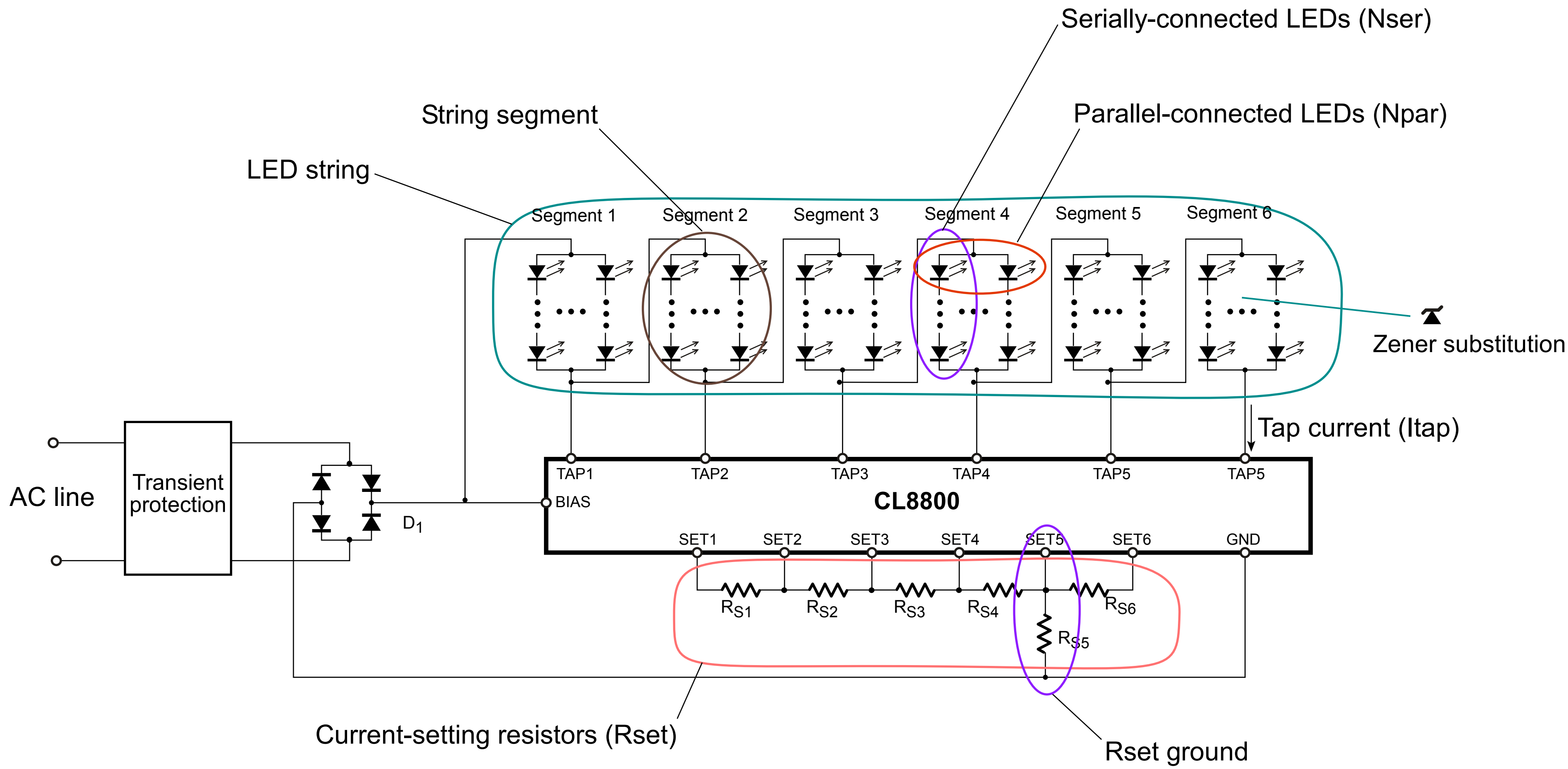
Supertex

CL8800 Design Guidelines


Serially-connected LEDs (Nser)
String segment
Parallel-connected LEDs (Npar)
LED string
Segment 1
Segment 2
Segment 3
Segment 4
Segment 5
Segment 6
Zener substitution
Tap current (Itap)
AC line
Transient protection
D1
TAP1
TAP2
TAP3
TAP4
TAP5
TAP5
BIAS
CL8800
SET1
SET2
SET3
SET4
SET5
SET6
GND
RS1
RS2
RS3
RS4
RS5
RS6
Current-setting resistors (Rset)
Rset ground

Conditions

Used to specify the operating conditions and the components and their characteristics.

Choose the LED by entering the number of the LED on the left side LED list.

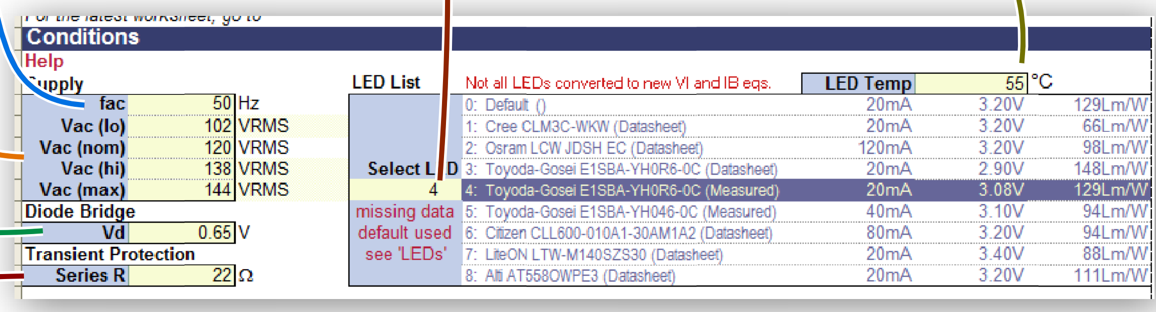
Temperature of the LED for simulation.

Line frequency

Line voltage range. Vac(lo), Vac(nom), and Vac(hi) are the normal operating range, Vac(max) is the highest continuous voltage the lamp must survive but not necessarily meet spec. For convenience, Vac(lo), Vac(hi), and Vac(max) may be referenced to Vac(nom) (e.g. –15%, +15%, and +20%).

Voltage drop of a single rectifier in the bridge.

Total resistance in series with the AC line (normally used for transient protection. 120VAC = 22 220-240VAC = 55)



ENTER DATA INTO YELLOW CELLS ONLY!

Initial guesses shown in blue cells.

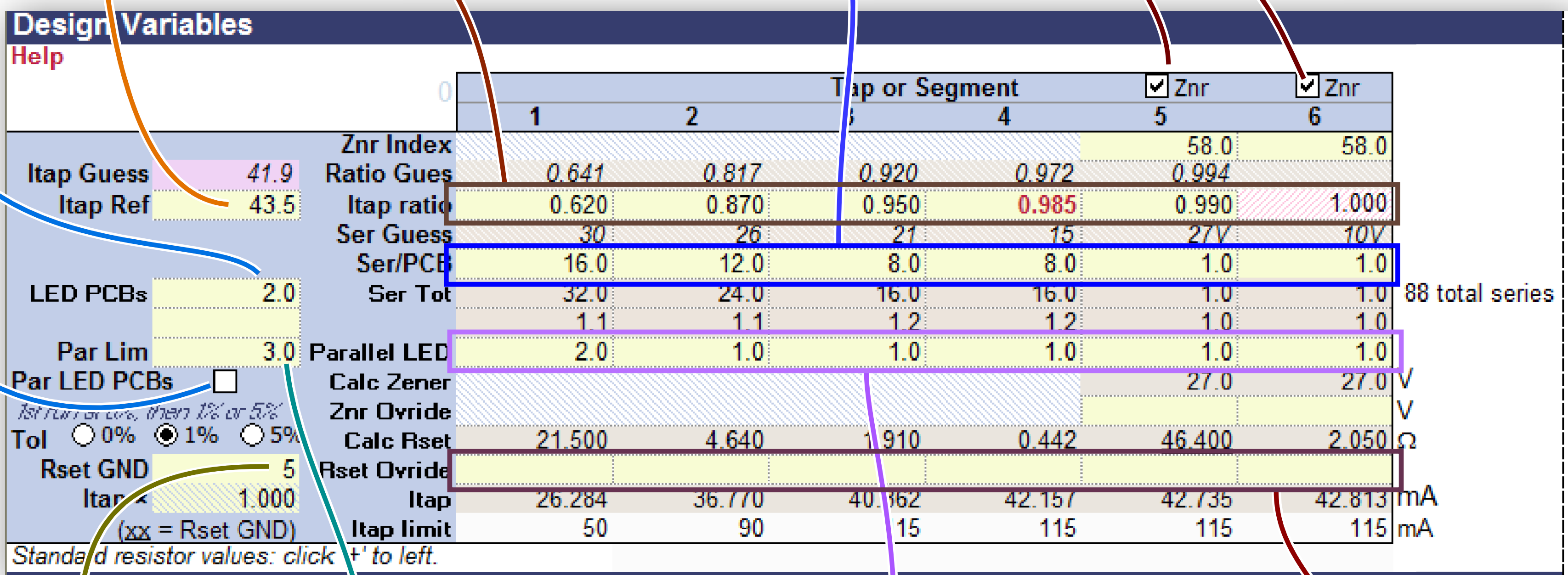
Tap currents are referenced to this value.

Refer to the LED PCB section. Otherwise, enter ‘1’ and uncheck.

Sets the current for each tap as a fraction of Itap Ref Must be monotonic.

When ‘LED PCBs’ is set to 1, this is the number series LEDs for each segment.

Activates zener substitution.



Leave blank when using Solver. When setting the current-setting resistors (Rset) manually, enter ‘5’.

Limits the number of parallel LEDs that Solver chooses.

Sets the number of parallel LEDs for each segment. When ‘Par LED PCB’ is checked, Solver will use the value entered in ‘LED PCBs’ .

The current-setting resistors may be manually selected by entering the values in this row. Otherwise leave blank.

ENTER DATA INTO YELLOW CELLS ONLY!

This table is used to specify the desired performance of the lamp and presents results of the simulation. Solver uses this information to optimize the design. Since compromises are frequently needed, both a target criteria and a minimum acceptable criteria are provided. Each set of criteria is assigned a weighing factor to designate the importance (higher = more important). A ‘zero’ means the criteria is unimportant and Solver will not try to optimize for it.

Solver first attempts to meet all the minimum acceptable criteria. Once (or if) the minimum requirements are met, Solver will try to attain the targets, with priority given to those criteria with a higher weighing factor.

When using measured LED data, simulation predictions are typically within 5% of the actual circuit.

Simulation results shown in tan cells.

Minimum acceptable

Ideal

Degree of importance

Sets the goal as an upper limit, a lower limit, or exact value. May be changed by typing in ‘min’, ‘nom, or ‘max’.

Results of the simulation.
Color-coded:
grey = unimportant
red = does not meet minimum acceptable
purple = meets minimum but not target
green = meets target

The margin between target or acceptable and the result of the simulation. Expressed as a ratio. Positive values exceed requirements.
Color-coded:
grey = unimportant
red = does not meet goal
green = meets goal

Light output.

