1 Scope

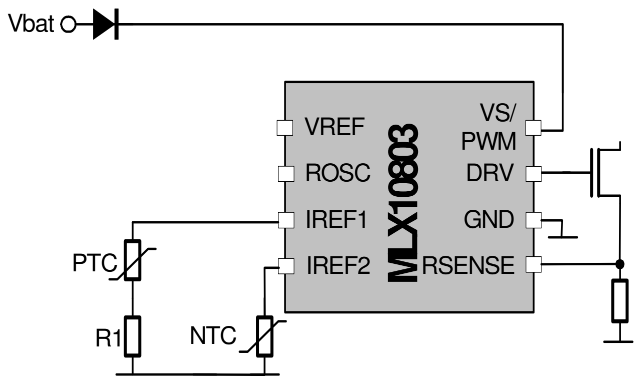
The scope of this application note is to provide some examples of how to apply temperature compensation and protection on the LED current using MLX10803 for different LED colors and different topologies like Buck and Buck-Boost.

2 Table of Contents

3 PTC compensation + NTC Overtemperature protection

The below example explains how to combine

- PTC compensation
- And overtemperature protection that regulates the LED current down above 80C.



3.1 Define PTC value

The PTC resistors from Tyco's LT73 series have a temperature dependence of 3900ppm/C

- 0805 up to 3 kOhm
- 1206 up to 6.2 kOhm

Compensation compared to 20C can be calculated to be:

- +23% at 80C
- -23% at -40C

For larger resistance values the temperature coefficient drops quickly. For instance the 27k value only has 1400ppm/C, or +/-8% from -40 to +80C.

The Vishays PTFT series offer a 1206 size up to 15 kOhm (ref: PTFT1206L1502KZ) with 2300ppm/C, or +/-14% from -40 to +80C.

For R_IREF1 = 12k at 20C, we maximize the temperature compensation effect by using four 3 kOhm PTCs in series on IREF1.

3.2 Define NTC value

The voltage on IREF2 has to become smaller than the voltage on IREF1 at 80C.
Therefore NTC(80C) ~ PTC(80C) = 14808 Ohm.

In order to maximize the drop in LED current a high beta is ideal.
A suitable NTC is the 150 kOhm Murata NCP15WM154p03RC

Part Number	Resistance (25°C)	B-Constant (25-50°C) (K)	Permissive Operating Current (25°C) (mA)	Rated Electric Power (25°C) (mW)	Typical Dissipation Constant (25°C) (mW/°C)	Operating Temperature Range (°C)
NCP15WL333☐03RC	33k ohm	4485 ±1%	0.17	100	1.0	-40 to 125
NCP15WB473☐03RC	47k ohm	4050 ±3%	0.14	100	1.0	-40 to 125
NCP15WL473☐03RC	47k ohm	4485 ±1%	0.14	100	1.0	-40 to 125
NCP15WD683☐03RC	68k ohm	4150 ±3%	0.12	100	1.0	-40 to 125
NCP15WL683☐03RC	68k ohm	4485 ±1%	0.12	100	1.0	-40 to 125
NCP15WF104☐03RC	100k ohm	4250 ±3%	0.10	100	1.0	-40 to 125
NCP15WL104☐03RC	100k ohm	4485 ±1%	0.10	100	1.0	-40 to 125
NCP15WL154☐03RC	150k ohm	4485 ±1%	0.08	100	1.0	-40 to 125
NCP15WM154☐03RC	150k ohm	4500 ±3%	0.08	100	1.0	-40 to 125
NCP15WM224☐03RC	220k ohm	4500 ±3%	0.06	100	1.0	-40 to 125
NCP15WM474☐03RC	470k ohm	4500 ±3%	0.04	100	1.0	-40 to 125

