LITIX™ Basic+ LED driver family

Power Shift feature of TLD1114-1EP

About this document

Scope and purpose

This document intends to explain the main operating principle and structure of the power shift feature integrated in the TLD1114-1EP LED driver and how to configure the dimensions of the additional external components.

Intended audience

HW designers, LED system architects and engineers for LED lighting applications

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1 LITIX™ Basic+ power shift feature main operating principle

This application note describes the power shift feature integrated in the TLD1114-1EP LED driver. The main operating principle and a component dimensioning guideline will be described in the following pages. In addition, protection circuits for safe operation and an application example will be shown.

The TLD1114-1EP LED driver supports a wide output current range from 14 mA up to 360 mA. It can be used in various LED lighting applications for example, automotive LED rear lights. Applications with increased power loss (e.g. due to high output current and/or high supply voltage) often can't be driven easily with a linear current source. This increased power loss is usually located in one single heat source (i.e. LED driver IC package), which can create a local hot spot on the printed circuit board. Due to the additionally integrated power shift feature of the TLD1114-1EP a significant part of this heat can be moved outside of the IC package. This power can then be distributed evenly across the given PCB space by placing an appropriate number of power resistors. This separation of one big heat source into several smaller heat sources, with the same total power loss, can help to avoid local overheating of the system.

Note: *For lower power applications the power shift circuitry described in the following pages can be skipped and the relevant pins (PWR_SHG and PWR_SHS) can be left open.*

1.1 Current control and power shift circuit

The power shift circuit integrated in the TLD1114-1EP device works in such a way, that a part of the output current is bypassed from the internal high-side power stage to an external n-channel MOSFET/resistor circuit, as shown in Figure 1. This means that only a part of the LED current flows into the supply pin VS of the TLD1114-1EP.

The power shift current I_{PS} does not flow directly to the LEDs, but is fed back into the TLD1114-1EP device through the PWR_SHS pin. This happens prior to the output current measurement shunt to ensure precise constant current control. The control loop measures the power shift current I_{PS} and then adds the remaining current I_{OUTS} from the high-side power stage to achieve the desired LED output current I_{OUT}.

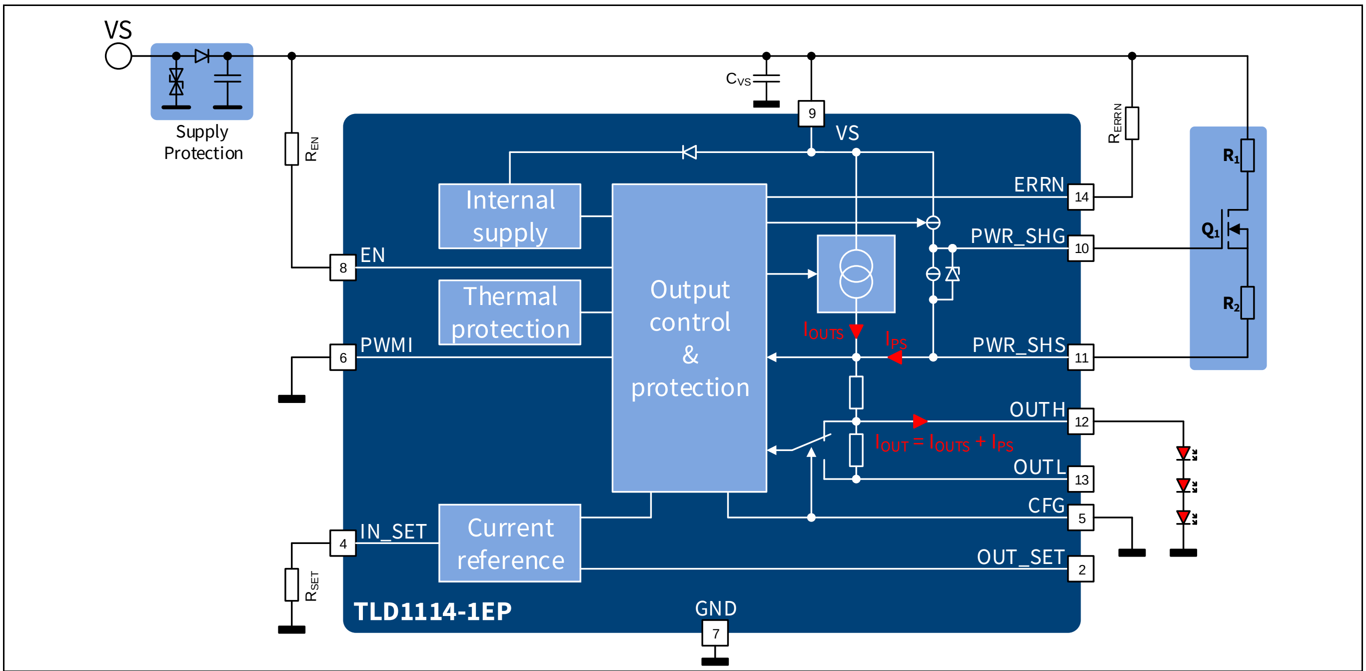

Figure 1 **Typical TLD1114-1EP schematic with power shift circuit**

The current split between internal power stage and power shift circuit mostly depends on the size of the selected external resistors and on the supply voltage as shown in Figure 2.

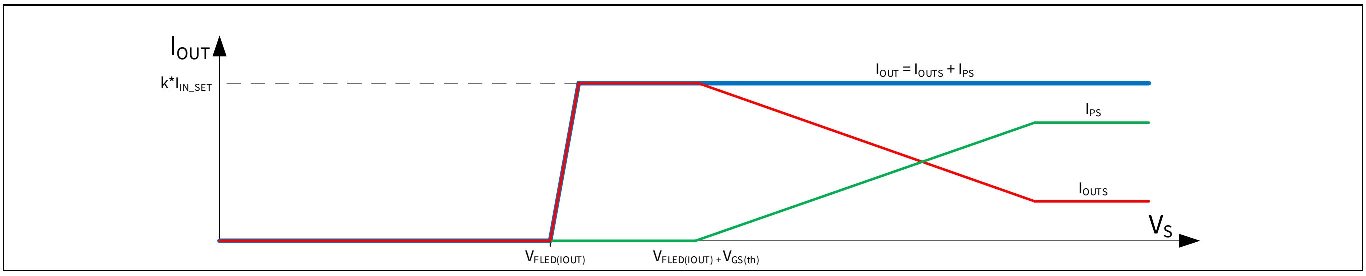

Figure 2 Output current I_{OUT} split into external power shift I_{PS} and internal power stage current I_{OUTS} over V_S

Depending on the supply voltage level and the output voltage the following system states can be observed:

