Never stop thinking

# Application Note

## PROFET™+ UNREGULATED PWM FOR LAMP

What the designer should know

Application Note

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Body Power

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# 1 Introduction

As the lamp's impedance is function to the effective power supply, the current flowing into the filament is not only dependant to the supply voltage but also depends on the duty cycle. Some applications in the automotive industry request duty cycle which is independant to the supply voltage. Famous examples are cornering lights, dome lights or brake lights dimming. This application notes describes a simple way to estimate the load current in the lamp and therefore estimate the average power losses flowing into PROFET+ high side switches.

# 2 Lamp Current

## 2.1 Theory of the lamp

The current flowing into the filament can be estimated by **Equation (1)**.

$$I_{LAMP} = \sqrt{\frac{V_{LAMP}}{V_{REF}}} \times \frac{P_{LAMPREF}}{V_{REF}} \quad (1)$$

The **Table 1** sums up the parameters for common lamps used in the automotive application.

**Table 1 Electrical Wattage Lamp**

| Lamp (W) | Accuracy (%) | $V_{REF}$ (V) | Max DC current (A)[1)] | PWM current (A)[2)] | Maximum current (A)[3)] |
|---|---|---|---|---|---|
| 5 | 10 | 13.5 | 0.5 | 0.7 | 0.9 |
| 7 | 10 | 12.8 | 0.7 | 1 | 1.3 |
| 10 | 10 | 13.5 | 1 | 1.3 | 1.8 |
| 15 | 10 | 13.5 | 1.4 | 2 | 2.7 |
| 21 | 6 | 12 | 2.3 | 3.1 | 4.3 |
| 27 | 6 | 12.8 | 2.7 | 3.7 | 5.0 |
| 55 | 6 | 13.2 | 5.2 | 7.1 | 9.7 |
| 65 | 6 | 13.2 | 6.1 | 8.4 | 11.5 |

1) At 18V
2) At 18V with light emission regulation (with duty cycle regulated according **Equation (2)**)
3) At 18V with 2% PWM

## 2.2 Constant Power Control by PWM

Most application requires PWM to maintain a constant lighting power. The classical used formula is **Equation (2)**

$$d = \frac{V_{PWM}^2}{V_{LAMP}^2} \quad (2)$$

Typically values are $V_{PWM}$ = 13.2V in Europe and $V_{PWM}$ = 12.8V in North America.

To keep a constant lighting power means to keep a constant electrical power at the filament, thus keep the temperature filament constant. By the usage of **Equation (2)**, the filament resistance is no more depending on to the root of the supply voltage but remains constant. **Figure 1** compares both current assuming a H4 55W lamp and 13V voltage regulation. A difference of 1A can be observed at 18V between DC and power regulated mode.