Luminous efficiency

Variation in light output as voltage varies.

Number of LEDs

Additional LEDs relative to the number of LEDs when driven at the `steady-state nominally rated current..

An approximation of the LEDs’ safe operating area. Values over 1 exceed the LEDs SOA.

Minimum tap current can be specified to accommodate phase dimmers.

Line current THD is calculated in the time domain, so results will be slightly different to actual frequency domain measurements.

Performance Advanced Controls: click '+' to left

Help

Summary and Optimization *Repeat Solver for different results.*

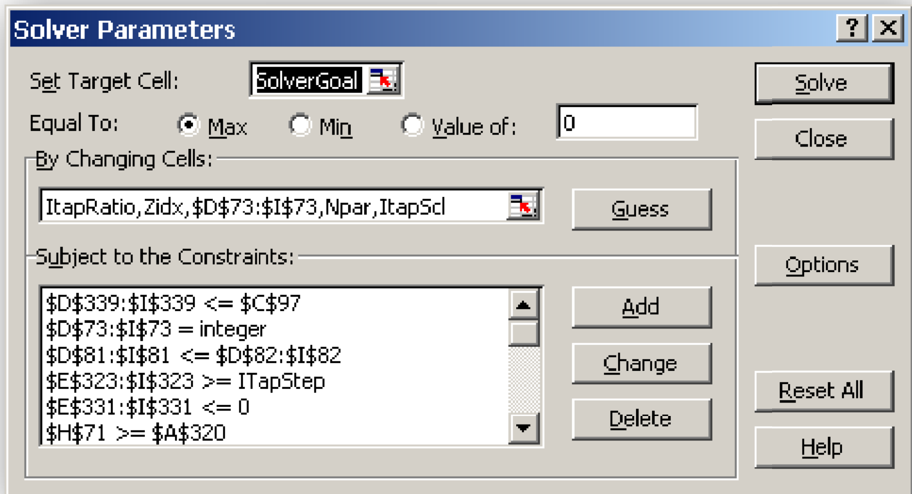
Parameter	Wgh Fctr	Target	Accept	Dir	Result	Units	Conditions	Mgn Trgt	Mgn Acpt
Light	7	810	750	min	816	Lm	nom line	0.7%	8.8%
Lum Eff	3	100	90	min	111	Lm/W	nom line	11.1%	23.4%
Line reg, hi	1	10	15	max	12.2	%	hi line	-22.3%	18.5%
Line reg, lo	1	-10	-20	max	-21.6	%	lo line	-116.2%	-8.1%
Nled	6	160	200	max	120		—	25.0%	40.0%
Extra LEDS	4	40	50	max	22	%	—	45.7%	56.6%
max Pled	2	125	125	max	91	mW	lo–max line	27.5%	27.5%
Pout	0	10	10	nom	6.4	W	nom line	-35.7%	-35.7%
PF	2	0.9900	0.9000	min	0.9881		nom line	-0.2%	9.8%
LED SOA	9	0.850	0.900	max	0.766		nom line	9.9%	14.9%
Pdrv	8	0.650	0.800	max	0.770	W	lo–max line	-18.5%	3.7%
Elec Eff	0	92.0	85.0	min	88.6	%	nom line	-3.7%	4.2%
min Itap	0	33		min	26.3	mA	—	-20.4%	—
THD	5	10	20	max	14.5	%	nom line	-45.2%	27.4%

ENTER DATA INTO YELLOW CELLS ONLY!

Solver may be used (with various degrees of success) to automatically find the most optimal design given the choice of LED, operating parameters, and performance goals. Success depends in large part on the initial guesses for design variables. Use the suggested values in the blue cells.

If the results do not meet expectations, adjust the goals and weighing factors. Also try manually tweaking the design variables. Sometimes rerunning Solver will improve the results.

Check your version of Excel on how to open Solver. There is no need to adjust anything in the Solver window — just click 'Solve'.



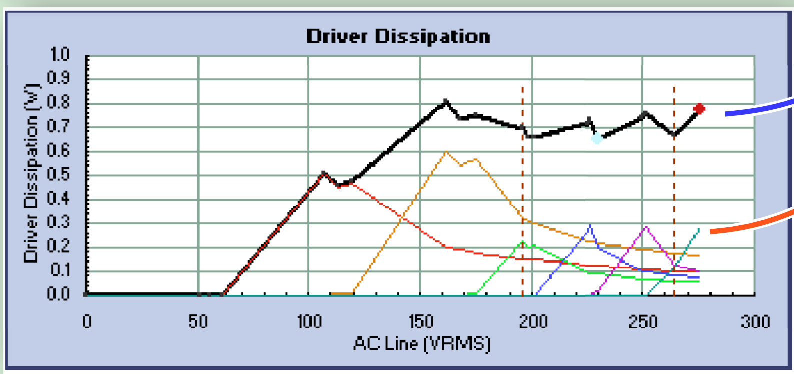
If Solver cannot find a feasible solution check the Design Variables table for red lettering and adjust yellow cells appropriately. Sometimes rerunning Solver will clear the 'cannot find a feasible solution' problem.

Solver sometimes does not achieve the most optimal design. Manual tweaking, as explained in the following 4 pages, can improve Solver's results.

The Driver Dissipation graph shows the power dissipation of each linear regulator in the CL8800 as line voltage varies. It gives an idea which regulators are being underutilized and which are being overused. If the voltage drop across an LED string segment is high, the power dissipation in the preceding stage will climb too high before the next regulator takes over. Conversely, if the voltage drop across a segment is too low, the downstream regulator will take over before the upstream regulator has been fully utilized. For this reason, this graph is used to configure the number of series LEDs per segment and the zener voltages.

Good

Zener					32.0	39.2	V
Calc Zener					33	43	V
Ser Guess	31	27	22	16	30	10	
Ser/PCB	30.0	25.0	23.0	11.0	1.0	1.0	



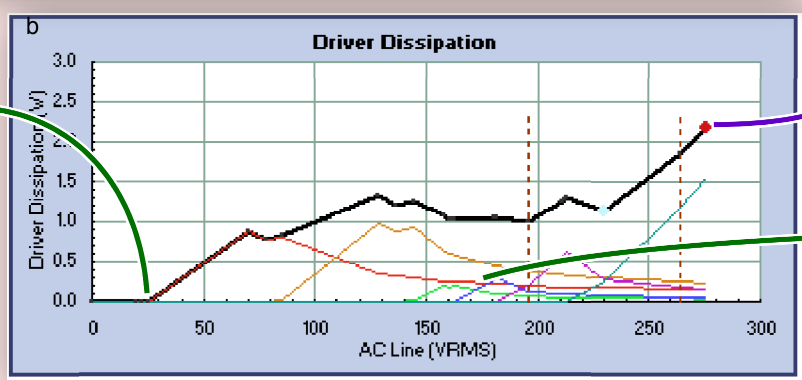
Overall dissipation (thick black line) is reasonably flat over a wide input voltage range.

Individual peak regulator dissipation is fairly equal in the input voltage range.

Bad

Zener					22.0	39.2	V
Calc Zener					24	43	V
Ser Guess	31	27	22	16	30	10	
Ser/PCB	11.0	25.0	23.0	7.0	1.0	1.0	

Regulator 1 turns on too early, resulting in high regulator voltages at the other end of the input voltage range, causing excessive power dissipation. Increase the voltage of segment 1 by increasing the number of LEDs.



The last regulator overheats at high line voltages. Voltage must be increased in upstream stages by increasing the number of series LEDs or increasing zener voltage.

Regulators 3 & 4 are underutilized. Increase the voltage in segments 4 & 5.

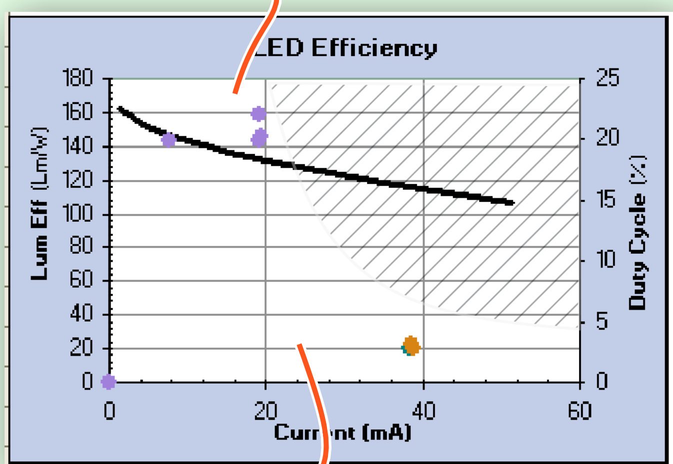
LED EFFICIENCY

The LED Efficiency graph combines the LEDs' efficiency curve with the LED drive currents. It shows how efficiently the LEDs are being driven. Ideally, the drive currents should be on the left side of the graph where LED efficiency is highest.

Drive current duty cycle indicates the relative importance of the point — higher duty cycles have more of an effect than lower duty cycles.

Good

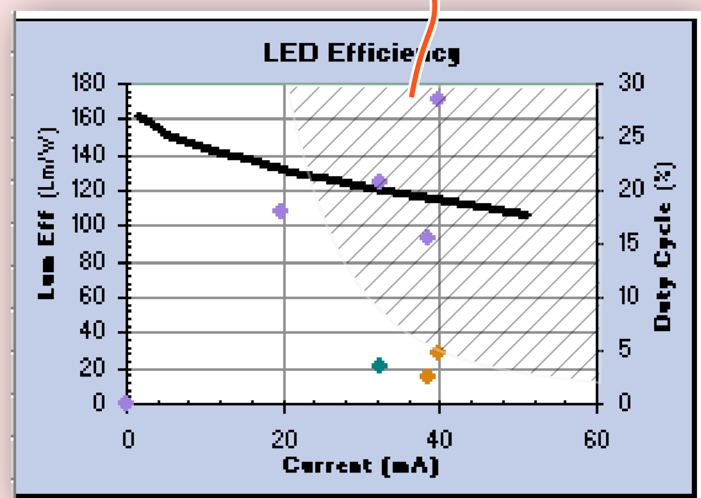
The LED drive points are on the left side of the graph, where LED efficiency is high.



Try to keep the drive points within this general area.

Bad

The LED drive points are towards the middle and right side, where LED efficiency drops off.



To correct, reduce tap current or parallel LEDs.

LED SOA

The LED SOA graph is an approximation of the safe operating area of the LED. Peak currents are maintained and the duty cycle is adjusted to obtain the average LED current. Time restrictions may apply.

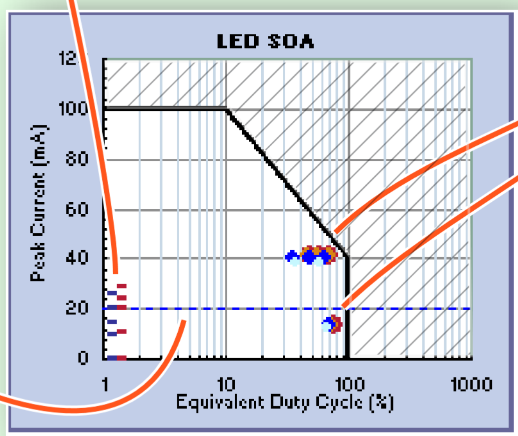
Good

Parallel LED	2.0	1.0	1.0	1.0	1.0	1.0

Average LED current for each tap at nominal and max line voltage .