- **$V_S > V_{fLED}$:** When the supply voltage of the enabled TLD1114-1EP rises above the LEDs forward voltage, the output current regulation starts to work and provides full current once a sufficient drop voltage $V_{PS(CC)}$ is given.
- **$V_S > V_{fLED} + V_{GS(th)}$:** The power shift circuit starts to operate as the voltage between the PWR_SHG and PWR_SHS pin exceeds the gate-source threshold voltage of the external MOSFET. The MOSFET opens and a current I_{PS} starts to flow through the power shift circuit offloading the TLD1114-1EP device. This current will increase with further increasing supply voltage. The voltage between the PWR_SHG and PWR_SHS pin directly follows the drop voltage on the LED driver, but is internally clamped around 5.5 V.
- **$V_S > V_{S(max)} + V_{overhead}$:** With further increasing supply voltage the external current I_{PS} is increased. Depending on the selection of the power shift resistors, a current limitation can be achieved to avoid overcurrent in the LEDs or the LED driver. This is done by forcing the external MOSFET into a linear conduction mode using a proper selection of R_2. As this causes a heat-up of the switch the current limitation threshold voltage is usually placed above the maximum possible constant supply voltage (e.g. 3-5 V above $V_{S(max)}$). In the further description, the term $V_{overhead}$ will be introduced for this additional overhead voltage. When the overhead voltage is selected high enough, this current limitation is only active during jump starts, load dumps or other short-term overvoltage events, or also during a short circuit to ground event (until the short circuit protection disables the power shift circuit. See Chapter 3.3)

1.2 Control-loop feedback configuration (CFG)

The current control of LITIX™ Basic+ devices is done by measuring the output current through a small shunt and comparing it with a copy of the reference current I_{IN_SET}. Increasing the resistor size can be used to improve the output current accuracy. On the other hand, this directly causes an additional increase of the required voltage drop of the LED driver. To provide good output current accuracy and also a low required drop voltage across the big output current range of the TLD1114-1EP, this device features a configurable current feedback network as shown in the lower right part of Figure 1. The setting is done by properly connecting the configuration pin CFG and output pins OUTH and OUTL. Table 1 shows the allowed combinations of the CFG and OUTx pin configurations. Other combinations must not be used.

Table 1 CFG and OUTx configurations

CFG	OUTL (I_{OUT} < ~180 mA)	OUTH (I_{OUT} > ~180 mA)
Connected to GND	Open	Connected LED load
Open	Connected to LED load	Open

2 Component dimensioning

2.1 External components for power shift feature

The power shift feature of the TLD1114-1EP requires additional components shown in Figure 1:

- **Q_1:** An n-channel enhancement type MOSFET will be used as a switch activating the external power shift current path. In case a short circuit is detected, or the output is disabled, the MOSFET will be turned off. For power shift applications without the use of this MOSFET refer to Chapter 4.
- **R_1:** The resistors R_1 and R_2 define the power shift current I_{PS} depending on the supply and output voltage (as long as the used NMOS is fully activated).
- **R_2:** The resistor R_2 is present to limit the current of the power shift current I_{PS}. This is done by squeezing the MOSFET's gate source voltage and forcing it into saturation. The maximal power shift current finally depends on the MOSFET (V_{GS}), the V_{GS_PWRSH} parameter of the TLD1114-1EP and the resistance R_2. The gate driver voltage between PWR_SHG and PWR_SHS is clamped between 4.5 V and 6 V (typical 5.5 V).

2.2 Dimensioning guideline

The following steps can be taken during the dimensioning phase of a TLD1114-1EP based LED lighting system with power shift feature:

- Define maximal allowed power dissipation of the TLD1114-1EP depending on the system and application requirements (R_{th} and ambient temperature), for example 1 Watt.
- Select an overhead voltage $V_{overhead}$ which will define when the power shift current will go into current limitation (Gate-source voltage will be squeezed when the voltage drop on R_2 increases with increasing V_S), see Chapter 1.1. In case an overvoltage lockout circuit is used, select the overhead high enough to fit the overvoltage lockout threshold in between $V_{S(max)}$ and $V_{S(max)} + V_{overhead}$.
- Select the maximum current I_{PSmax} through the power shift resistor at $V_S = V_{S(max)} + V_{overhead}$. Start with a low value (e.g. $I_{PSmax} = 10$ mA) and perform the following calculation steps. In case the power dissipation of the TLD1114-1EP exceeds the target value, increase I_{PSmax} and repeat the calculation. Repeat this process until the requirements are met. Note that the I_{PS} current must not exceed the maximum ratings of the TLD1114-1EP.
- Preselect a MOSFET and use the on-state resistance R_{DSON} and the gate source voltage V_{GS} at the operating point for further calculations
  - For the MOSFET, select a type with a low $V_{GS(th)}$ voltage. This is especially important when high currents are used, as the power loss of the driver might exceed the desired limit. This can happen when the power shift circuit is activated at higher supply voltages due to a higher V_{GS}.
- Calculate R_1 and R_2:
  - $R_2 = (V_{GS\_PWR\_SH(typ)} - V_{GS})/I_{PSmax}$
  - $R_1 = (V_{S(max)} + V_{overhead} - V_{OUT} - R_{Shunt} * \max(I_{OUT}, I_{PSmax}))/I_{PSmax} - R_2 - R_{DSON}$
  - R_{Shunt} is the resistance of the internal shunts (indicated in Figure 1) used for current control:
    - $R_{Shunt} = 750\ m\Omega$ when CFG is connected to GND
    - $R_{Shunt} = 1.5\ \Omega$ when CFG is left open
- Calculate the power shift current over expected supply voltage range as shown in Figure 2.
- Subtract the power shift current from the target output current to acquire the device internal current.
- The power shift current should be below the target LED current within the nominal supply voltage range to ensure precise constant current control.

Component dimensioning

- Calculate and evaluate power loss of TLD1114-1EP device over the given V_S range. If the power loss is too high, adapt the maximum power shift current and repeat the calculation steps above:
  - $P_{TLD1114} \approx R_{Shunt} * I_{OUT}^2 + (I_{OUT} - I_{PS})*(V_S-V_{OUT}-R_{Shunt}*I_{OUT})$

In some cases, especially at high output currents, simply increasing the maximum power shift current I_{PSmax} may not lead to the expected results. A reason can be that the gate source voltage of the used MOSFET is too big. The activation of the MOSFET happens only at increased supply voltages, where already a high drop voltage is present. This means that the full output current has to be driven by the TLD1114-1EP device over a bigger supply voltage range. A countermeasure can be to select a MOSFET with decreased V_{GS} threshold voltage. This results in the power shift current to start improving heat distribution at a lower supply voltage in the operating area when V_S is near the output voltage.

An Infineon toolbox application is available for use, to facilitate an easier component dimensioning for the above calculation steps.

Depending on the selected external components, the power shift current might exceed the target output current. In this case the control loop disables the internal power stage and only the power shift current is present. In this condition no current control is present and the output current depends on the resistor size and the supply voltage.

The calculated resistors R_1 and R_2 may be split further to distribute the heat to additional heat sources for additional power distribution, as shown in the application example in Chapter 5.2.

Note: The design hints above are only an estimation for an initial component dimensioning using the typical device performance characteristics. The calculated setup must be verified in real applications.