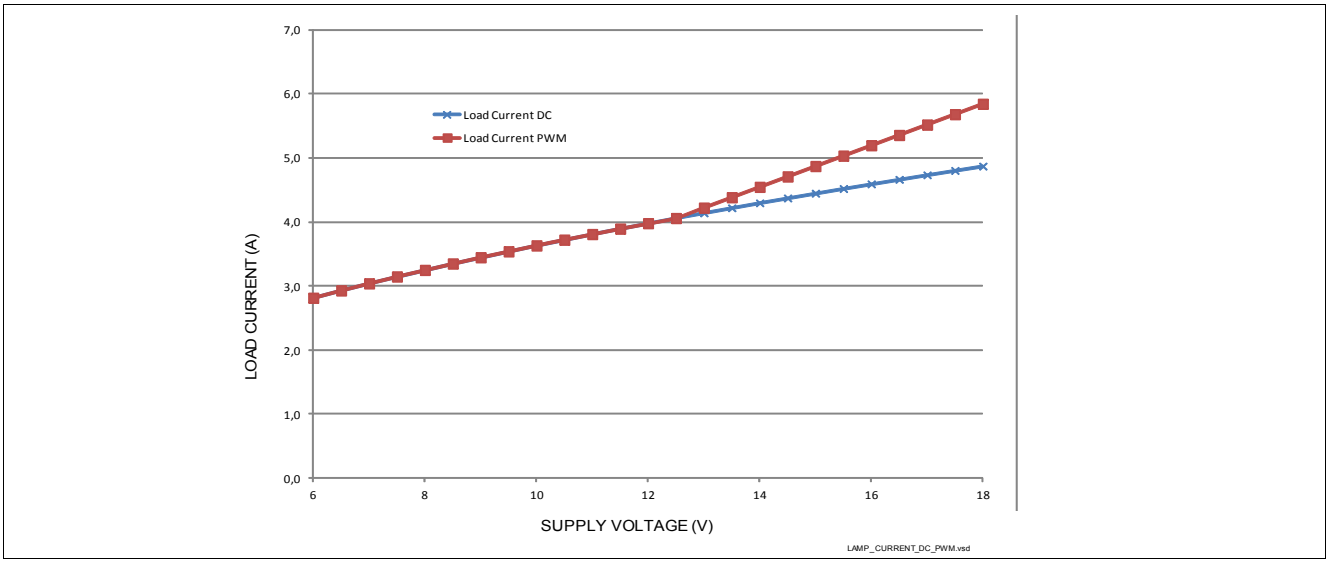


**Figure 1 Load Current in DC and Power Regulation. H4 55W with 13V Regulation**

## 2.3 Unregulated PWM

The unregulated PWM should be understood as a duty cycle law which is not subject to the supply voltage, but follows another physical dimension, eg time (ramp-up and down of dome lights), steering wheel angle, etc... In those application, the PWM can be 5 to 95% duty cycle at 18V. To find the effective load current requires to suppose that this given duty cycle is coming from a power regulated law. Using **Equation (2)**, the artificial voltage regulation is found by **Equation (3)**.

$$V_{PWM} = \sqrt{d} \times V_{LAMP} \tag{3}$$

For example, to perform a 5% PWM at 18V is equivalent to have regulated the lamp at 4V. It results in a much higher current at 18V than in DC. **Figure 2** and **Figure 3** show the load current at three different PWM duty cycle (5%, 50% and 100% or DC) and three voltage, for a H4 55W.

