016.

Related Datasheets

FL77904 Phase-cut Dimmable Compact LED Direct AC Driver

FL77905 Analog/PWM/Phase-cut Dimmable Compact LED Direct AC Driver

FL77944 Analog/PWM Dimmable High Power LED Direct AC Driver

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