Switching Inductive Loads with TLE724xSL

Application Note

Rev. 1.1, 2011-09-19

Automotive Power

1 Abstract

Note: The following information is given as a hint for the implementation of the device only and shall not be regarded as a description or warranty of a certain functionality, condition or quality of the device.

This Application Note is intended to provide the knowledge and tools to calculate and measure the energy to be dissipated during switch-OFF of an inductive load. This energy will be used for a comparison with the TLE724xSL energy capabilities in order to judge whether a certain inductive load can be driven by the device.

The focus of this document is on low side switches TLE724xSL. But the contents, especially the second part, is valid for every low side switch which has to drive an inductive load.

Table 1 Terms in use

Abbreviation	Meaning
E_{AS}	Maximum Energy Dissipation One Channel, Single Pulse
E_{AR}	Maximum Energy Dissipation One Channel, Repetitive Pulse
$I_{D(0)}$	Drain Current (= Load Current) at starting point
$i_L(t)$	Load Current as function of time
$I_{L(nom)}$	Nominal Load Current
L_L	Coil Inductivity of Relay
$R_{DS(ON)}$	On-state Resistance
R_L	Coil Resistance of Relay
t_{CL}	Clamping Time
$T_{j(0)}$	Junction Temperature at starting point
V_{BAT}	Battery Voltage
$V_{DS(CL)}$	Output Clamping Voltage
$v_{DS}(t)$	Drain-Source-Voltage of DMOS as function of time

2 Introduction

The Multichannel LowSide Switch Family TLE724xSL (see **Table 2**) was developed to drive small loads with a current range < 0.5A. One of the main applications for those products is the control of relays.

The relay as an inductive load will store a certain energy during ON mode which has to be dissipated during the switch-OFF phase. There are two ways to dissipate the energy:

- by using a freewheeling diode or resistor in parallel to the load; this approach will increase the switch-OFF time and leads to a faster aging of the relay contacts, therefore is usually not choosen in application
- by using the energy capability of the switch

Table 2 SPIDER LowSide TLE724xSL Product Overview

Type	$I_{L(nom)}$	$R_{DS(ON,max)}$ @ 150°C	E_{AS}	E_{AR} (10^4 cycles)	E_{AR} (10^6 cycles)
TLE7240SL	210mA	3.0Ω	25mJ @ $T_{j(0)}$ = 150°C, $I_{D(0)}$ = 0.4A	13mJ @ $T_{j(0)}$ = 105°C, $I_{D(0)}$ = 0.3A	11mJ @ $T_{j(0)}$ = 105°C, $I_{D(0)}$ = 0.3A
TLE7243SL[1)]	260mA	2.1Ω	67mJ @ $T_{j(0)}$ = 150°C, $I_{D(0)}$ = 0.5A	38mJ @ $T_{j(0)}$ = 105°C, $I_{D(0)}$ = 0.35A	30mJ @ $T_{j(0)}$ = 105°C, $I_{D(0)}$ = 0.35A
TLE7244SL[1)]	290mA	1.7Ω	67mJ @ $T_{j(0)}$ = 150°C, $I_{D(0)}$ = 0.5A	31mJ @ $T_{j(0)}$ = 105°C, $I_{D(0)}$ = 0.4A	24mJ @ $T_{j(0)}$ = 105°C, $I_{D(0)}$ = 0.4A

1) TLE7243SL and TLE7244SL both have the same energy capability. Different E_{AR} values are caused by the different load currents.

The datasheet specifies E_{AS} and E_{AR} for a certain load current (**Figure 1**). The energy capability will be different for higher or lower load currents which are possible depending on application requirements. In **Chapter 3**, the current-energy-characteristic for TLE724xSL is shown to allow customers to select the right product according to the maximum load current in their application.

4.1.6	Maximum energy dissipation one channel	E_{AS}				mJ	[2)]V_{bat}=16V, V_{clamp}=45V,
	single pulse		–	25			$T_{j(0)}$ = 150 °C $I_{D(0)}$ =0.40 A
	repetitive (1 · 10^4 cycles)	E_{AR}	–	13			$T_{j(0)}$ = 105 °C $I_{D(0)}$ =0.30 A
	repetitive (1 · 10^6 cycles)		–	11			$T_{j(0)}$ = 105 °C $I_{D(0)}$ =0.30 A

Figure 1 Single and Repetitive Pulse Energy Specification TLE7240SL

There are two ways possible to determine the energy stored in the relay coil:

- by calculation
- by measurement

In **Chapter 4**, the results of both approaches are compared. Based on this analysis some recommendations will be given to support the selection of the right device to drive a certain relay.