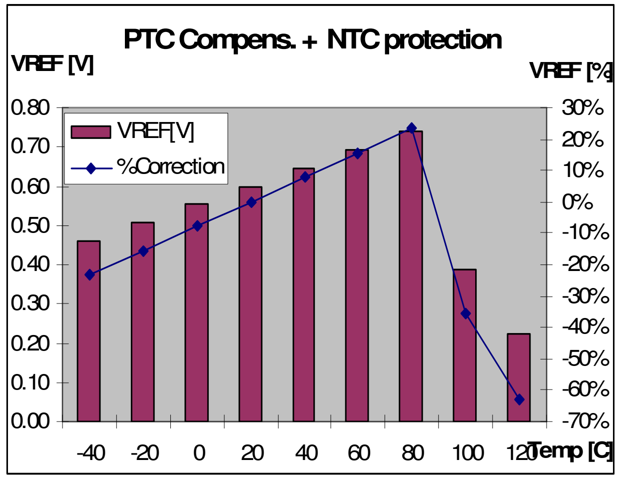
A Resistance R3 = 470 Ohm can be put in series with the NTC in order to match it better with the PTC resistance value at 80C.

	R_IREF1	= 4 * PTC	R_IREF2	= NTC + R3
	4* PTC		NTC	
	R0 = 4* 3000		150000	
	Temp Coeff = 3900	ppm/C	4500	Beta
	R = R0*(1+K*(T0-T))		$R = R_0 e^{B\cdot(1/T-1/T_0)}$	
-40	9192	Ohm	10130124	Ohm
-20	10128	Ohm	2200688	Ohm
0	11064	Ohm	597934	Ohm
20	12000	Ohm	194091	Ohm
40	12936	Ohm	72745	Ohm
60	13872	Ohm	30676	Ohm
80	14808	Ohm	14265	Ohm
100	15744	Ohm	7202	Ohm
120	16680	Ohm	3898	Ohm

3.3 Conclusion

The below table and figure shows the LED current is reduced by 63% at 120C compared to the nominal LED current at ambient temperature.

LED Temp	Min (R_IREF1, R_IREF2)		ILED reduction
-40C	9192	ohm	-23%
-20C	10128	ohm	-16%
0C	11064	ohm	-8%
T0 = 20C	12000	ohm	0%
40C	12936	ohm	8%
60C	13872	ohm	16%
80C	14808	ohm	23%
100C	7744	ohm	-35%
120	4440	ohm	-63%



4 NTC based compensation example for amber LEDs

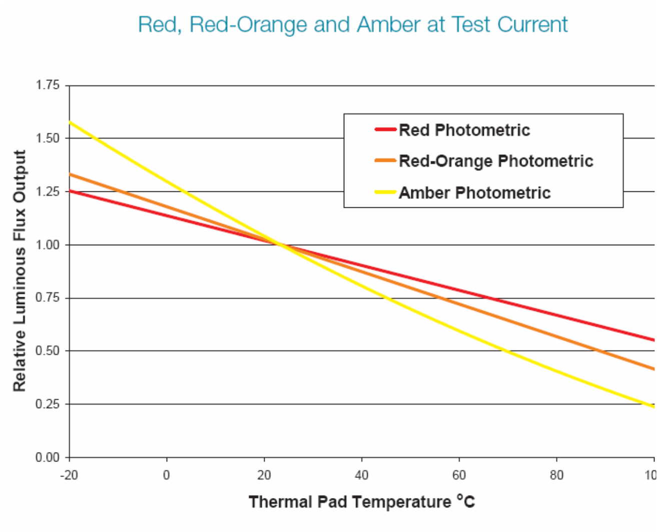
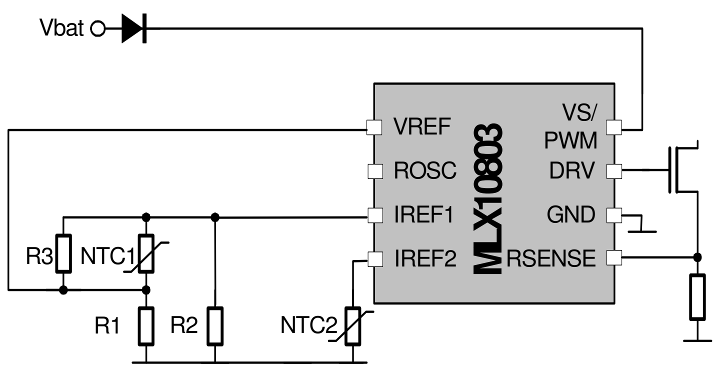


Figure 7. Relative light output vs. Thermal Pad temperature for Red, Red-Orange and Amber.