Note: Not all application conditions may be served directly using the TLD1114-1EP LED driver with power shift circuit. An example would be a single LED at high current. In this case it is highly recommended to additionally increase the output voltage to the maximum possible value (depending on the minimum supply voltage) using additional (Zener-) diodes or resistors in between the LED driver output and the LED. In general, also for applications at lower currents this approach may help to minimize the number of external components used or permit less stress on the power shift circuit, allowing the usage of a smaller MOSFET. An additional possibility is to "offload" a portion to a second TLD1114-1EP device (with or without power shift feature). This can be done by connecting the outputs in parallel. With this approach also LED currents above the maximum output current of one TLD1114-1EP can be achieved, since the current of the device remains below the maximum output current.

3 Protection Circuits

3.1 Overvoltage lockout

LITIX™ Basic+ devices are protected against overtemperature, by an integrated thermal derating or shutdown circuit. The thermal shutdown feature of the TLD1114-1EP is only designed to protect the IC itself. For the external power shift circuit additional protection schemes might need to be introduced, to protect against overtemperature. One main contributor for device overtemperature in linear current sources is overvoltage, therefore an overvoltage lockout circuit is a suitable protection method.

The LED driver system consisting of the TLD1114-1EP and its power shift circuit, is a linear constant current source. This means that with increasing supply voltage the power dissipation and therefore temperatures will increase. For operation in the typically used supply voltage range (e.g. 8 V to 16 V) the external components have to be designed and properly placed on the PCB to have a robust design for operation at higher ambient temperatures (e.g. 85°C). For operation at voltages beyond the typical automotive supply range, for example during a jump start event, in some cases a further enhanced thermal capability is needed. This can be realized by further splitting the R_1 and R_2 resistors, choosing a different MOSFET package (bigger package), increasing the PCB size and/or choosing a better PCB substrate or other cooling scheme. To avoid this cost-increase, a small overvoltage lockout circuit can be added instead. This is a simple circuit monitoring the supply voltage and deactivating the Basic+ device and the power shift circuit during overvoltage. This avoids overtemperature conditions by deactivation at high supply voltages. A potential solution for how to implement such a functionality is shown in Figure 3. A transistor is used to pull down the ERRN pin in case of overvoltage. The TLD1114-1EP output will be deactivated when the ERRN voltage is below $V_{ERRN(th)}$. The transistor control is done by a Zener diode and two resistors. Depending on the selection of the Zener diode the overvoltage lockout voltage is defined. Similar solutions controlling for example the IN_SET, EN or PWMI pin are possible as well.

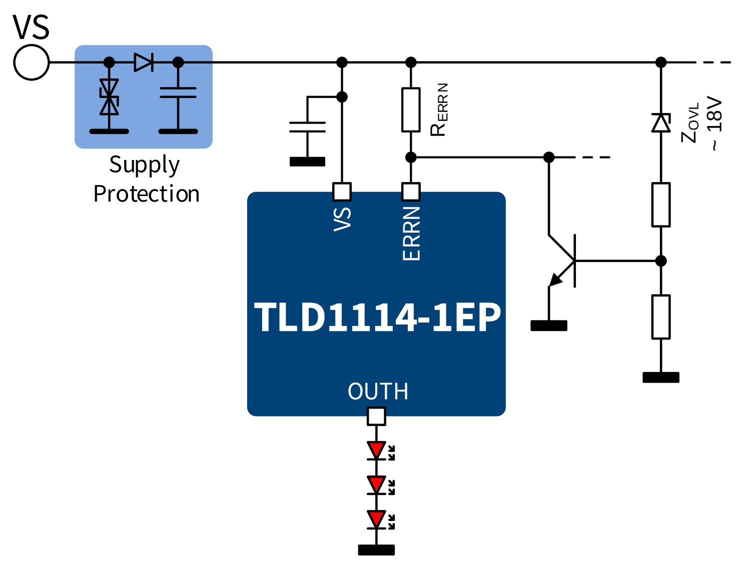

Figure 3 Example for overvoltage lockout circuit controlling ERRN (simplified drawing)

Note: The above examples have to be verified during design phase. Due to limitations like for example, the Zener diode's leakage current, different implementations or variations of the above implementation might be required.

3.2 Reverse battery protection

All LITIX™ Basic+ devices including the TLD1114-1EP are reverse battery protected. Although the TLD1114-1EP device is reverse battery protected, an additional reverse protection circuit, typically a simple reverse diode, may be required. Due to the body diode of the used n-channel MOSFET a reverse current path is built across the LEDs, the sensing resistors in-between PWR_SHS and OUTx and the body diode of the power shift MOSFET.

In case the used LEDs are not designed for reverse operation, this current path needs to be blocked. Typically a reverse diode as shown in the supply protection block in Figure 1 is used for reverse battery protection. Together with an additional transient suppressor diode and a buffer capacitance this circuitry is able to protect the LED driver module against the typical supply voltage transients and pulses found in the automotive environment. One drawback of this solution is that the forward voltage of the reverse battery diode adds to the minimal drop voltage of the LED driver and limits its usability in the area of low supply voltage.

In case the power shift circuit is used, the reverse battery protection diode can also be placed directly in the power shift current path as shown in Figure 4. To protect the device in case of negative pulses the transient voltage suppressor (TVS) diode may be split into two unidirectional ones. To protect against positive pulses typically a 35 V TVS-diode is used and to protect against the negative pulses for example, a 15 V TVS-diode can be used.

This solution enlarges the cranking capabilities of the LED driver system.