3 E_A=f(I_L) characteristic

The energy capability of the low-side switches is dependent on the load current. The datasheet specifies E_{AS} and E_{AR} for a specific load current condition only. For applications with higher or lower current than specified in datasheet, the following characteristics can be used in order to derive the energy capability of the devices.

3.1 TLE7240SL

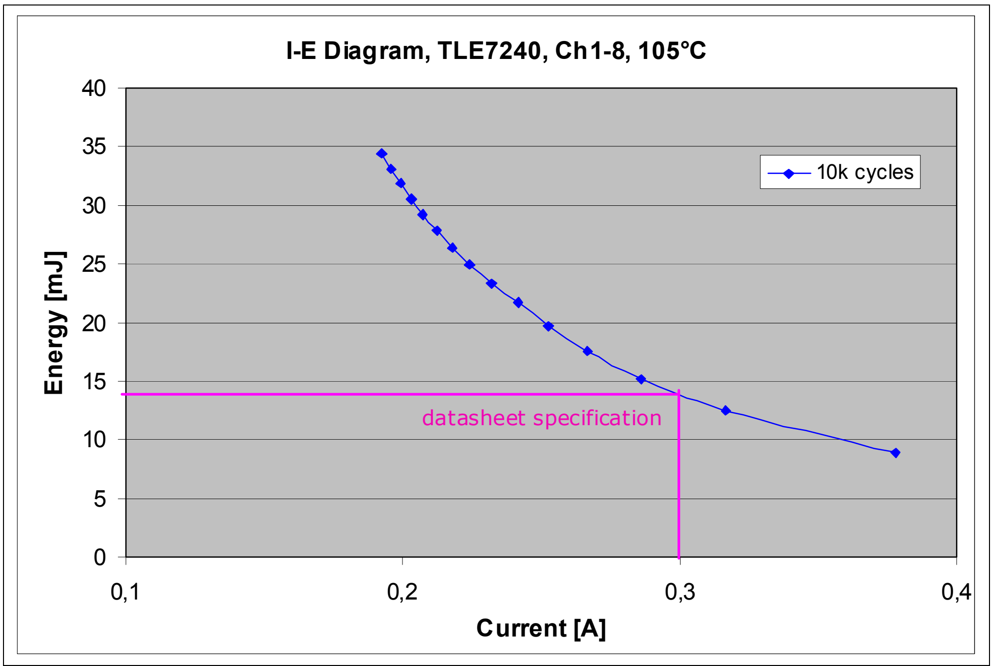