The Luminous flux of an amber LED can be 80% higher at -40C compared to 20C, and -60% at 80C (reference: Lumileds rebel datasheet). PTC's can not offer such compensation effect.
This paragraph explains how to realize a higher compensation effect using NTC resistors.

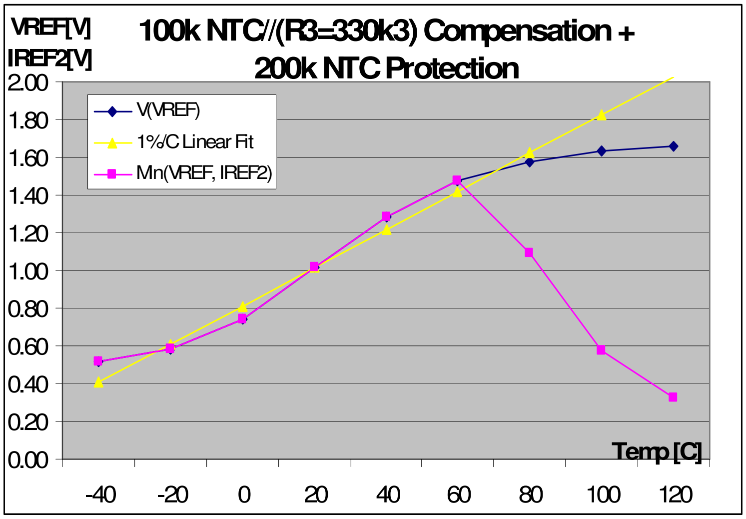
4.1 Application Schematic review



NTC based temperature compensation schematic

- R1 and R2 define the voltage level. R1=R2=68k is a good starter value to ensure enough voltage swing (VREF >1V at 20C).
- Making R3 larger will increase the compensation effect at low temperature. 40% to 50% compensation can be achieved with values that are 4 to 5 times larger than R1. NTC1 should be closer to R1 than to R3.
- To ensure overprotection takes place above 80C, NTC2 has to be chosen large enough. Adding series resistances with NTC2 will reduce the protection effect.

4.2 Calculation examples

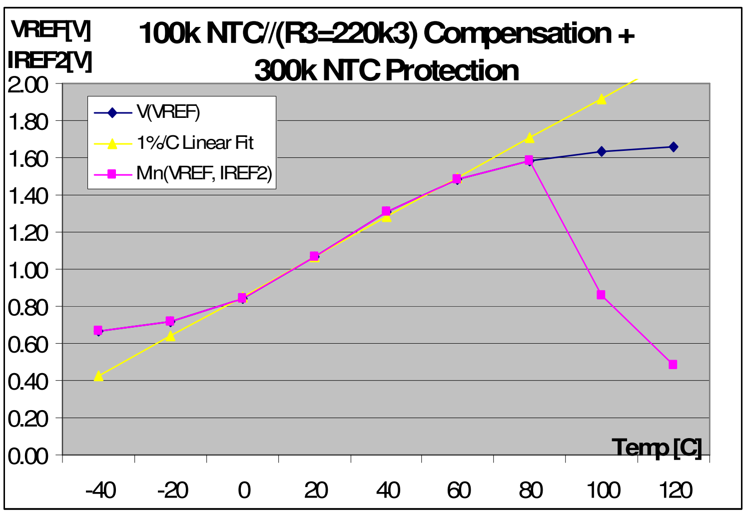


Compensation network:
- R1 = 68 kOhm
- R2 = 68 kOhm
- R3 = 330 kOhm
- NTC1 = 100 kOhm
  with Beta =4250