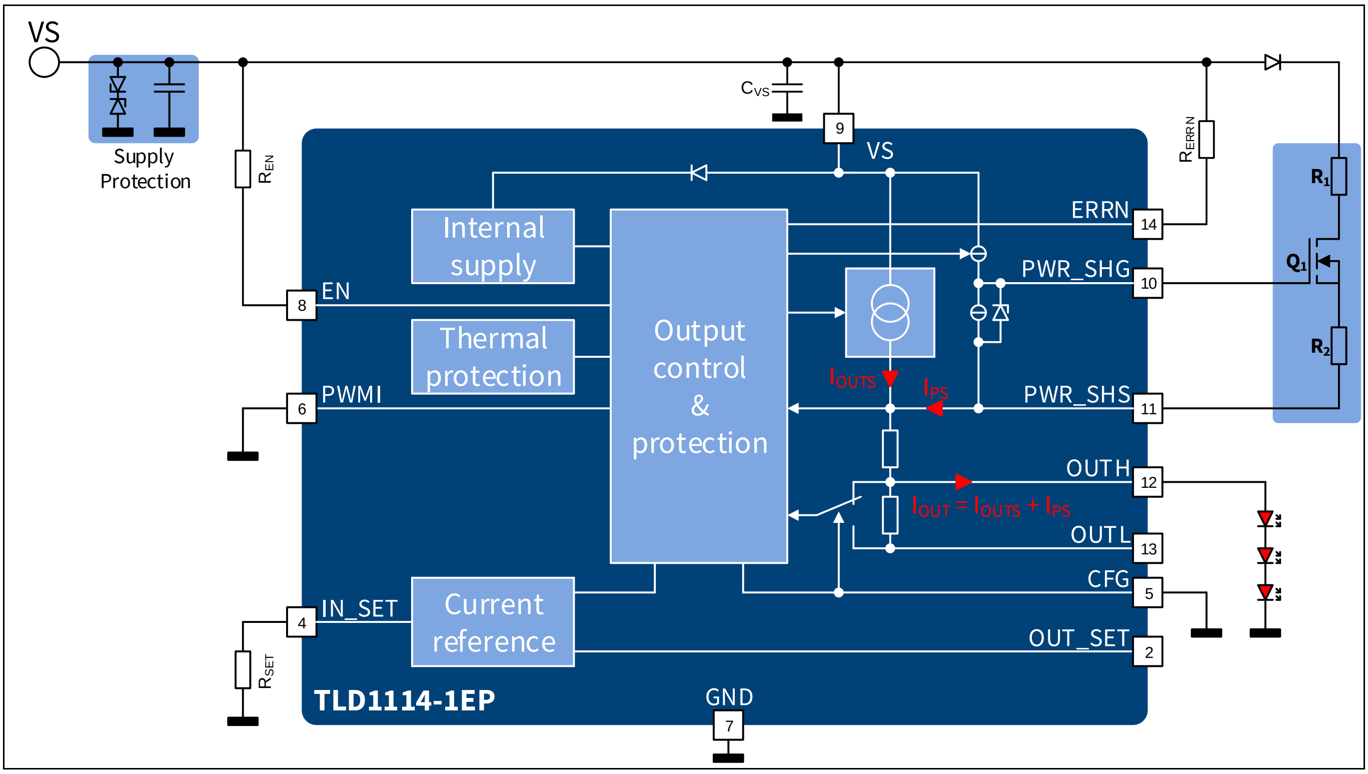

Figure 4 **TLD1114-1EP system with reverse battery diode in power shift path and two TVS**

3.3 Short circuit protection

All LITIX™ Basic+ devices are equipped with an integrated short circuit to ground protection which automatically disables the power stage in case of a short circuit to ground event. The TLD1114-1EP constantly monitors the output voltage and deactivates the power stage and the power shift circuit, in case of a short circuit to ground fault. The power shift deactivation happens after typically 80 µs. During this fault detection filter time, the short circuit output current is determined by the supply voltage level and the external component dimensioning as indicated in Figure 5. This current is limited to either I_{PSmax} (see Chapter 2.2) or $I_{OUT(SC)} = V_S/(R_1 + R_2 + R_{DSON} + R_{Shunt})$, depending which one is smaller.

When the power stage and the power shift circuit are turned off during short circuit the output current is reduced to a small start up current $I_{OUT(startup)}$, typically in the range of 600 µA. Once the fault condition is removed, this current is used to precharge the output above the short circuit detection threshold ($V_{OUT(CC,max)}$ = 1.4 V). Above this voltage the main power stage and power shift circuit take over and the output current is regulated to $I_{OUT(typ)}$.

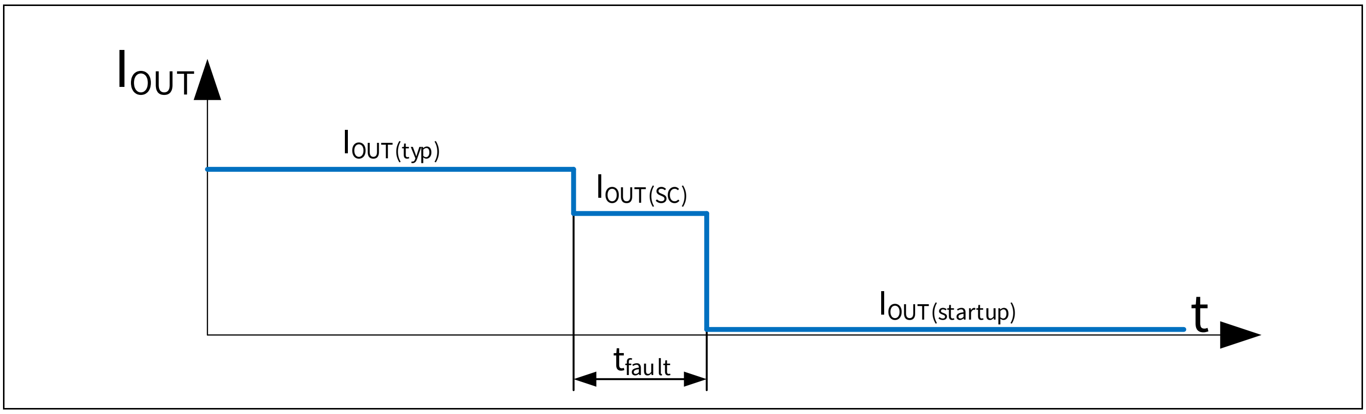

Figure 5 Output current timing diagram during short circuit to ground fault with power shift feature

Note: The additional short circuit to GND protection feature of the TLD1114-1EP works similarly to the diagnosis features found in other LITIX™ Basic+ devices, e.g. TLD2331-3EP. However, in this case, no fault case is reported on ERRN. This means the status of the ERRN pin stays unchanged during a short circuit to ground event. In case a diagnostic functionality is needed, the TLD1114-1EP device may be connected in parallel to any other LITIX™ Basic+ device offering LED load diagnosis.

Note: Select the external components of the power shift circuit in such a way that the current flowing into the PWR_SHS pin does not exceed the maximum ratings of the device during a short circuit to ground or overvoltage event.

4 Power shift feature without additional external MOSFET

In certain application areas, the usage of the LITIX™ Basic+ power shift feature without an external MOSFET can be feasible. This application mode offers the advantage to save the additional cost of the external switch, but certain boundaries have to be considered.

Taking the main LED driver concept from Figure 1 and simplifying it by removing the external MOSFET leads to the schematic shown in Figure 6. For simplicity also the two resistors R_1 and R_2 have been combined to one resistor R_1.

It can be seen that there is always a current path from the battery pin to the LEDs, independent of the state of the TLD1114-1EP. This means the TLD1114-1EP LED driver has no possibility to disconnect the LED from the supply line. The control of the LED state has to be done directly by the module supplying the LED driver. For simple applications, such as reverse or fog lights, this may be an appropriate solution.