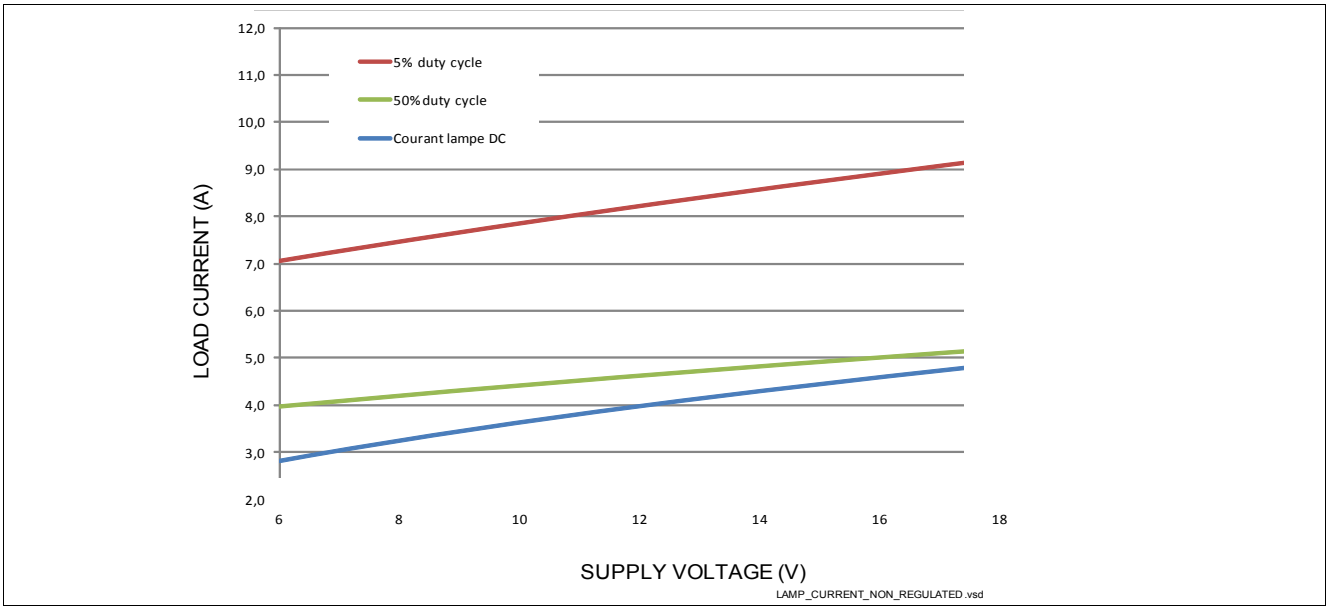


**Figure 2 Load Current Function of Supply Voltage at Different Duty Cycle. H4 55W as Example**

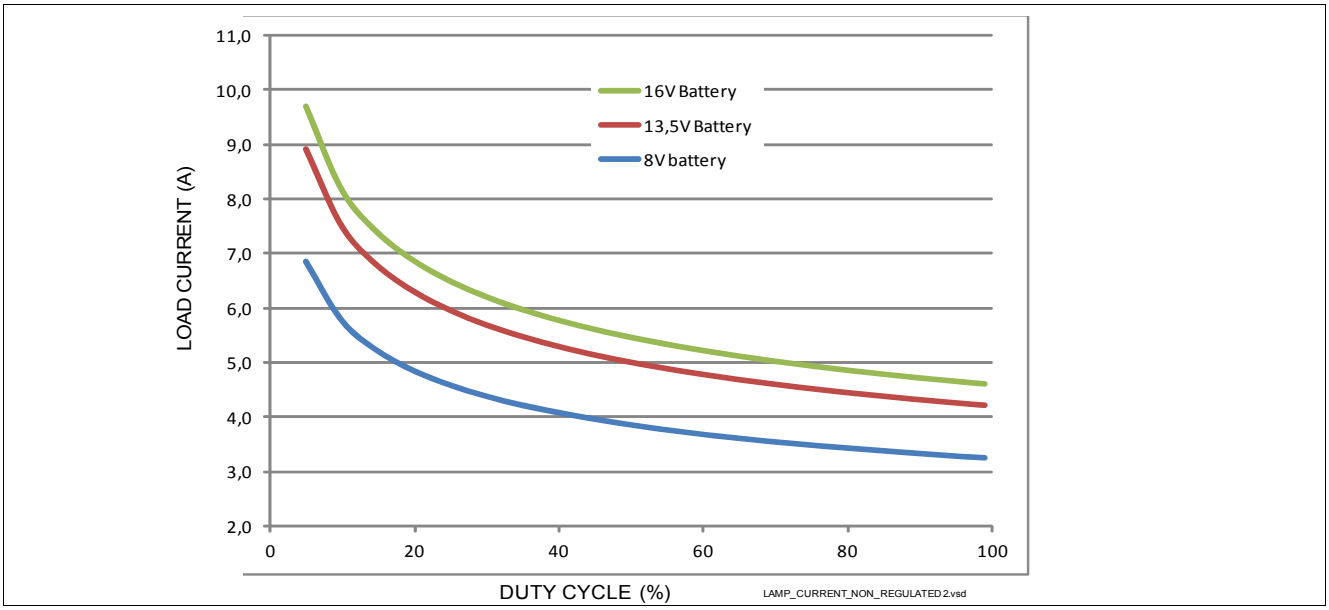


**Figure 3 Load Current function of Duty Cycle at Different Battery Voltage. H4 55W as Example**

# 3 Power Losses Calculation in the PROFET+

The PROFET+ control the switching slopes and guarantees a fixed switch ON time. The switching speed is then battery depdendant and the switching time rather independant.

**Figure 4** and **Figure 5** show the power losses at three different PWM duty cycle (5%, 50% and 100% or DC) and three voltages, for a H4 55W, using BTS5010-1EKB. The PWM frequency is fixed to 150 Hz.