Compensation With R3 = 3*NTC1
- -49% at -40C
- +56% at 80C (see VREF value)

Protection:
- NTC2 = 2*100 kOhm
  with Beta =4250

⇨ Protection starts already at 60C



Compensation network:
- R1 = 68 kOhm
- R2 = 68 kOhm
- R3 = 220 kOhm
- NTC1 = 100 kOhm
  with Beta =4250

Compensation With R3 = 2*NTC1
- -38% at -40C
- +48% at 80C

Protection:
- NTC2 = 3*100 kOhm
  with Beta =4250

⇨ Protection starts at 80C

The above calculation examples show the influence of playing
- with R3 to increase/reduce the compensation effect
- with NTC2 to increase/reduce the point where the overtemperature protection becomes active.

5 PTC based protection

In case the LED current may be switched off entirely at overtemperature condition, protection PTCs like the Murata PRF18Bx471QB1RB can be used in stead of high ohmic NTCs.

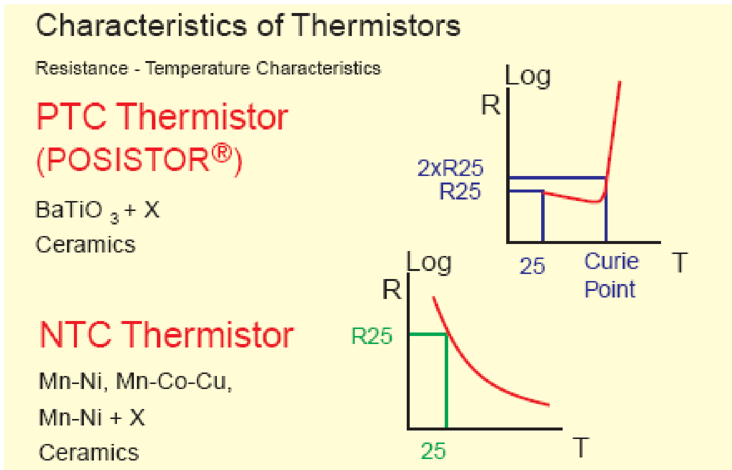
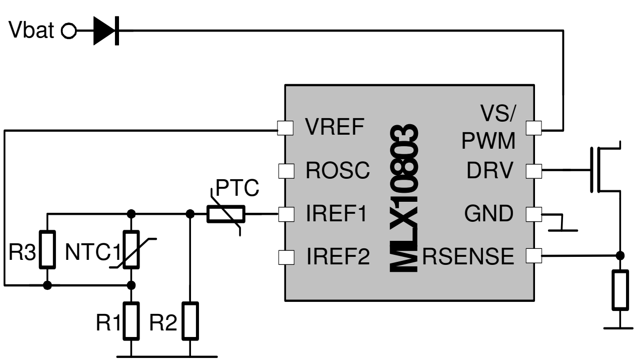


Image from the Murata catalogue

Such PTCs have a low nominal resistance of 470 Ohm, and can be put in series with the compensation network without affecting its compensation effect.
At a selected temperature, for instance 125C for the PRF18B**A**471QB1RB, the PTC resistance value increases abrupt to the MegaOhms range.
The input voltage on VREF reduces then below Vswoffmin = 15mV (see datasheet) such that the MLX10803 will shut down.



Overtemperature protection with PTC

6 Compensation and Protection for the Buck-Boost Topology

6.1 Temperature protection

The Buck-Boost topology reference design works optimally when R_IREF is maximized to allow a maximum 'supply-compensation' span on Rsense using a Current mirror or a Zener supply compensation network.
Therefore in a Buck-Boost topology the total NTC protection resistance should be aimed at ~ 70k at 80C.