Figure 2 TLE7240SL, E_{AR}=f(I_L) @ 105°C, 10^4 cycles

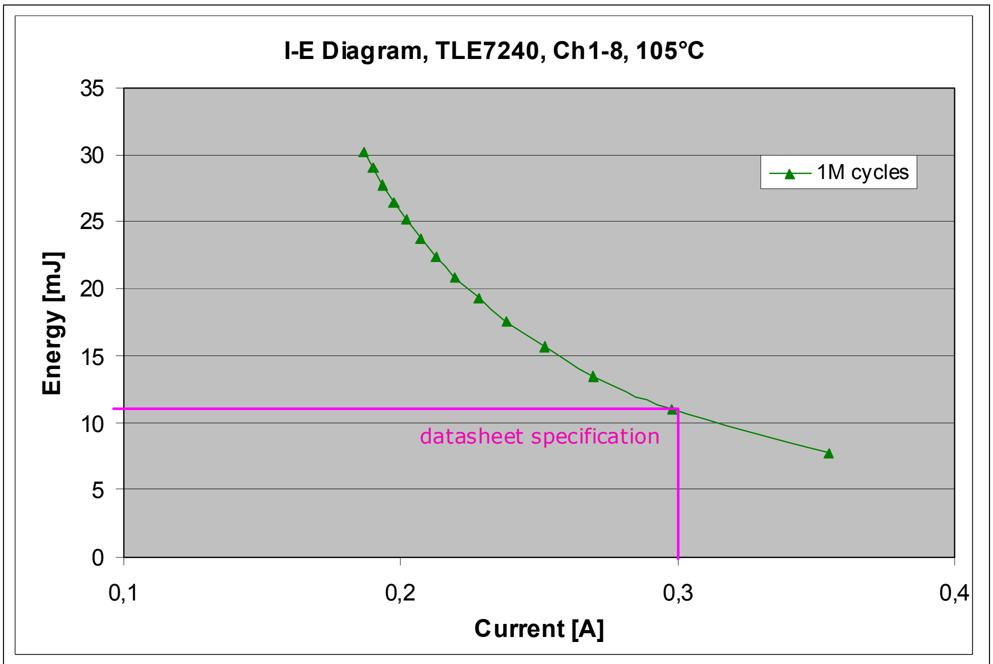

Figure 3 TLE7240SL, E_{AR}=f(I_L) @ 105°C, 10^6 cycles

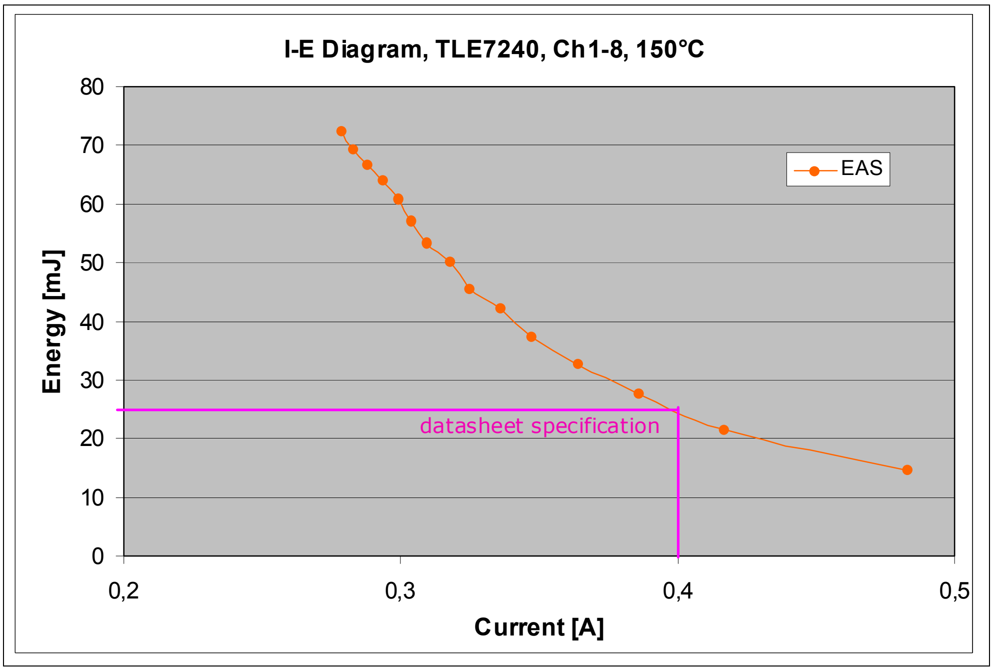

Figure 4 TLE7240SL, E_{AS}=f(I_L) @ 150°C

3.2 TLE7243SL / TLE7244SL

Both devices have the same E=f(I) characteristic, but are specified at different load currents for E_{AR} in the datasheet.