All the tap currents at the various line voltages are shown.

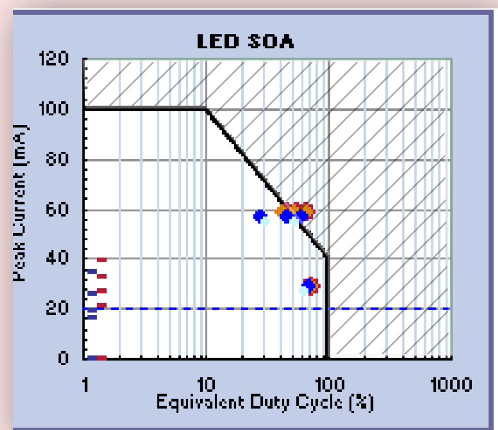
Nominally rated LED current



The LED drive points are within the SOA.

Bad

Parallel LED	2.0	1.0	1.0	1.0	1.0	1.0



The SOA is exceeded at high line voltages. Lower current or parallel LEDs

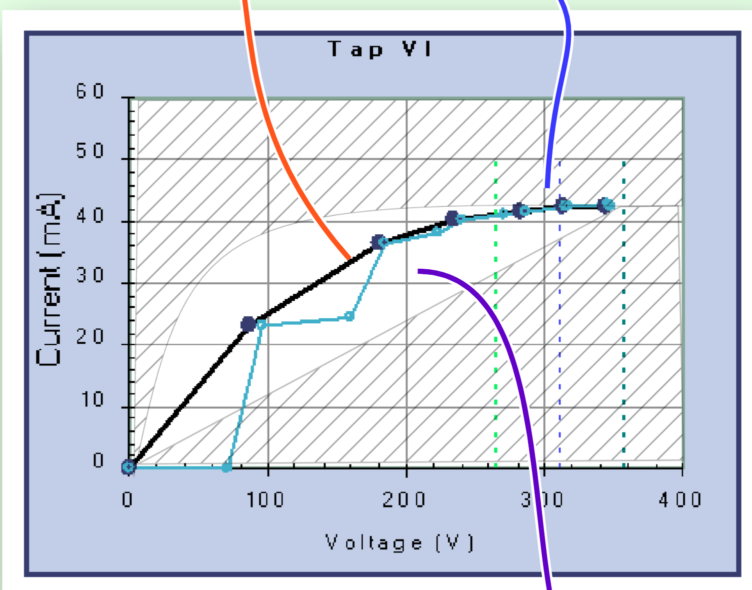
While the Regulator Dissipation graph is primarily used to determine the number of series LEDs and zener values (voltage), this graph is used to determine tap currents.

Good

Itap Ref	42.2	Itap ratio	0.300	0.350	0.950	0.977	0.990	1.000

The curve resembles a sine wave

Current flattens-out in the normal input voltage range, providing better line regulation.



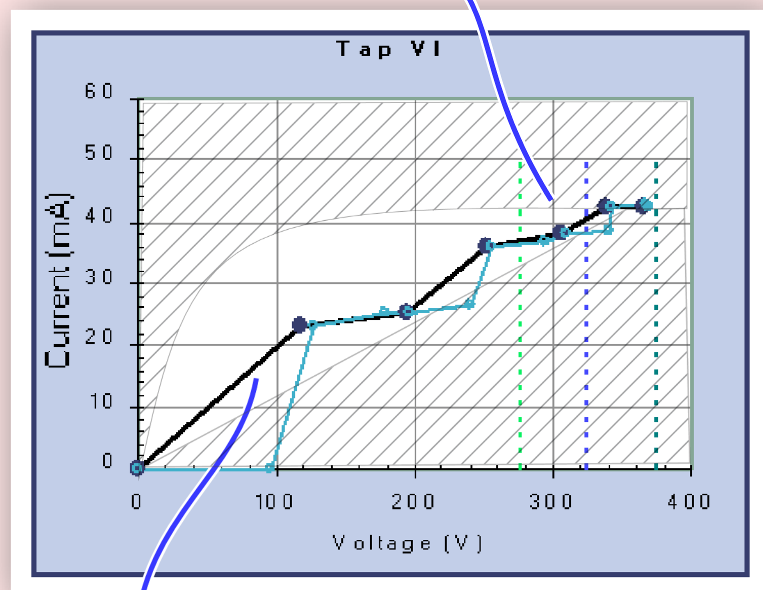
Steeper leading edges improve line regulation but increases THD.

Keep the curve in this general area.

Bad

Itap Ref	60.0	Itap ratio	0.480	0.800	0.950	0.977	0.990	1.000

The current continues to vary in the input voltage range.



The curve is rough and does not resemble a sine wave.

From the LED datasheet

Type	Color temperature	Luminous Intensity[1) page 20] I_F = 20 mA I_V (mcd)	Luminous flux[1) page 20] I_F = 20 mA I_V (mlm)	Or
LCW JNSH.PC-BRBT-5H7I-1	5000K	2100 ...2590	7400 (typ.)	Q
LCW JNSH.PC-BRBT-5L7N-1	4000K	2100 ...2590	7300 (typ.)	Q
LCW JNSH.PC-BQBT-5R8T-1	3000K	1940 ...2590	6800 (typ.)	Q

Durchlassspannung[6) Seite 20]	(min.)	V_F	2.8	V
Forward voltage[6) page 20]	(typ.)	V_F	3.05	V
I_F = 20 mA	(max.)	V_F	3.4	V

From the Excel worksheet, LED page

Help	missing data			missing data
Do not enter in col B!	2	Index →	0	2
LED Mfg	Osram		Default	Osram
LED PN	LCW JDSH EC			LCW JDSH EC
General		Select Override (x) →		x
Source	Datasheet			Datasheet
By	SLL			SLL
Date	18Jun12			18-Jun-12
Candela to lumen calculator				
LED Characteristics (italic = default sub)				
Nominal Iled	120.00	mA	20.000	120.000
Vled	-0.11	V	3.200	3.200
Vled Model	-0.11			-0.106
TC Vled	*-2.00*	mV/°C	-2.000	
Brightness	—	Lm	6.000	37.600
TC Brightness	*0.00*	%/°C	0.000	
Luminous Eff	#VALUE!	Lm/W	#VALUE!	97.917
Color Temp	—	°K	—	
Lum Bin	—		—	
Color Bin	—		—	
Vf Bin	—		—	
Series LEDs/Pkg	1.00		1	1.000
LED Ratings				
Ipulse(max)	300.00	mA	480	300.000
@ Duty	0.50	%	10	0.500
Idc(max)	180.00	mA	180	180.000
Power	*-19.14*	mW	-19.14303573	

Enter 'x' to select the LED. The active LED is indicated by a vertical red stripe.

Better results can be obtained using measured data.

This value is calculated from V_F, I_{NOM}, and Brightness

A candela to lumen converter is available if the LED datasheet does not specify lumens.

From the LED datasheet

Absolute Maximum Ratings (Ta=25℃)

Parameter	Symbol	Rating	Unit
Reverse Voltage	V_R	5	V
Forward Current	I_F	30	mA
Peak Forward Current (Duty 1/10 @1KHz)	I_{FP}	100	mA
Power Dissipation	Pd	110	mW
Electrostatic Discharge	ESD	1000	[illegible]

From the Excel worksheet, LED page

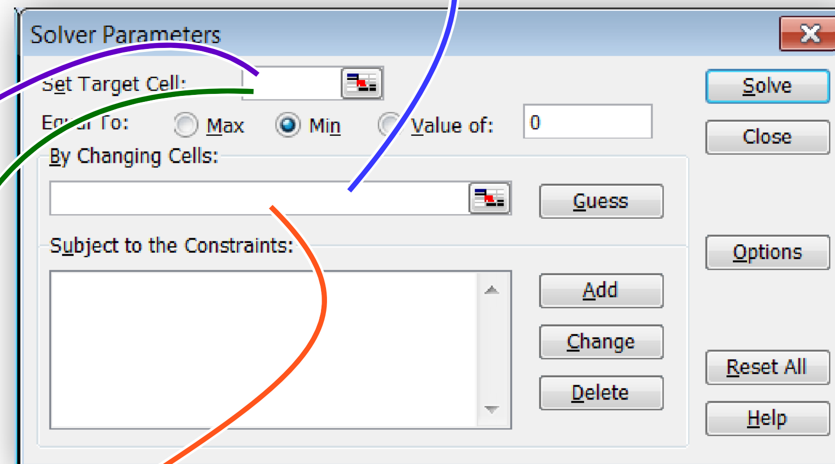
43	LED Ratings					
44	Ipulse(max)	100.00	mA	80		100.0
45	@ Duty	10.00	%	10		10.0
46	Idc(max)	30.00	mA	30	160.000	30.[illegible]
47	Power	110.00	mW	123.0926996	560.000	110.0
48	LED VI Coefficients					

LED VI Coefficients

Vnom	2.18 V	3	2.180
Rled	13.80 Ω	10	13.800
Knee	2.35	2	2.350

Voltage ~ Current

Current	Actual V	Model V	Err^2
5.172	2.733	2.732	1.72E-01
10.591	2.873	2.874	3.53E-01
19.951	3.080	3.067	6.65E-01
33.251	3.313	3.307	1.11E+00
49.754	3.580	3.581	1.66E+00
		Optimize Target	**3.78E+00**



LED BI Coefficients

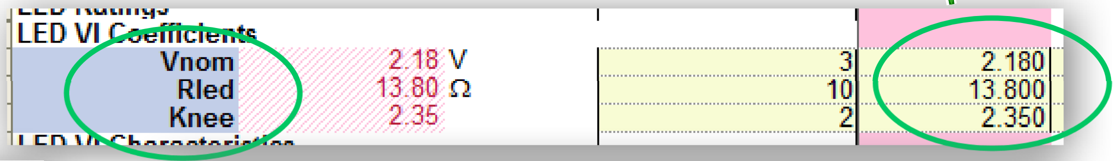
Slope	0.28	0.000	0.283
k	3.04	3.333	3.040
Knee	0.19	0	0.189

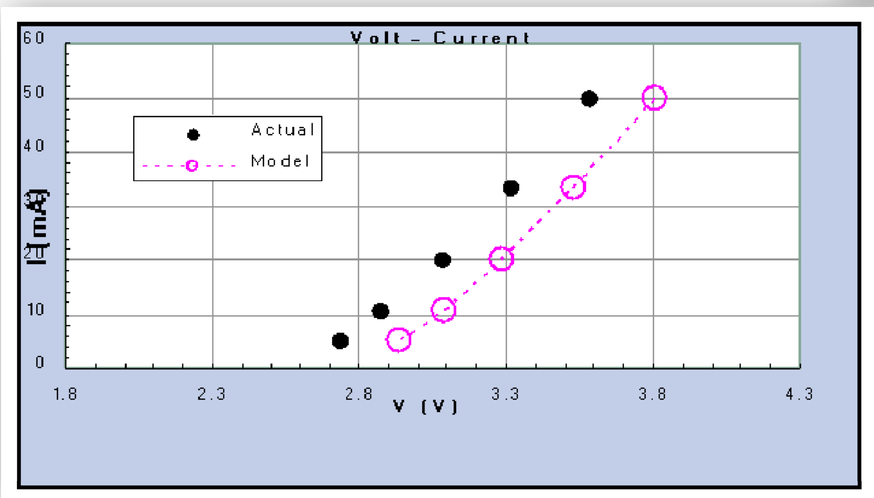
Brightness ~ Current

Current	Actual Brt	Model Brt	Err^2
5.366	0.201	0.194	5.80501E-05
12.927	0.456	0.434	0.000318918
20.488	0.710	0.640	0.004063318
34.878	1.134	0.956	0.033908148
50.000	1.515	1.207	0.122805058
		Optimize Target	**0.161153492**
30.00		0.859	