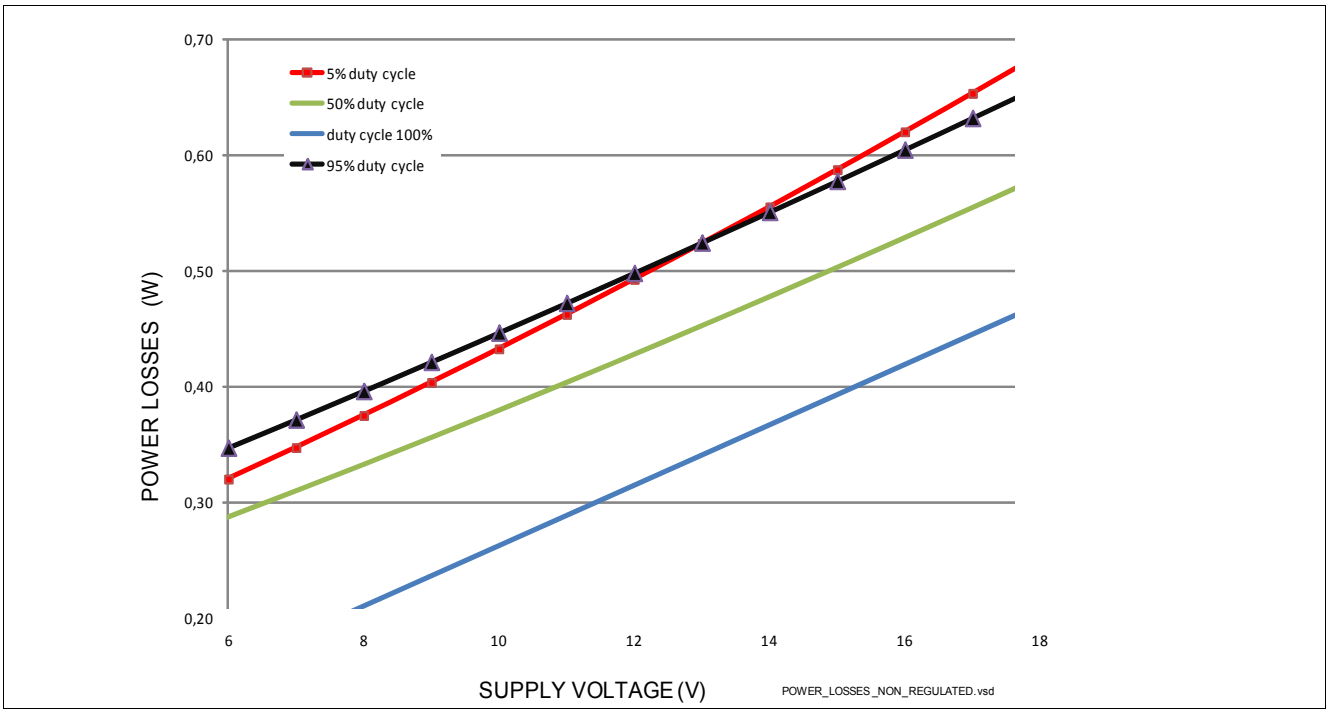


**Figure 4 Power Losses Function of Supply Voltage. H4 55W / BTS5010-1EKB as Example**

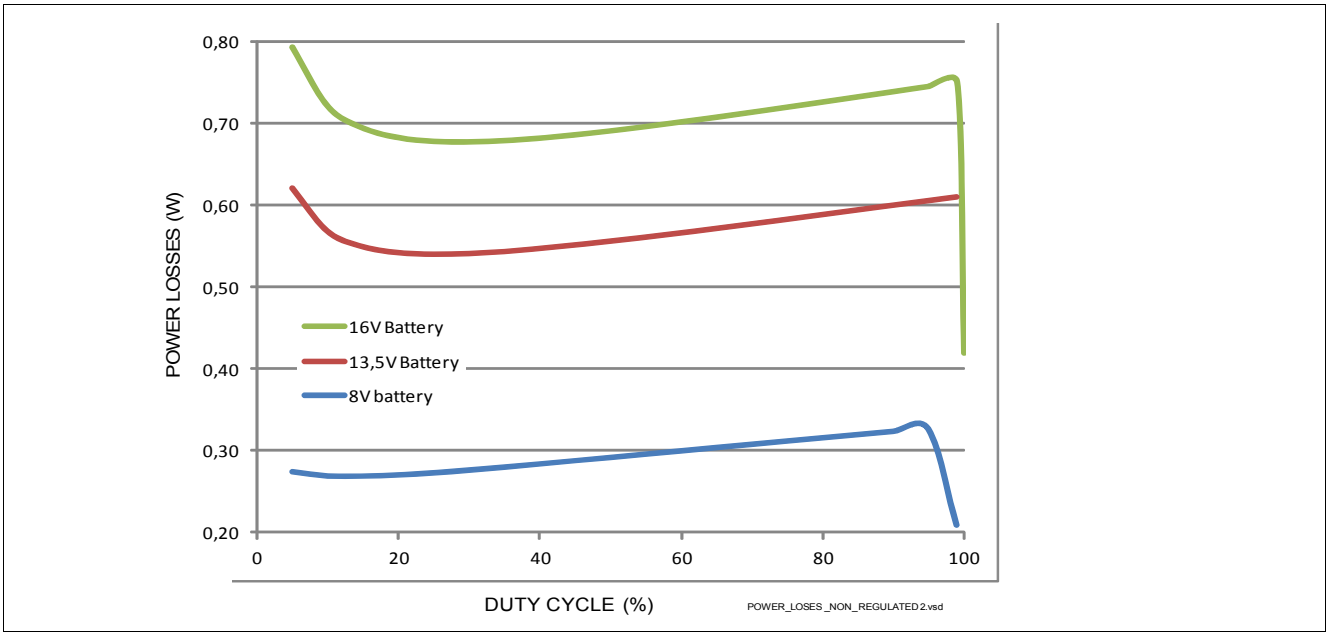


**Figure 5 Power Losses Function of Duty Cycle. H4 55W / BTS5010-1EKB as Example**

# 4 Conclusion

Performing non regulated PWM is possible using PROFET+ devices. The same device than for regulated power or DC usage is capable to drive unregulated PWM. Neverthteless, the power losses in the device increases due to the unregulated power in the lamp and the design should check the power losses in its specific application.

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