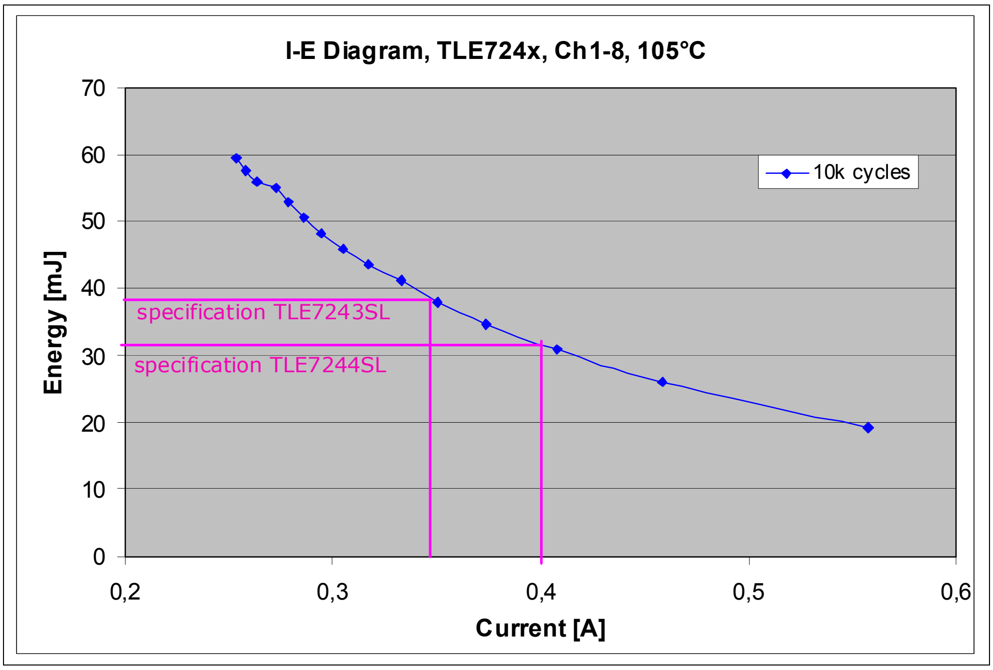

Figure 5 TLE7243SL, TLE7244SL, E_{AR}=f(I_L) @ 105°C, 10^4 cycles

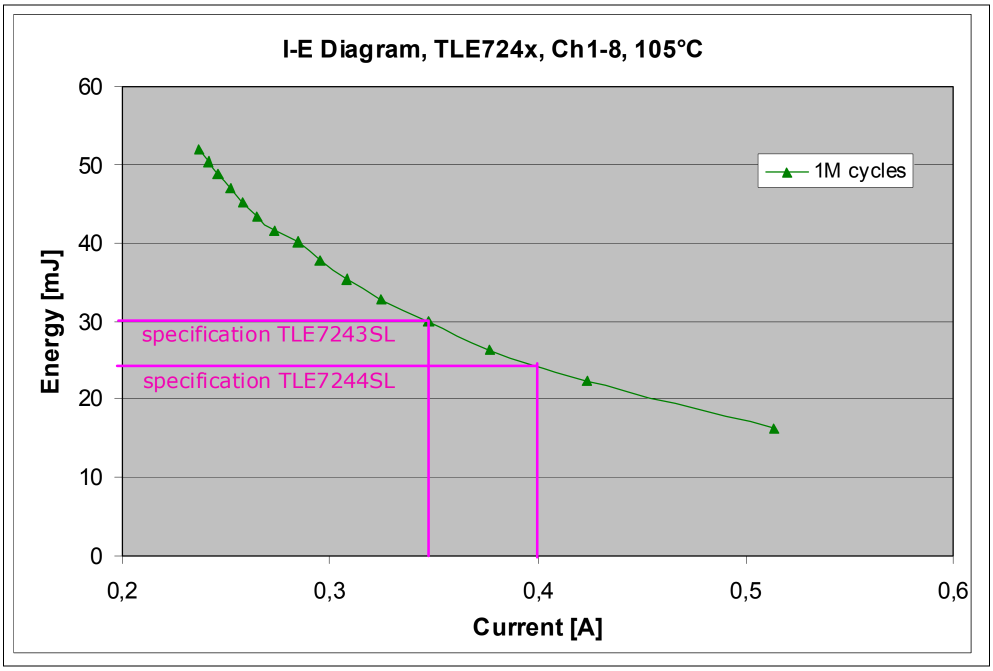

Figure 6 TLE7243SL, TLE7244SL, E_{AR}=f(I_L) @ 105°C, 10^6 cycles

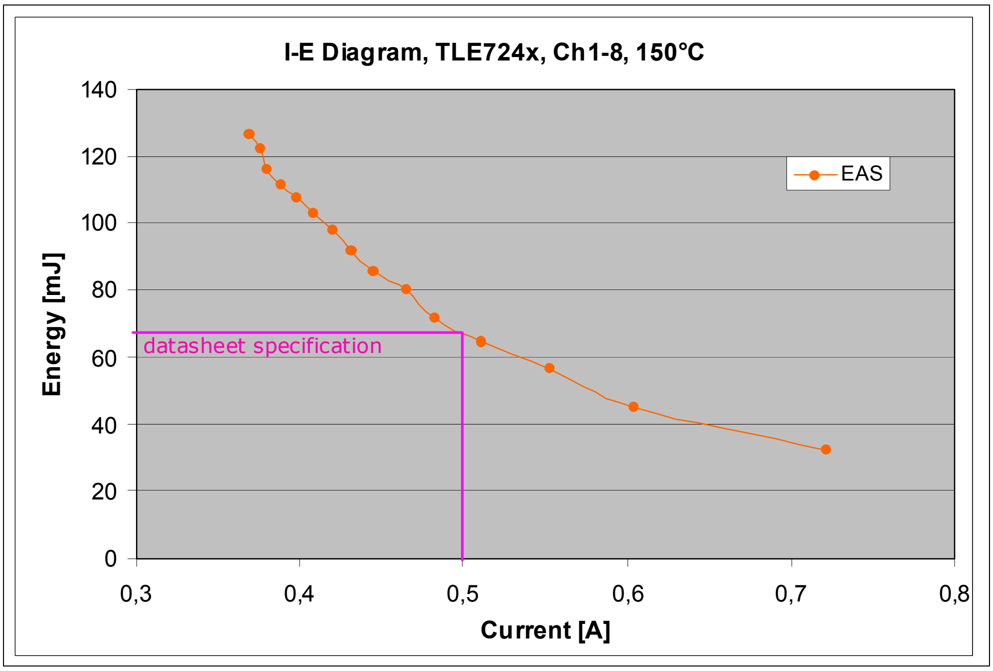

Figure 7 TLE7243SL, TLE7244SL, E_{AS}=f(I_L) @ 150°C

4 Inductive Loads

In this chapter the setup for measuring the clamping energy on an actual load will be described. The deviations of measured values from calculated ones will be explained for one example.

4.1 E_A Measurements

The best approach to evaluate the real load characteristics and obtain a value of the clamping energy, to be dissipated in the low-side switch, is to measure it. Of course, it's important to reproduce as much as possible the operating conditions of the actuator, as they would be in the