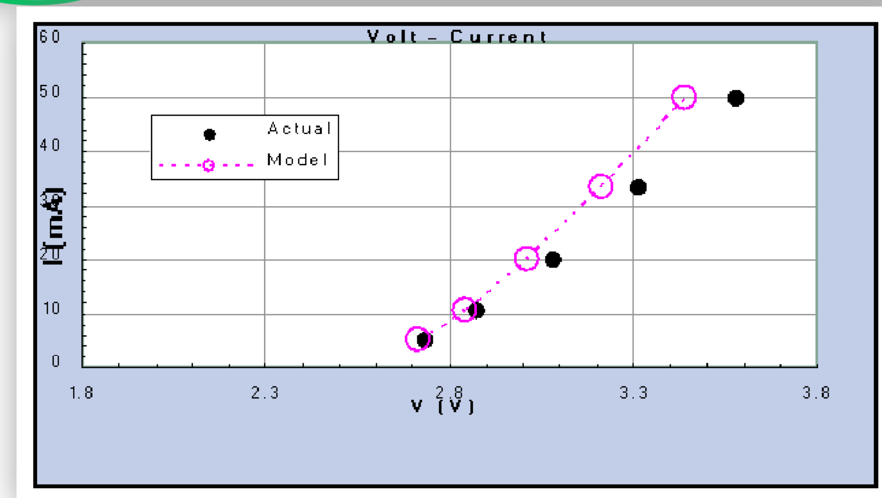
Solver does not always find the best fit.

Active LED ('x' in the 'Select override' row. Column should be highlighted.)

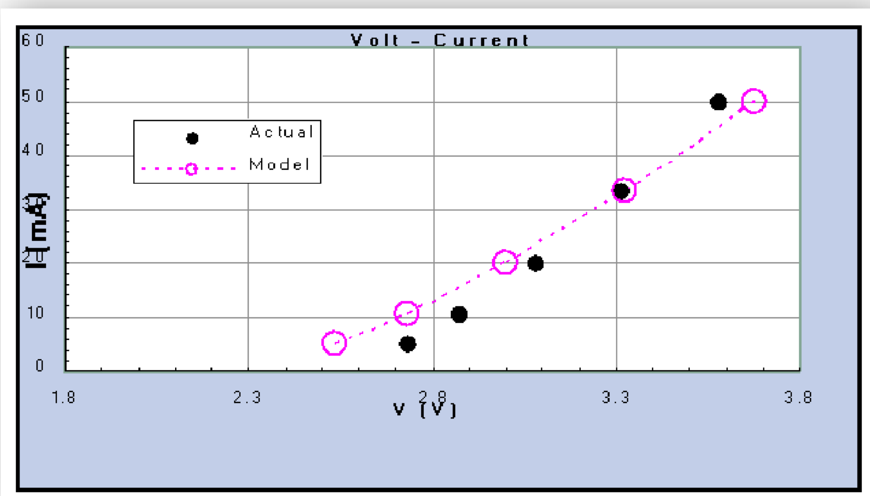




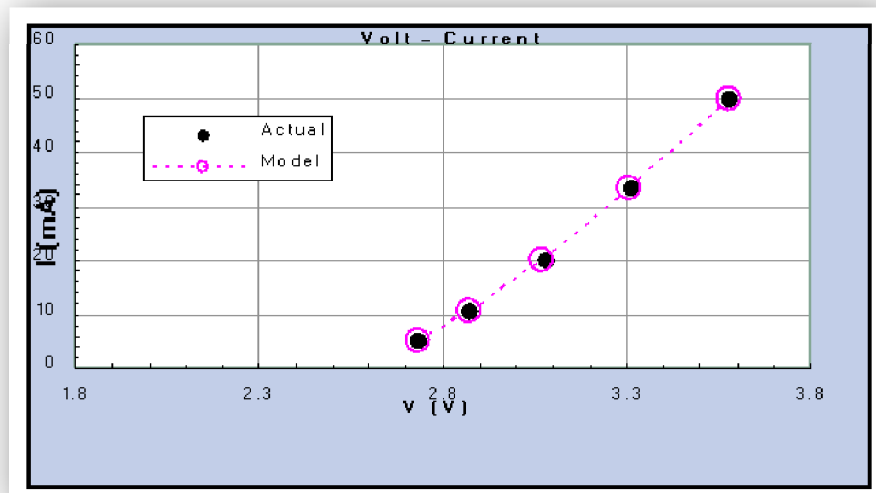
The curve is offset on the voltage axis. Change 'Vnom'.



The higher points diverge more. Change 'Rled'



The curve pivots about the middle. Change 'Knee'.

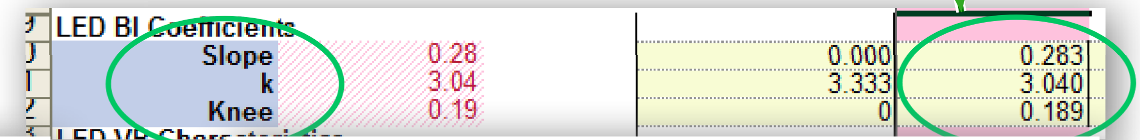


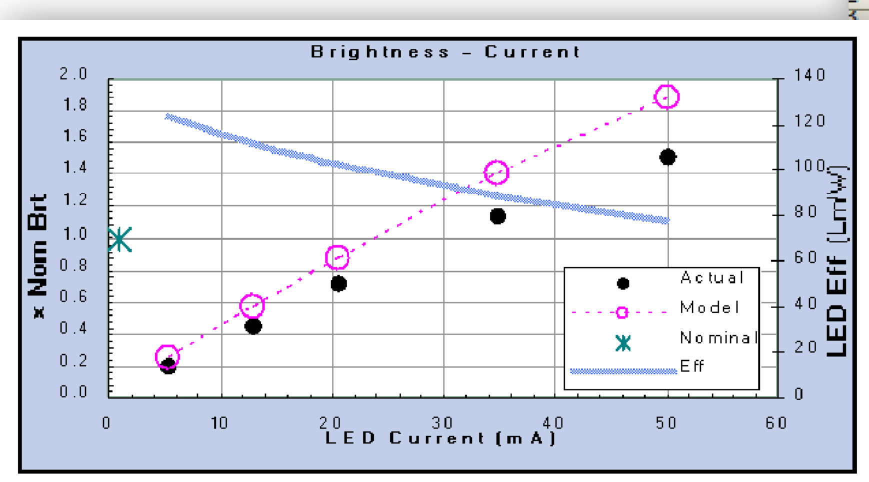
Acceptable fit.

LED BRIGHTNESS—CURENT FIT

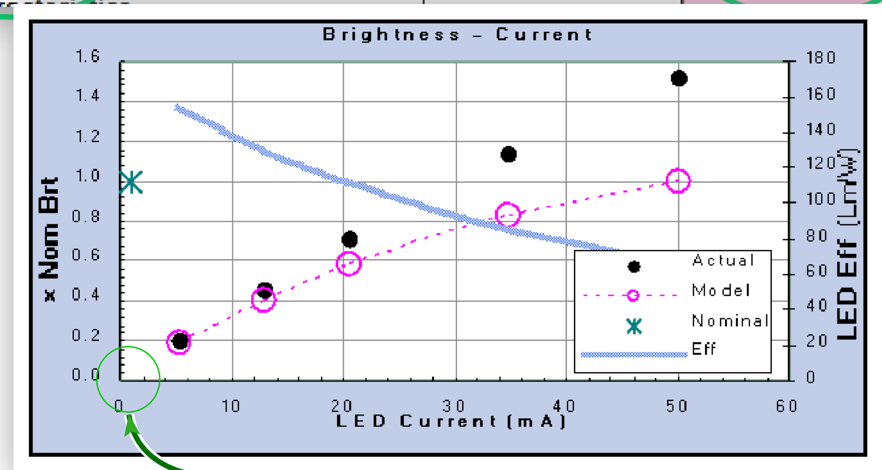
Like the VI curve, Solver does not always find the best fit.

Active LED ('x' in the 'Select override' row. Column should be highlighted.)

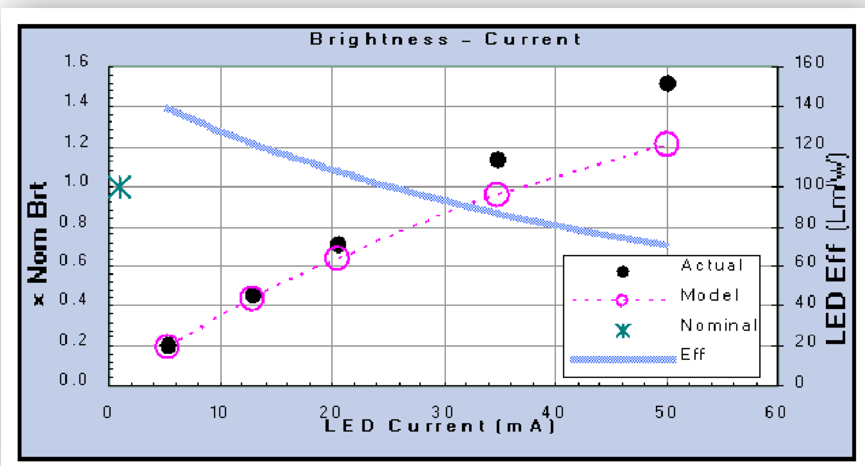




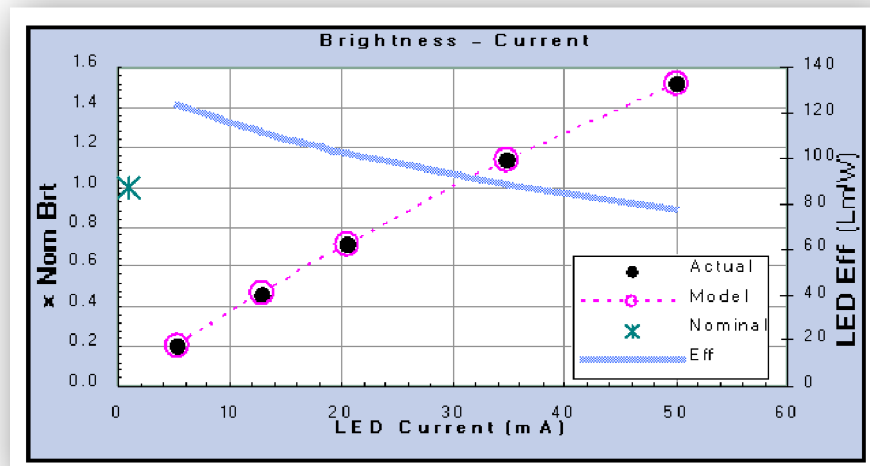
The Slope differs and the curve is offset vertically. Adjust 'Slope'.