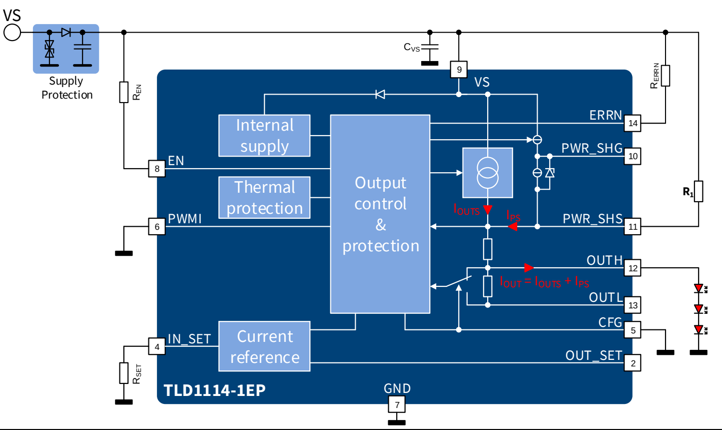

Figure 6 TLD1114-1EP power shift circuit without external MOSFET.

As seen in Figure 6 the current going through the external circuit is only limited by the resistor. This means the resistance has to be high enough to avoid overstress of the TLD1114-1EP sensing circuitry as well as the LED load.

The power shift current passes through one or two sense resistors (depending on whether OUTH or OUTL is used), see Chapter 1.2. Each sense resistor has a typical resistance of 750 mΩ. The maximum voltage drop through one internal shunt resistor is limited to 400 mV (see parameter P_4.1.7). In case of the usage of OUTL, the allowed voltage drop doubles to 800 mV (see P_4.1.46). This leads to an absolute maximum allowed current of 533 mA.

This means that the external resistance has to be selected high enough to ensure that this current is limited. Assuming that the maximum supply voltage may rise up to 40 V (towards the maximum rating of the TLD1114-1EP device itself) and the output could be at 0 V (during short circuit or start up) the minimum resistance can be selected accordingly, which would lead to:

R_{PS_min} = (40V - 400mV)/533mA ~75Ω

The power stage of the TLD1114-1EP adds current to the output as long as the power shift current I_{PS} is below the target output current. As soon as the power shift current exceeds the target current, the device will turn off the power stage and the output current I_{OUT} is only an uncontrolled open loop current.

The LEDs have to withstand possible overcurrent pulses, caused by high V_S It is recommended to keep the power shift current small to avoid such overstress.

5 Dimensioning and application example

5.1 Application case and component dimensioning

In this chapter a typical application board example is shown. Target for the application board is to drive a 360 mA LED load under typical supply voltage and temperature conditions. For the component dimensioning, an additionally available dimensioning tool was used. The application conditions taken into account for the dimensioning are:

- V_S = 8 V to 16 V
- $T_{ambient}$ = -40°C to 85°C
- I_{OUT} = 360 mA
- V_{OUT} = 6 V

For the calculation the additional inputs shown in Figure 7 and Figure 8 were used. The maximum supply voltage in the tool was decreased to 15.5 V considering a reverse battery protection diode. The minimal supply voltage was reduced to 7 V to show the performance also at supply voltages close to the output voltage. The maximum power dissipation of the TLD1114-1EP was set to 1 Watt in this example. For the MOSFET entered in Figure 8 a type with 2 V V_{GS} and around 1 Ω R_{DSON} was considered for the calculation.

Step 1: Enter system requirements

Parameter	Value	Unit	Description
Vsmin	7	V	Minimal required battery voltage for operation
Vsmax	15,5	V	Maximum applied battery voltage for continues operation. Note: reverse diode not considered in calc
VOUT	6	V	Output voltage at LED operating point
IOUT	0,36	A	Output current
Tambient	85	°C	Max Junction temperature
Rthja	65	K/W	Thermal resistance of TLD1114 observed in application condition
Pvmax	1	W	Maximum allowed power dissipation of the LED driver (Calculated using Rth,Tambient & Tjmax)
VPS_clamp_offset	5	V	At Vsmax + VPSclamp_offset the power shift current limiation will start

Figure 7 System requirements

Step 2: Enter NMOS Parameters

Parameter	Value	Unit	Description
RDSON	1	Ω	typical RDSON at operating point
VGStyp	2	V	typical VGS at operating point of NMOS

Figure 8 MOSFET parameters

These inputs then result in the proposed resistor values of

- R_1 = 20.68 Ω
- R_2 = 7.17 Ω

The selected resistor values of 20 Ω and 8.1 Ω shown in Figure 9 the final current split and power loss over the supply voltage were calculated. Figure 10 shows the expected split of the output current I_{OUT} into the power shift current I_{PS} and the internal power stage current I_{OUTS}. The curve shows that in the nominal supply voltage range the LED driver system is always able to provide a constant LED current. The power shift starts to work around 8 V and from then onwards it further increases, causing a decrease of the TLD1114-1EP internal current I_{PS}. These currents and the voltage drops lead then to the expected power losses shown in Figure 11. As the resistor currents increase with the supply voltage, the power loss in the resistors rises exponentially. This causes the nonlinear curve and power reduction at higher voltages of the LED driver IC. It can be seen that for this particular application case, the worst case voltage for the TLD1114-1EP is not at 16 V but at 12 V. This behavior changes depending on the application case and component dimensioning. Therefore, it is important to calculate the losses over the complete supply voltage range and not only at higher voltage. At high V_S the power loss of the LED driver IC itself drops as the power shift circuit takes over more and more of the heat although the overall power loss increases.

Note: The system performance can be further simulated using the TLD1114-1EP PSpice behavior model.

Step 3: Calculation result and adapt "R1 selected" & "R2 selected" in case of need

Result	Value	Unit	Description
R1	20,68	Ω	Recommended value for Resistor between VS and Power Shift NMOS Drain connector
R2	7,14	Ω	Recommended value for Resistor between Power Shift NMOS source connector and PWR_SHS pin
R1 selected	20,00	Ω	change R1 if necessary, else copy value from above
R2 selected	8,10	Ω	change R2 if necessary, else copy value from above
PR1 max	2,13	W	Max calculated power of selected R1 device within operating range
PR2 max	0,86	W	Max calculated power of selected R2 device within operating range
P1114max	0,99	W	Max calculated power of TLD1114 device within operating range with selected R1 & R2
RSET	3016,11	Ω	Recommended value for RSET resistor
CFG setting	low ▾	-	recommended setting for CFG pin