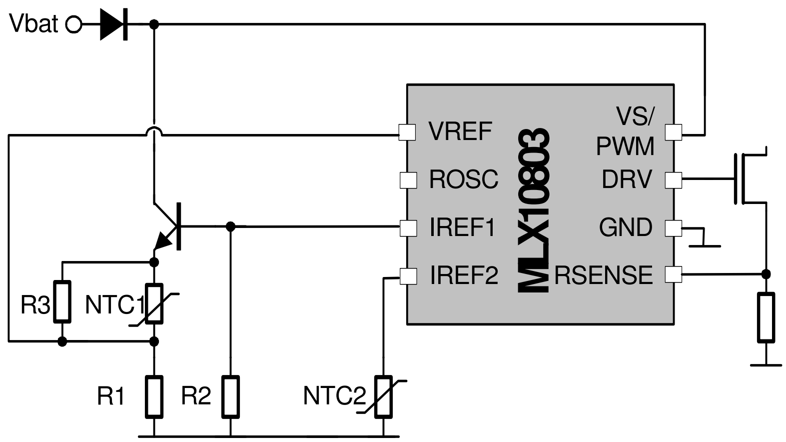
The below table shows an example that achieves 73% reduction of the LED current at 120C compared to 80C using NTC = 220 k + 470 k.

R0	**690000**		**ILED reduction**
Beta	**4500**		
-40	46598572	Ohm	
-20	10123166	Ohm	
0	2750497	Ohm	
20	892818	Ohm	
40	334627	Ohm	
60	141109	Ohm	
80	65621	Ohm	
100	33127	Ohm	-48%
120	17929	Ohm	-73%

Remark:
The 220k and 470k Values may seem high ohmic in view of humidity that may create leakage paths on the pcb. However the NTCs only influence the operation of the schematic above 80C. At this point their combined resistance value becomes lower than 66kOhm, and degradation due to humidity can be neglected.

6.2 'Active' Temperature compensation

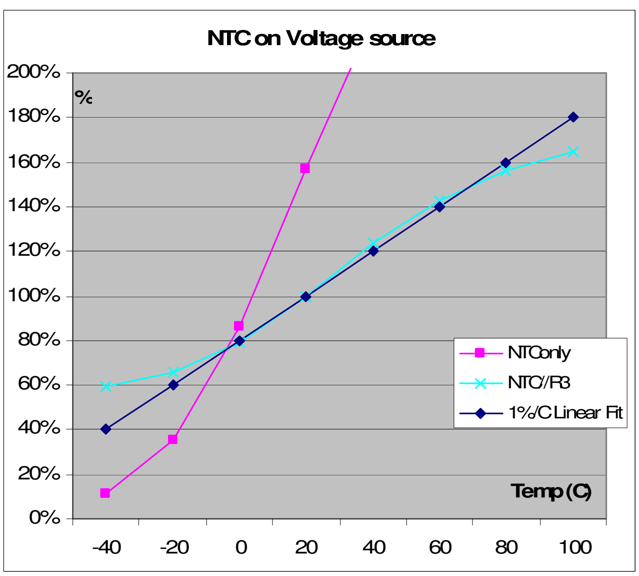
Achieve high voltages on IREF1 with a compensation network as described above is not possible without applying high ohmic resistance values. This limitation comes from the limited 50uA which is supplied by IREF. By realizing a supply regulator using a transistor this limitation can be removed as shown in the following application schematic.



'Active' Temperature compensation Schematic

The **Voltage range** is set by R2.
For instance R2 = 88kOhm maximizes the input voltage range on VREF = 3.5V.

The **compensation curve** is defined by R1, R3 and NTC1.



- R1 = 4700 Ohm
- R3 = 10 kOhm
- NTC = 4700 Ohm
  with Beta = 3500

The components have been selected to fit the 1%/C curve over a maximum span around 20C.

The resulting compensation compared to +20C is:

- -60% at -40C
- +58% at 80C

The plot shows 3 curves:

- NTConly: shows the case with R3 = open circuit. This shows how much compensation can be achieved with this network.
- NTC//R3: shows the actual compensation curve.
- Linear fit: The linear fit curve allows to verify that no overcompensation occurs over the full operating range.

7 Conclusions

This application note has shown how to realize different compensation networks for different applications, LEDs, and either buck or Buck-Boost topologies using MLX10803.