The curve pivots around the lowest point. Change 'k'.



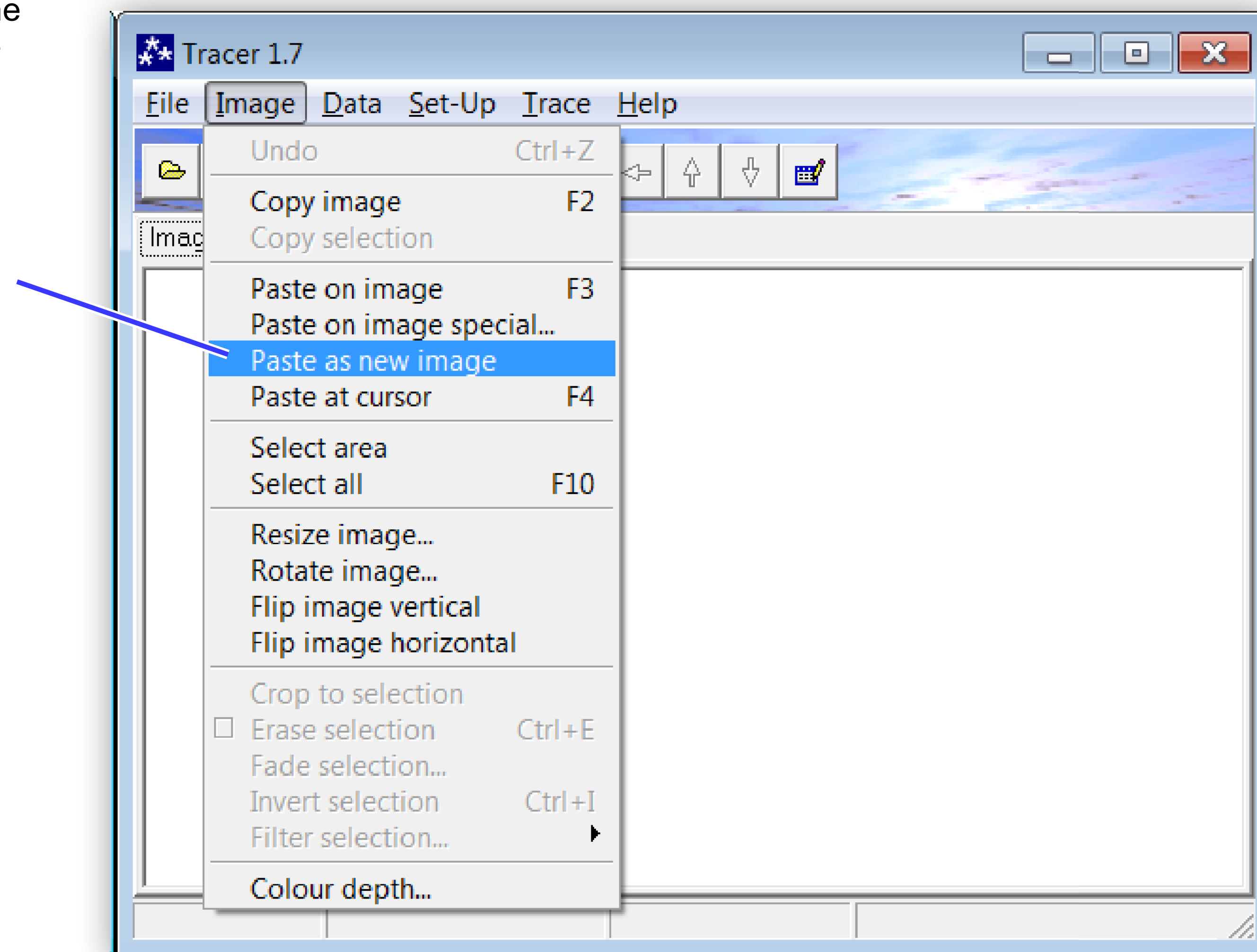
The location of the knee is not at the lowest point. Change 'Knee'.



Acceptable fit.

1 Use the Snapshot tool in Acrobat Reader to copy the graph onto the clipboard. If the Snapshot tool is disabled type Alt-Print Screen.

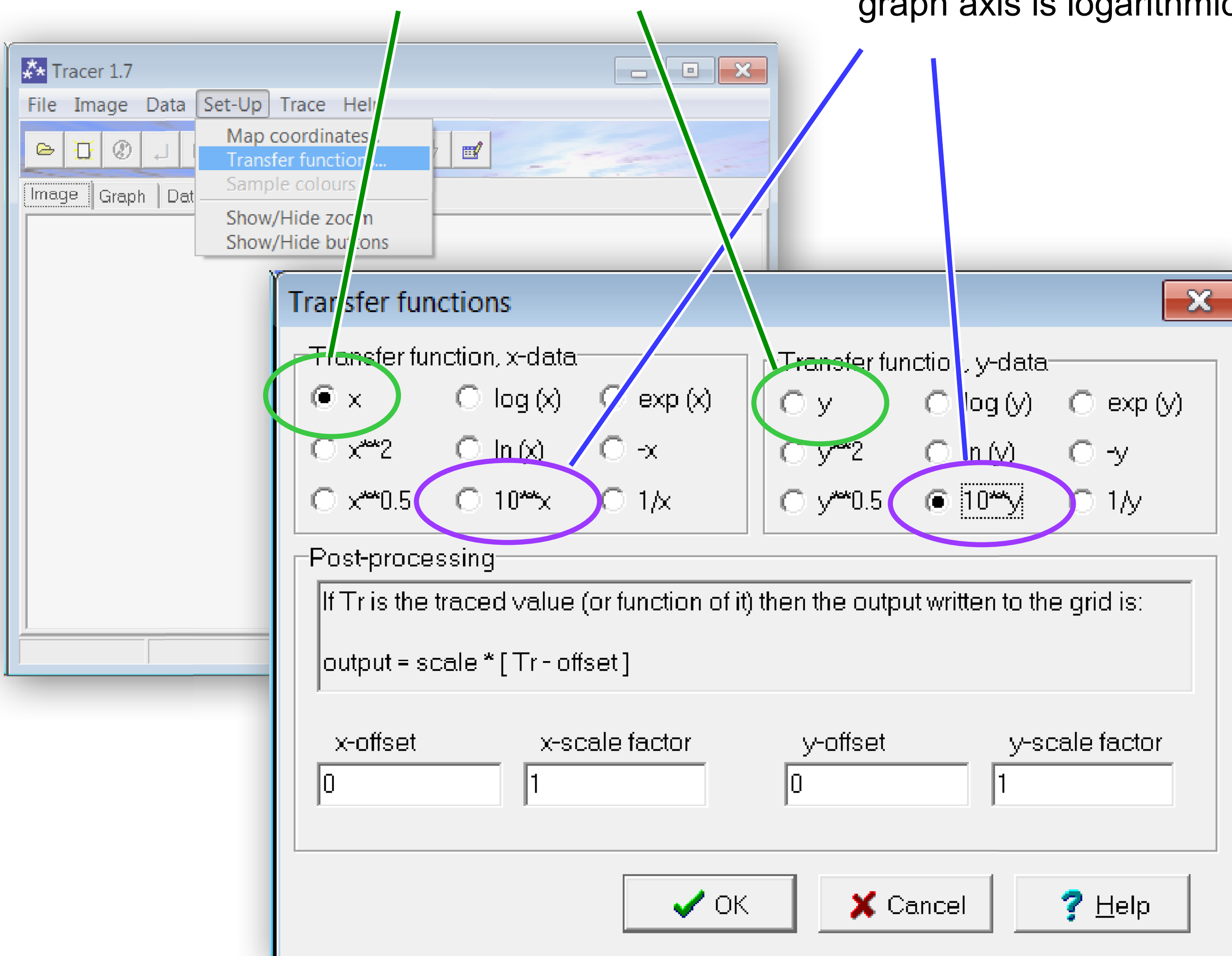
2 Go to Tracer and select 'Paste as new image.



LOGARITHMIC AXIS

Use this function when the graph axis is linear

Use this function when the graph axis is logarithmic



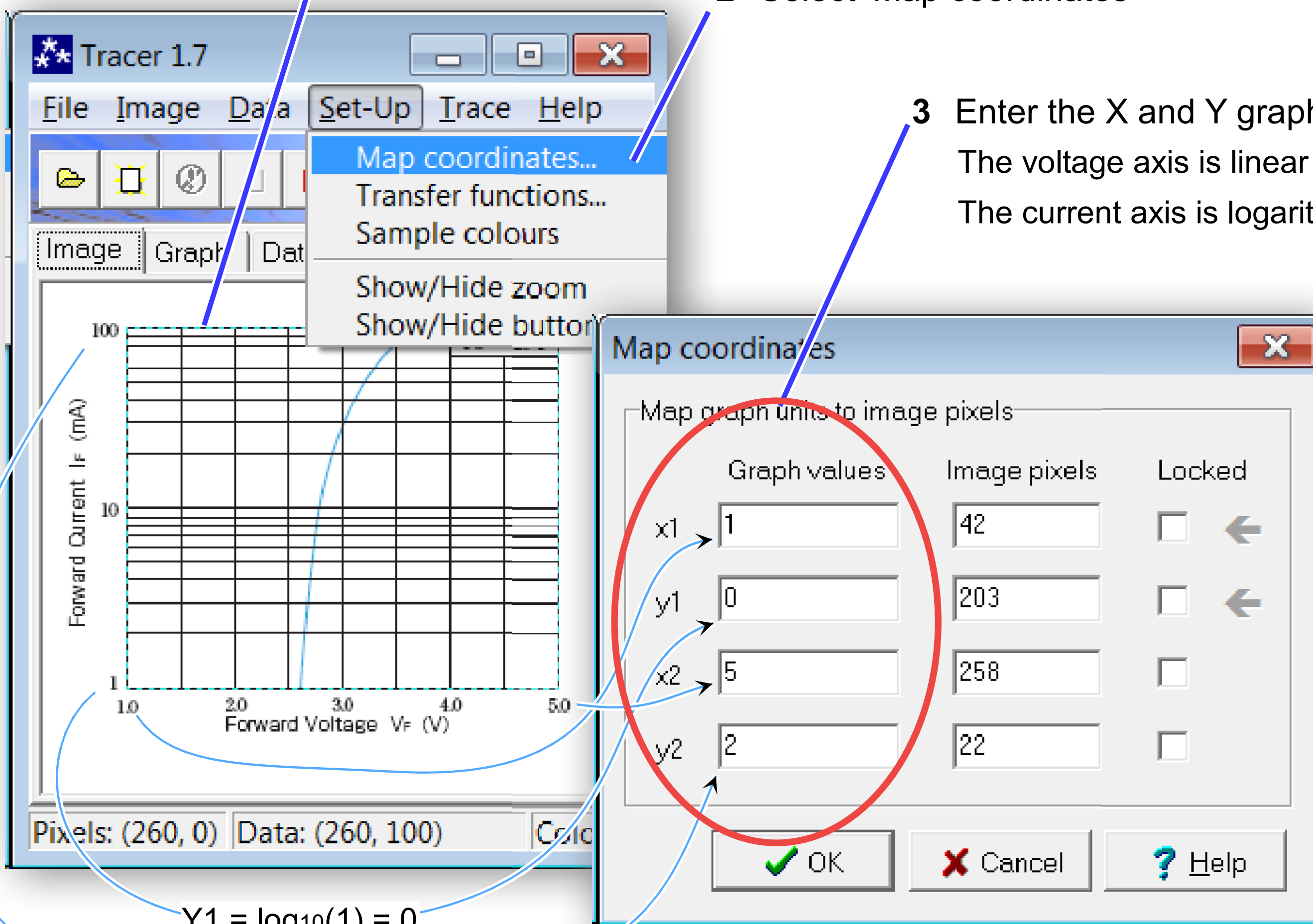
1 Select graph area by dragging cursor

2 Select 'Map coordinates'

3 Enter the X and Y graph axis reference points.

The voltage axis is linear so the value is entered directly.