Figure 9 Calculation results and final resistor selection

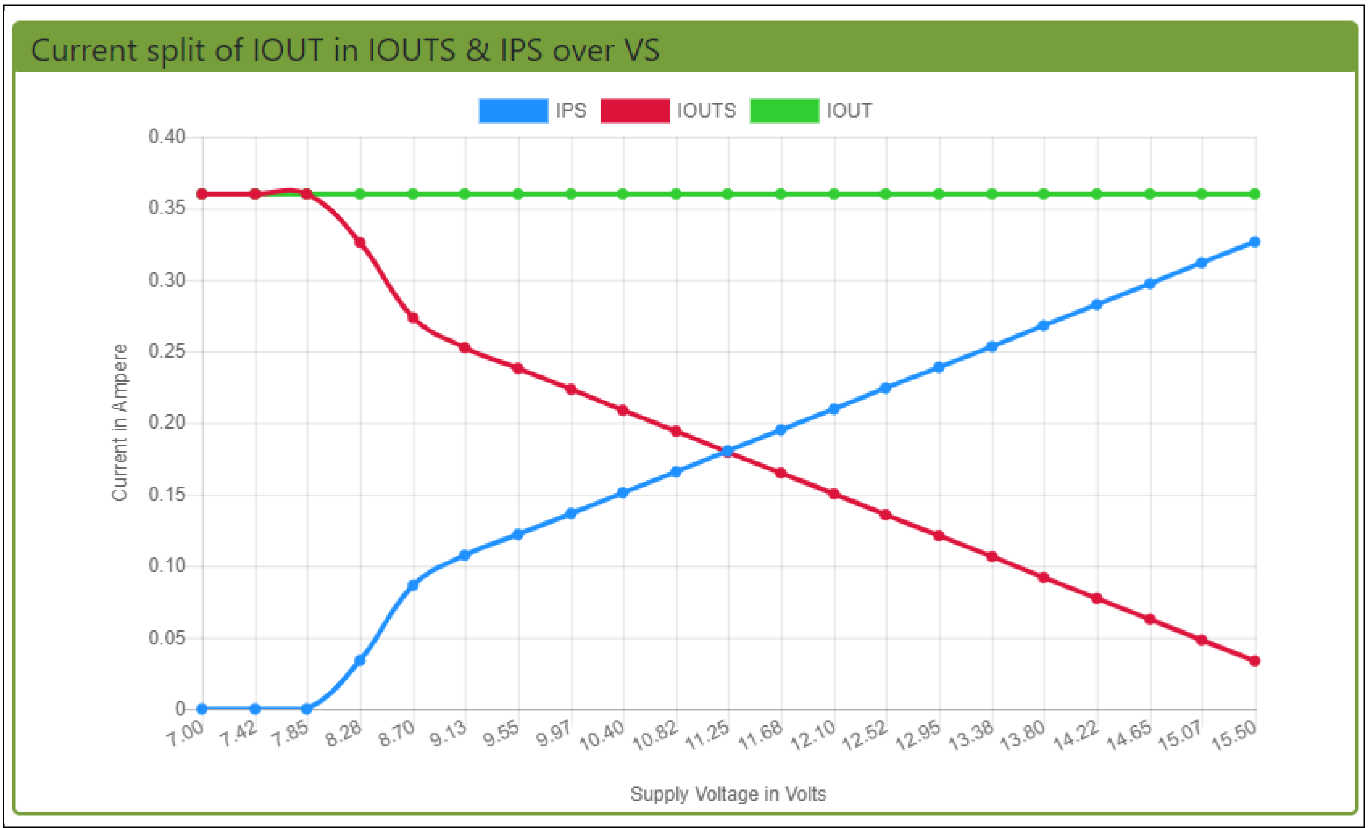

Figure 10 Current split between TLD1114 internal power stage and power shift circuit over V_S

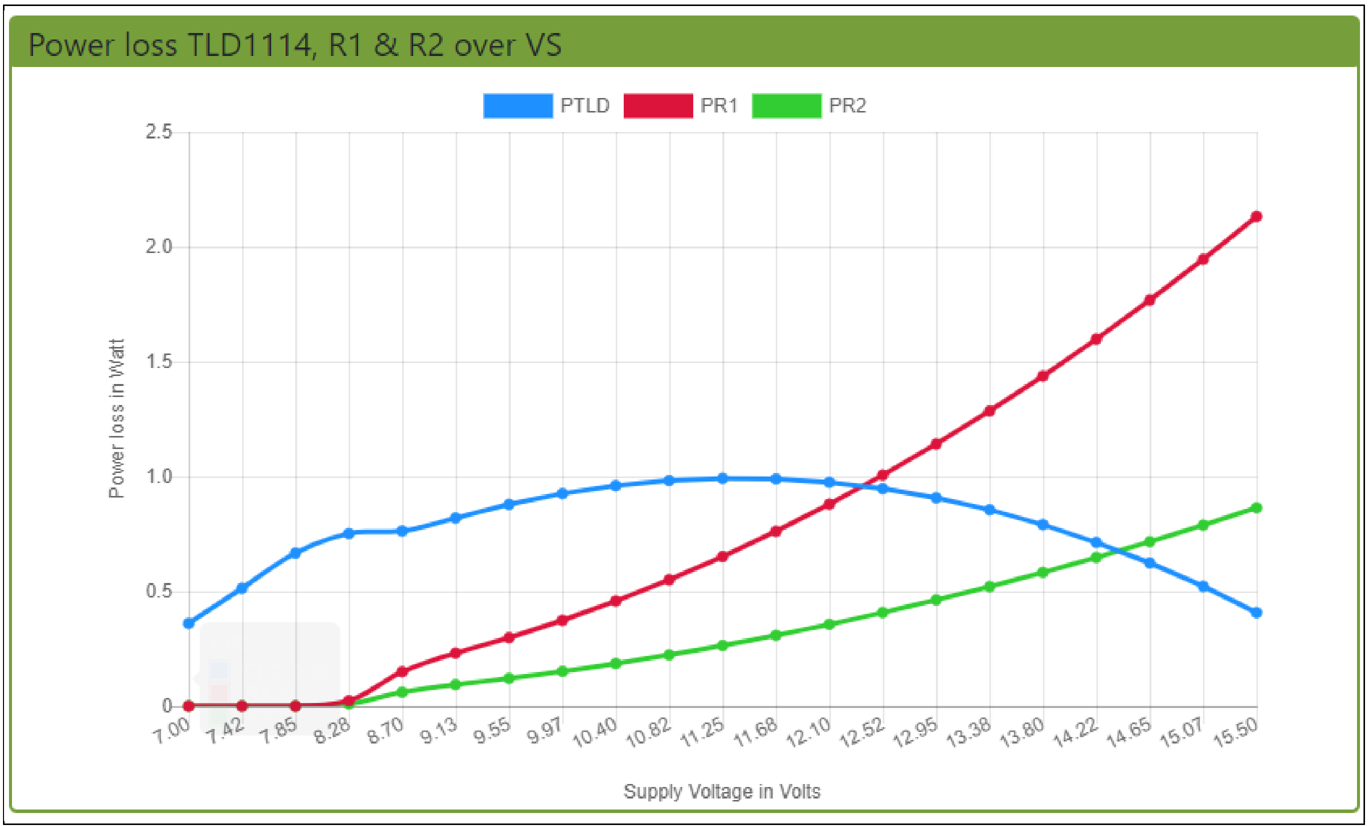

Figure 11 Power loss of TLD1114-1EP and power resistors R_1 and R_2 over V_S

5.2 Board design

With the resistors dimensioned in Chapter 5.1 the schematic shown in Figure 12 was developed. As shown in Figure 11 a high power loss is expected in the resistors R_1 and R_2. To have an optimized thermal design, the resistors have been split to spread the heat better. Ten R_1 and three R_2 resistors were used. Additionally, the Infineon BSP372N MOSFET was selected. Additionally placed components are a reverse battery protection diode as well as capacitors at the VS and OUTH pin. Due to the high output current of 360 mA the OUTH pin is used and the CFG pin is connected to ground.