The current axis is logarithmic so $\log_{10}$ of the value is entered

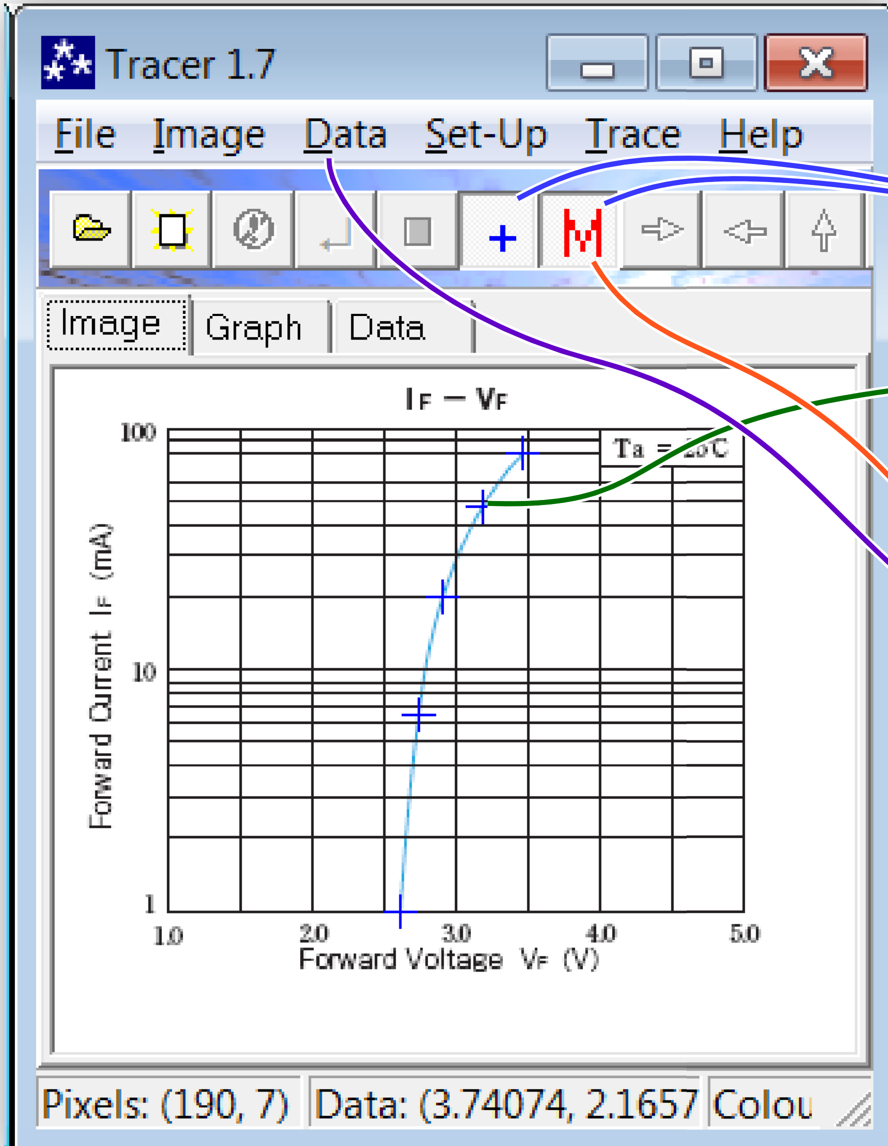


$Y1 = \log_{10}(1) = 0$

$Y2 = \log_{10}(100) = 2$

Applies to VI graph and current–brightness graph.

Currents are in mA.



1 Click the Marker button (+) then click the Manual button (M). As long as the Manual button is active, every mouse click records a data point.

2 Click 5 points on the curve to record graph data. One point should be near the nominal rated current.

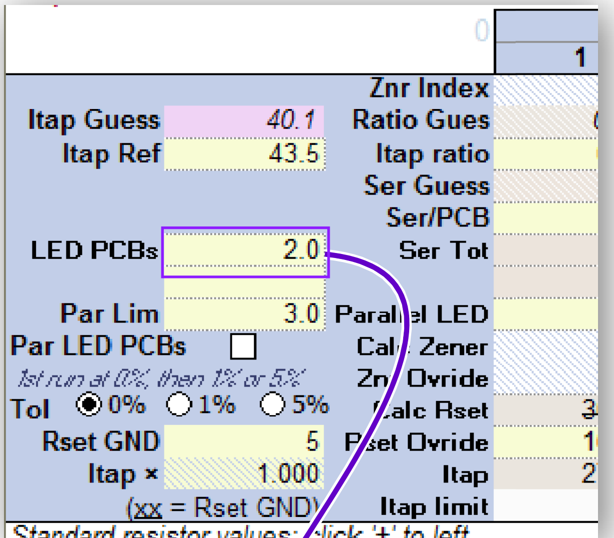
3 Unclick the Manual button.

4 Go to ‘Data’ and select ‘Copy all data’ or Ctrl-C.

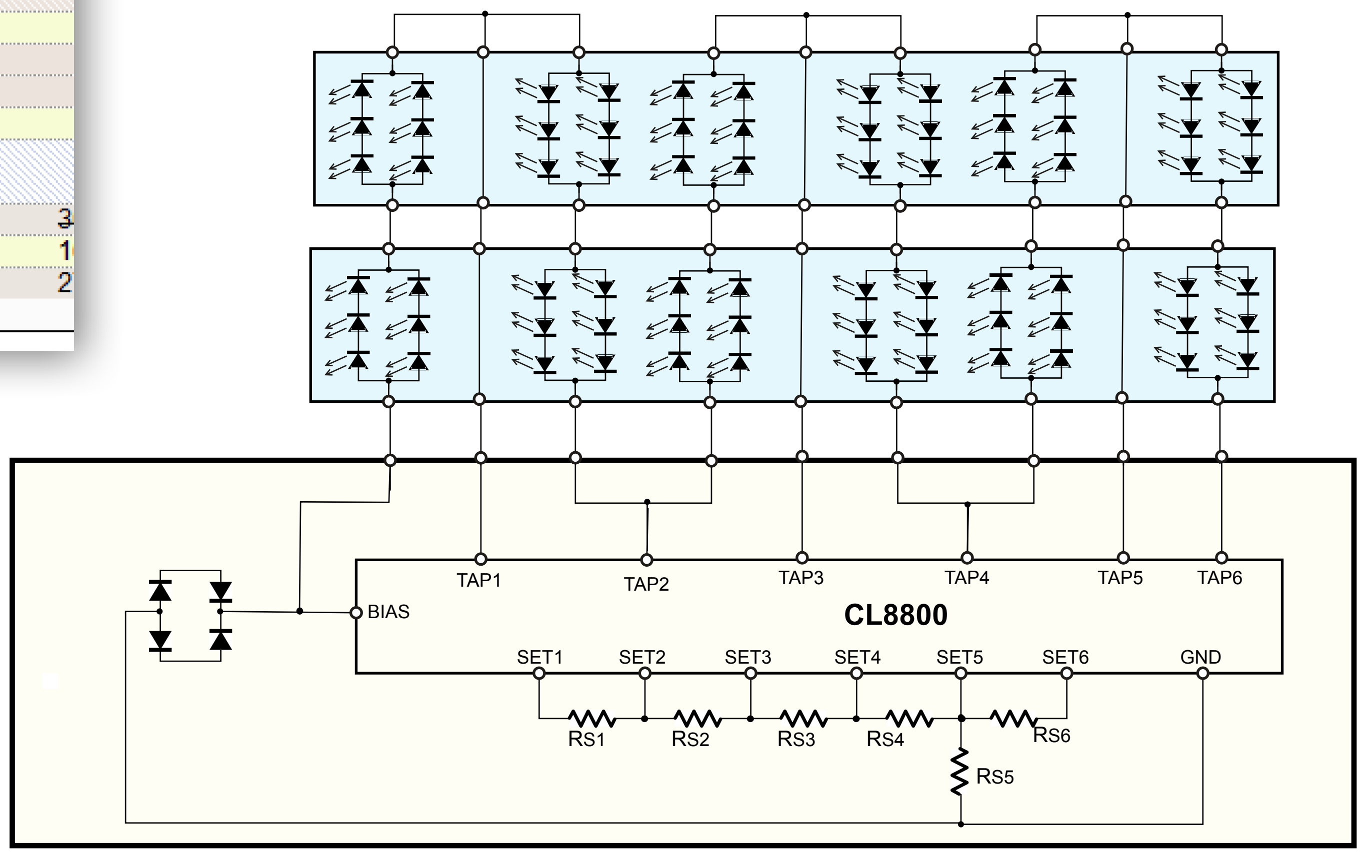
5 Switch to the Excel worksheet and paste into a blank area.

6 Select a column of data, copy, and ‘Paste Special – Values’ into the appropriate cells in the LED column. Repeat for the other column of data.

WIth a series connection, the number of series LEDs must be an integer multiple of the number of LED PCBs. The worksheet has controls for specifying the integer multiple for series LEDs.

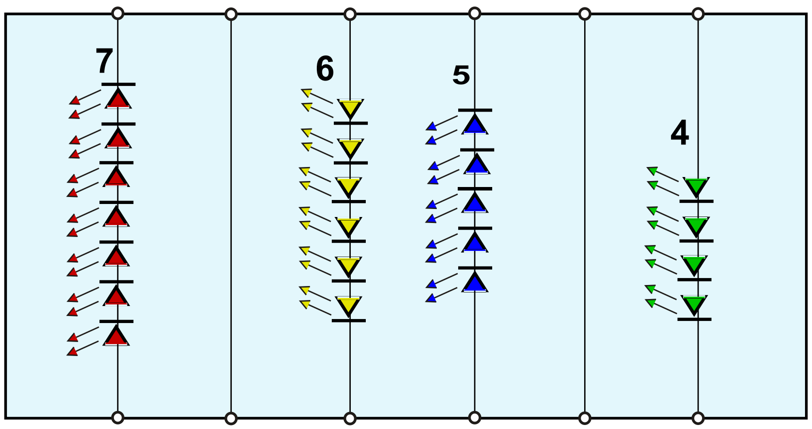


Set this cell to the number of LED PCBs. Solver will then choose an integer multiple of this value for the number of series LEDs.