Note: This schematic only intends to show the thermal performance of the TLD1114-1EP with power shift circuit. For real applications, additional components such as a transient voltage suppressor diode and an overvoltage lockout circuit (see Chapter 3.1), might be needed.

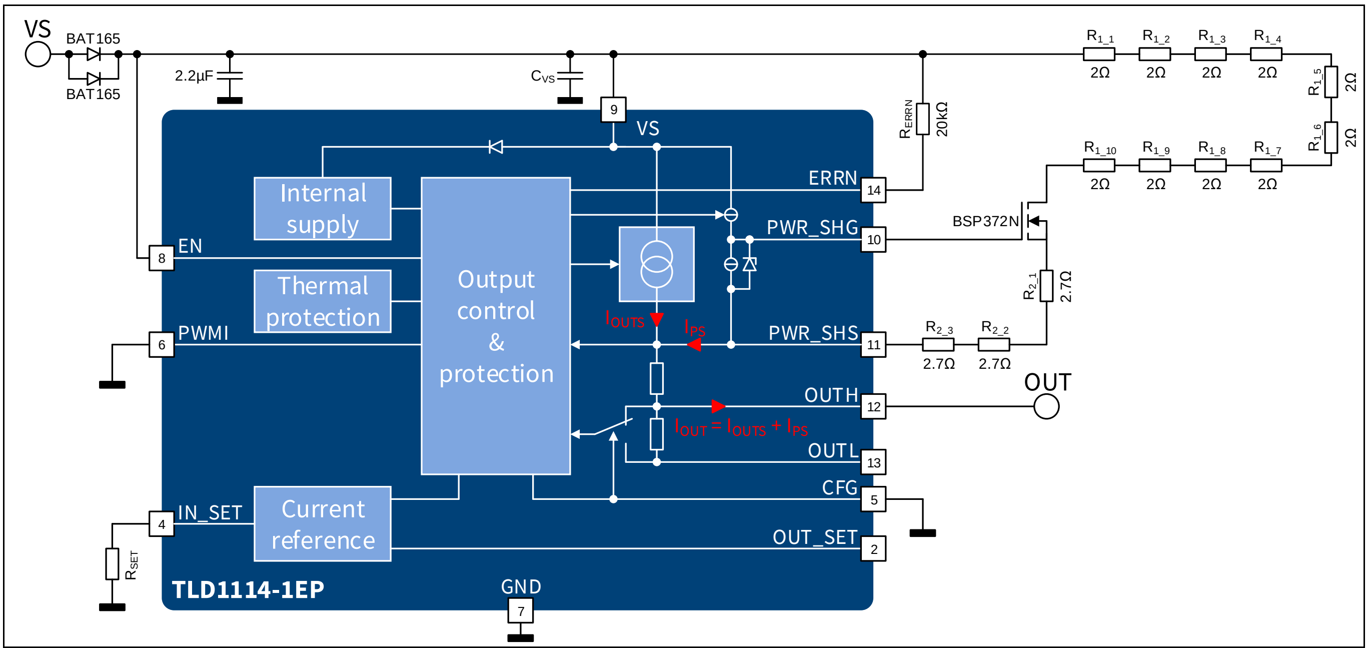

Figure 12 **Schematic of the TLD1114-1EP thermal evaluation board**

Based on this schematic the printed circuit board shown in Figure 13 was designed. The PCB size is 70 mm by 35 mm. The layer stack consists of two 35 µm copper layers on a standard FR4 PCB substrate. The TLD1114-1EP is placed on the lower left side of the PCB. The external components (R_{SET}, C_{OUT}, etc) were placed in such a way that the exposed pad has a good connection to the GND plane as shown in the top and bottom layer view in Figure 14 and Figure 15. Additionally, the PCB is stitched with thermal vias (also under the exposed pad of the TLD1114-1EP) to ensure a good vertical heat distribution. The power resistors are then evenly spread across the remaining PCB space to ensure an even heat-up of the PCB. All power components are connected to small cooling planes which are placed on the top and bottom layer connected with thermal vias.

Note: *The use of a thermal simulation tool (e.g. FloTherm PCB by Mentor Graphics®) can help to estimate needed PCB size and optimize the component distribution.*

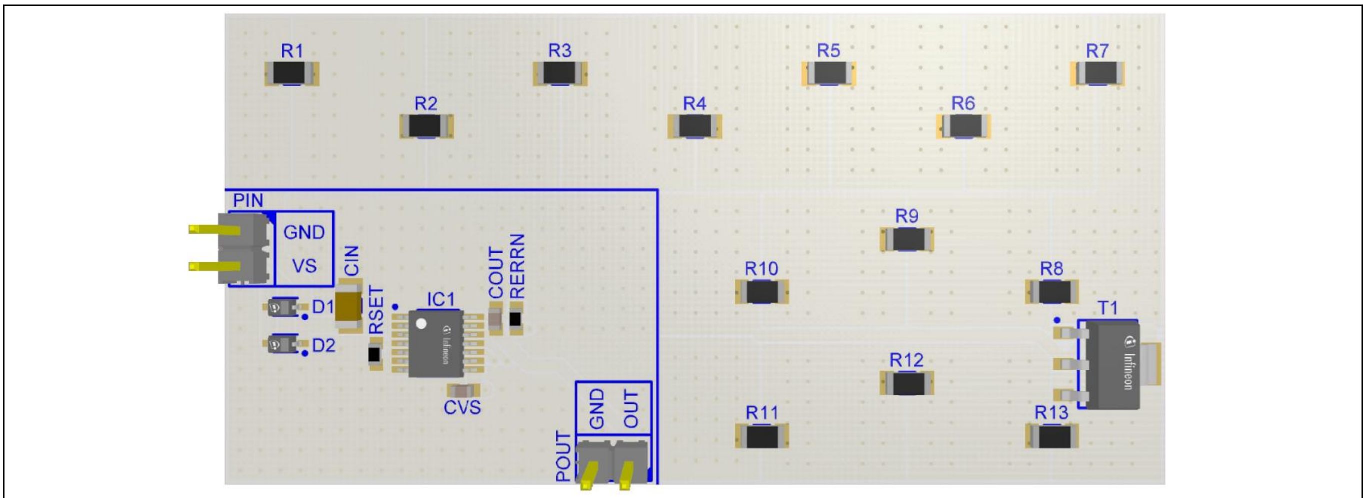

Figure 13 **Thermal evaluation board: 3D view**

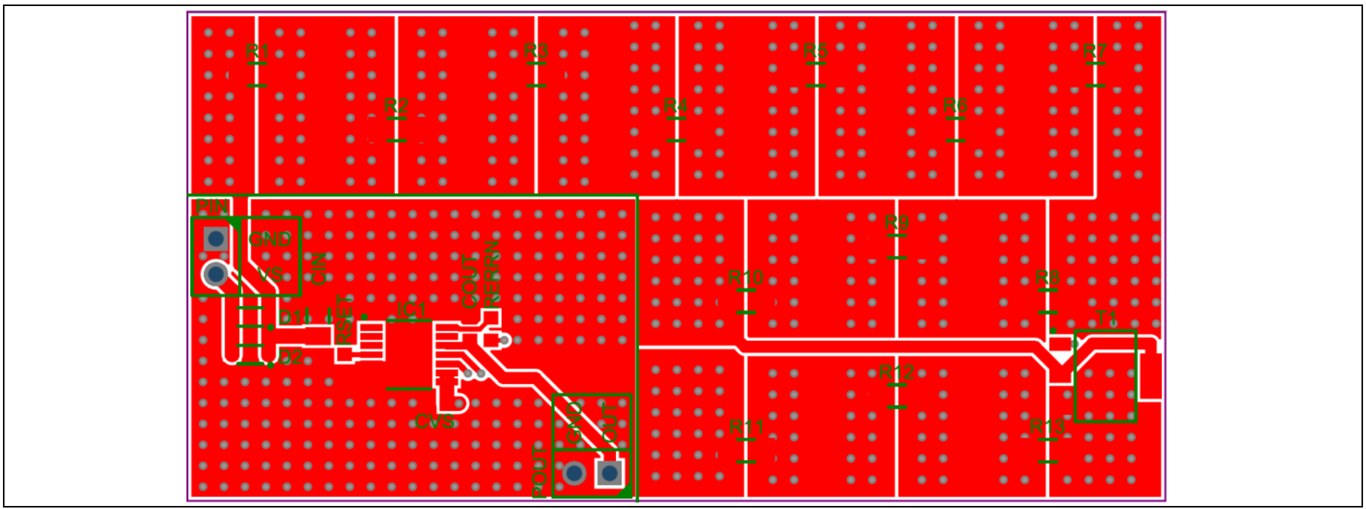

Figure 14 **Thermal evaluation board: Top layer**

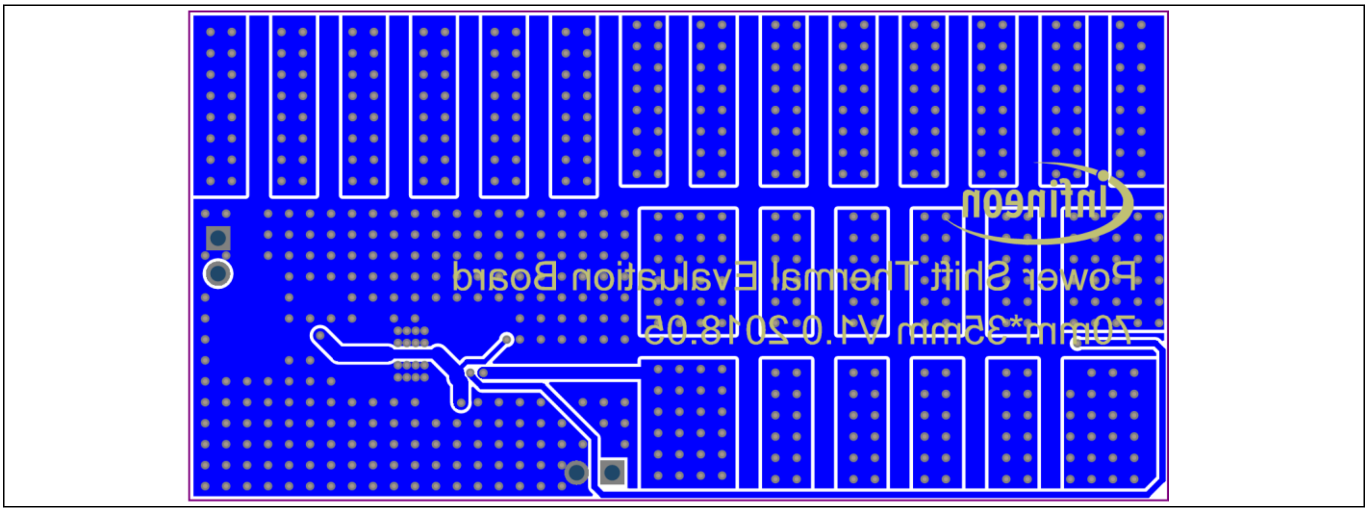

Figure 15 **Thermal evaluation board: Bottom layer**

5.3 Thermal measurement

The developed board was then tested with a LED load with a forward voltage of ~6V. To observe the effect of the power shift circuit the system was tested at different supply voltages at room temperature. In Figure 16 the results of two thermal measurements are shown. The LED driver board was tested at 13 V and at 16 V. As seen in Figure 11 the peak power dissipation of the TLD1114-1EP is not at 16 V but at lower supply voltage. This happens as the power shift circuit takes over a smaller part of the power loss. Although the total power dissipation is lower, the LED driver IC has to dissipate more. This can be seen in the left part of Figure 16 as the hotspot is in the IC, whereas the remaining part of the PCB stays cool. Increasing the supply voltage to 16 V raises the overall power consumption and it can be seen that the power shift circuit creates the hotspot in this operating point. The TLD1114-1EP temperature is cooler at 16 V than at 13 V.

The temperature measurement was done at an ambient temperature of around 25°C. The behavior at 85°C, which is usually the maximum ambient temperature for automotive rear light applications, needs to be interpolated. Looking at the maximum measured temperatures which are in the range of 80°C we can assume that the maximum expected temperature at 85°C ambient temperature is around 140°C. This assumption was made by simply adding the 60°C temperature difference of the results shown in Figure 16. Typically the thermal resistance drops slightly at higher temperatures which makes this approximation valid.

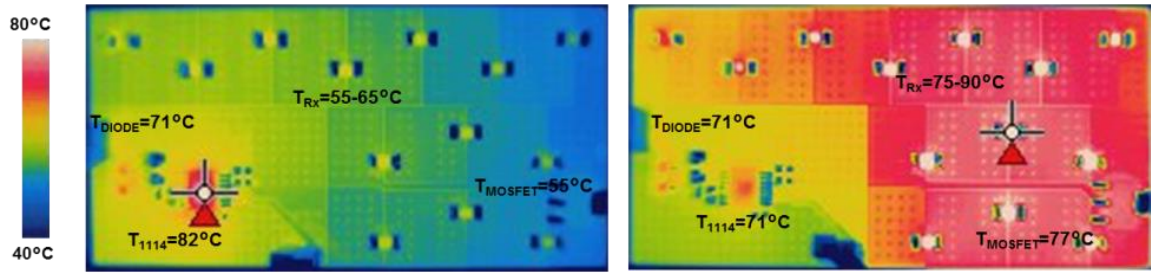

Figure 16 Thermal measurements at 13 V (left) and 16 V (right)

Revision history

Document version	Date of release	Description of changes
V1.0	2018-11-14	Initial version created

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