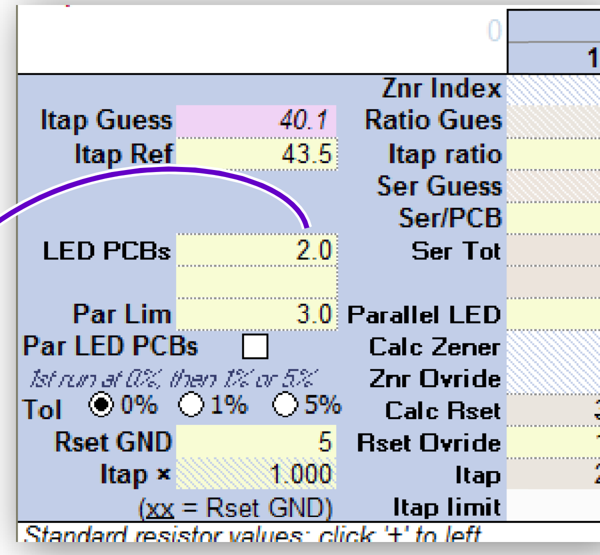


LED PCB Routing

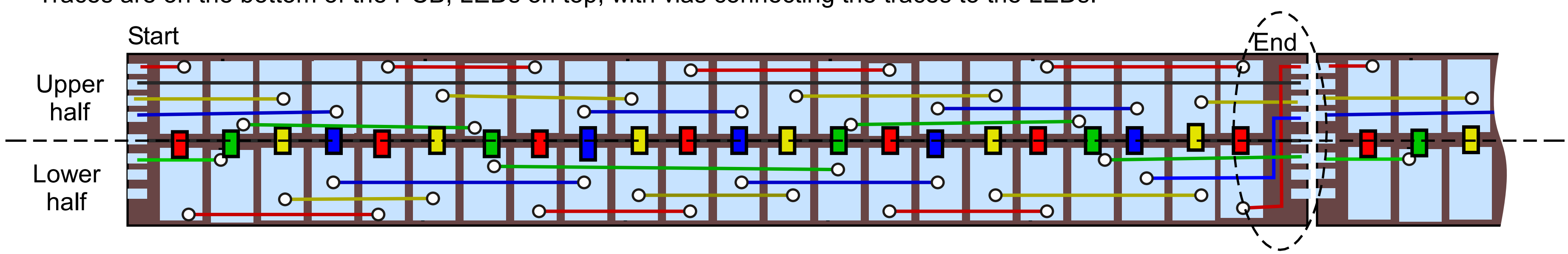
In this simplified example of LED PCB routing, 4 LED string segments are shown, represented by red, yellow, blue, and green.



Multiplying 'LED PCBs' by 2 assures an even number of LEDs. (e.g. if there are 2 PCBs, multiply by 2 to get 4)



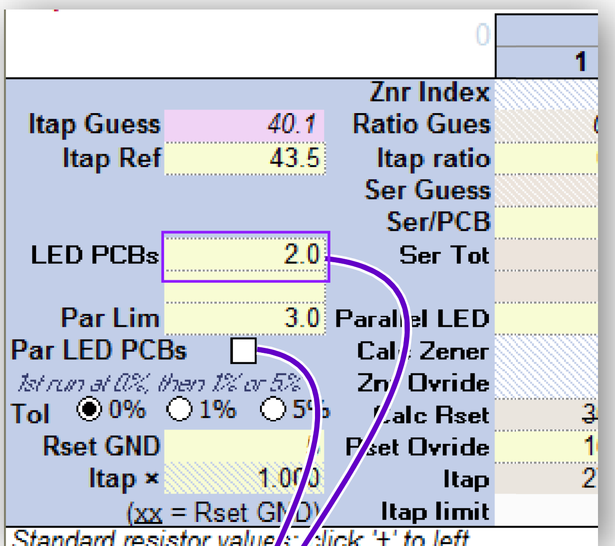
Traces are on the bottom of the PCB, LEDs on top, with vias connecting the traces to the LEDs.



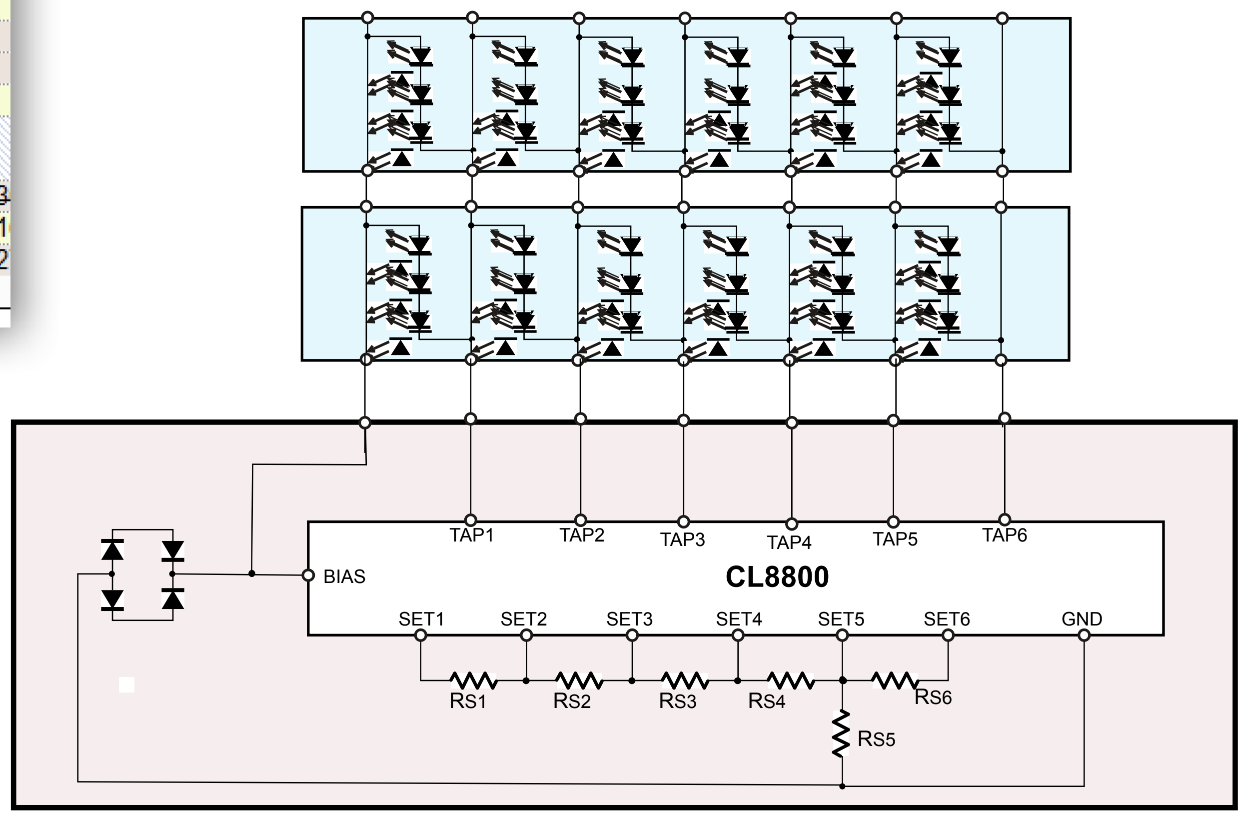
Red and Blue have an odd number of LEDs, placing start and end on opposite halves of the PCB, making routing difficult.

Yellow and Green have an even number of LEDs, keeping start and end on the same half of the PCB. This makes routing straightforward

With a parallel connection, the number of parallel LEDs must be an integer multiple of the number of LED PCBs. The worksheet has controls for specifying the integer multiple for parallel LEDs.

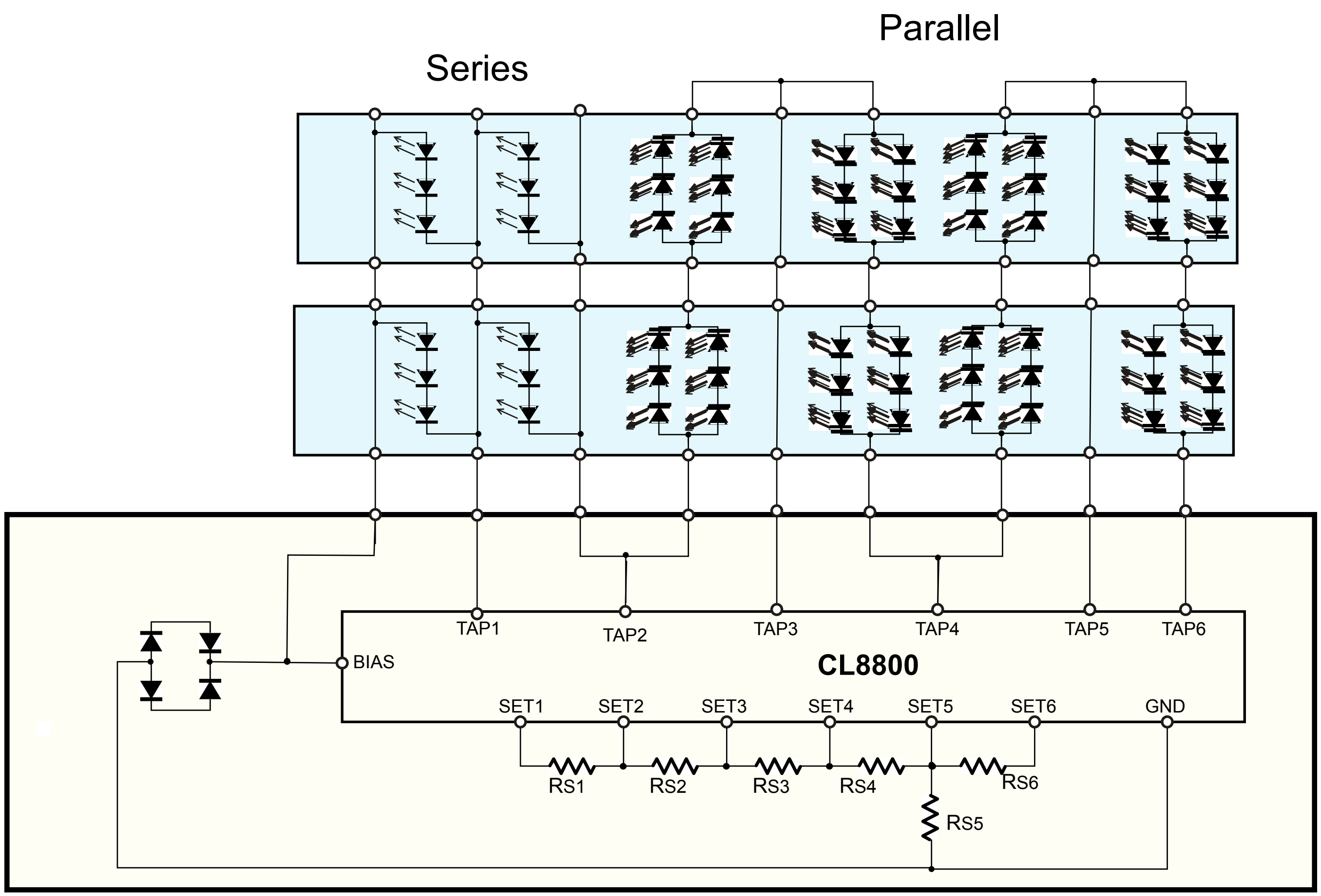


Set ‘LED PCBs’ to the number of LED PCBs and check ‘Par LED PCBs’. Solver will then choose an integer multiple of this value for the number of parallel LEDs.



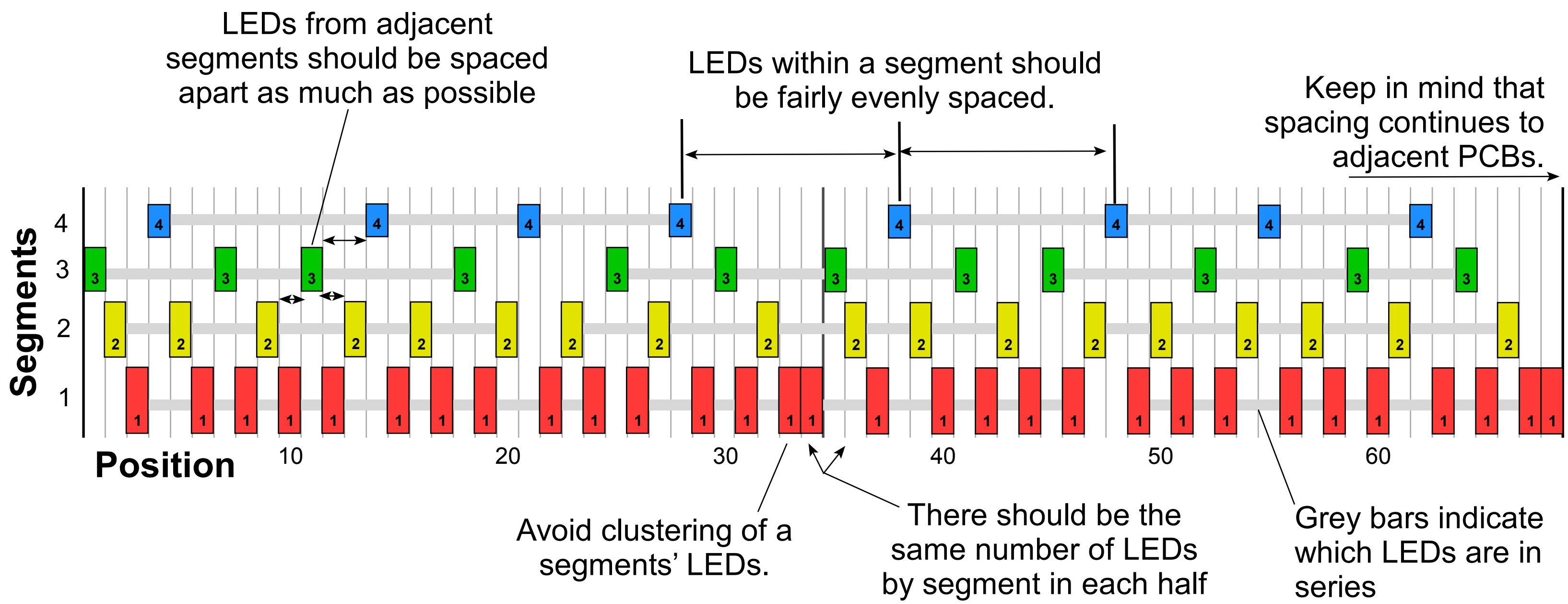
Hybrid LED Connections

Currently, the worksheet cannot handle this configuration, but will be available in the future.



LED DISTRIBUTION

Since LED string segments extinguish at low line voltages and during dimming, dark gaps will appear in the LED string. Zener substitution alleviates this problem, but care should be taken to distribute the LEDs to avoid cold spots.



Since the last segments are the first to extinguish, spacing priority should be given to them.

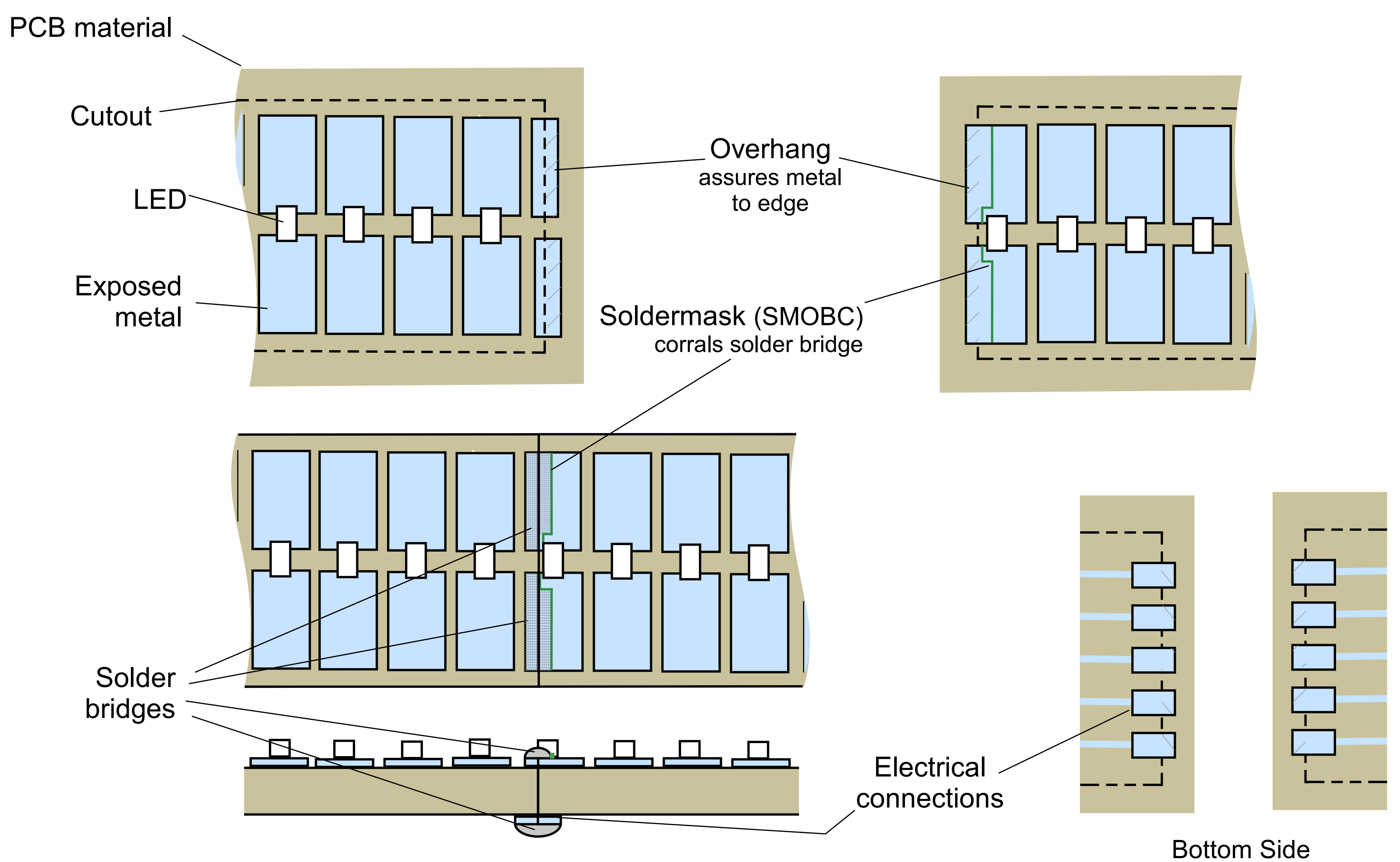
$$\text{Spacing Interval} = \frac{N_{SEG}}{N_{TOT}}$$

1 LED PCB represented

Use a graphics program to construct an LED distribution diagram.
If drawing program is unavailable, a spreadsheet could be used.

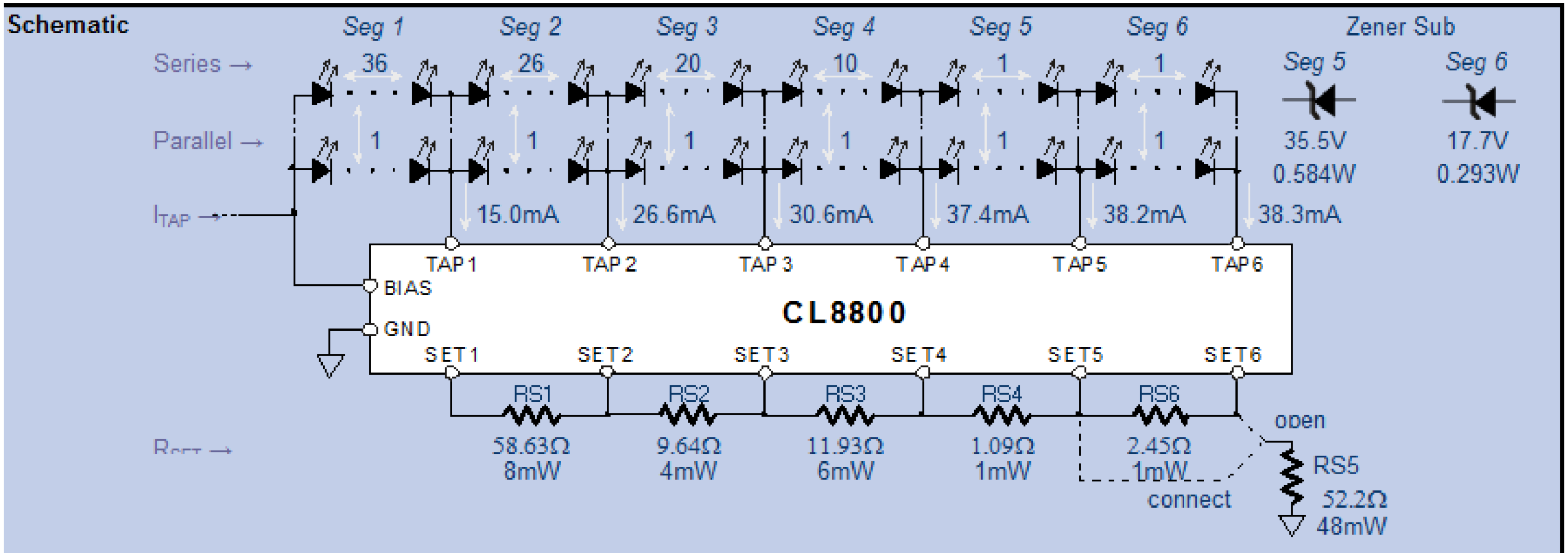
Gapless LED Strips

To provide more uniform light distribution, the gaps between multiple LED PCBs should be minimized. The following technique eliminates the gaps altogether.



Top and bottom solder bridges provide enough mechanical strength and rigidity for handling and assembly

DESIGN SCHEMATIC



NOTES