actual application. In **Figure 8** a setup for the measurement is suggested where the load is kept at the expected operating temperature inside a chamber.

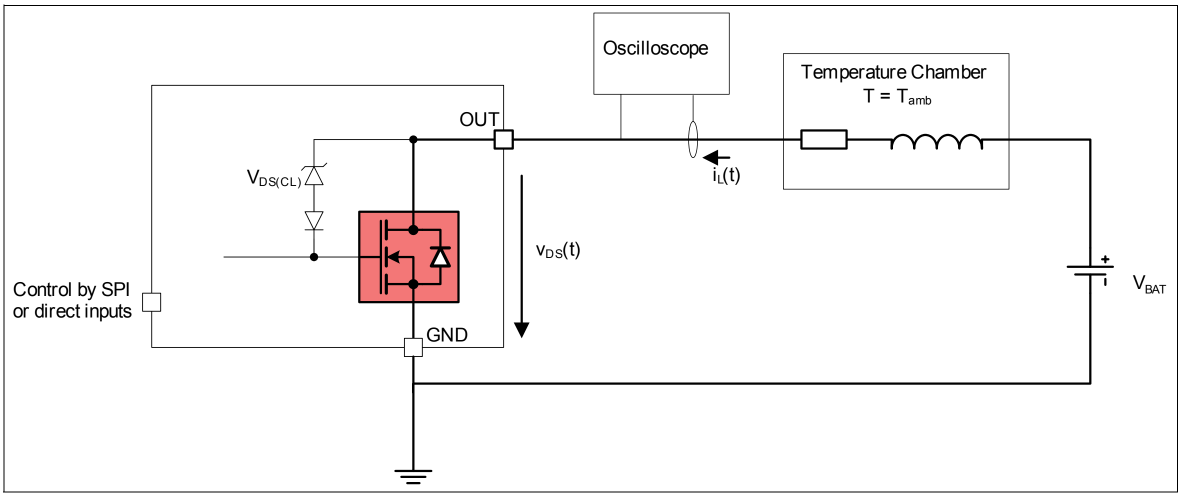

Figure 8 E_A measurement setup

The clamping energy is expressed by:

$$E_A = \int_0^{t_{cl}} v_{DS}(t) i_L(t) dt$$

where v_{DS} and i_L are, respectively, the clamping voltage and load current and t_{cl} is the time that the load current needs to reach zero after the switch-OFF event.

Following investigation was made with a Tyco 20A relay:

- Load Characteristics[1)]
  - R_L = 89.3Ω (@25°C)
  - L_L = 920mH (@25°C, 1kHz)
- Switch Characteristics
  - $V_{DS(CL)}$ = 46V (typ.)
  - $R_{DS(ON)}$ = 3Ω (@150°C)
- Expected Operating Conditions
  - V_{BAT} = 13.5V
  - T_{amb} = 25°C

1) Nominal values confirmed by LCR measurements

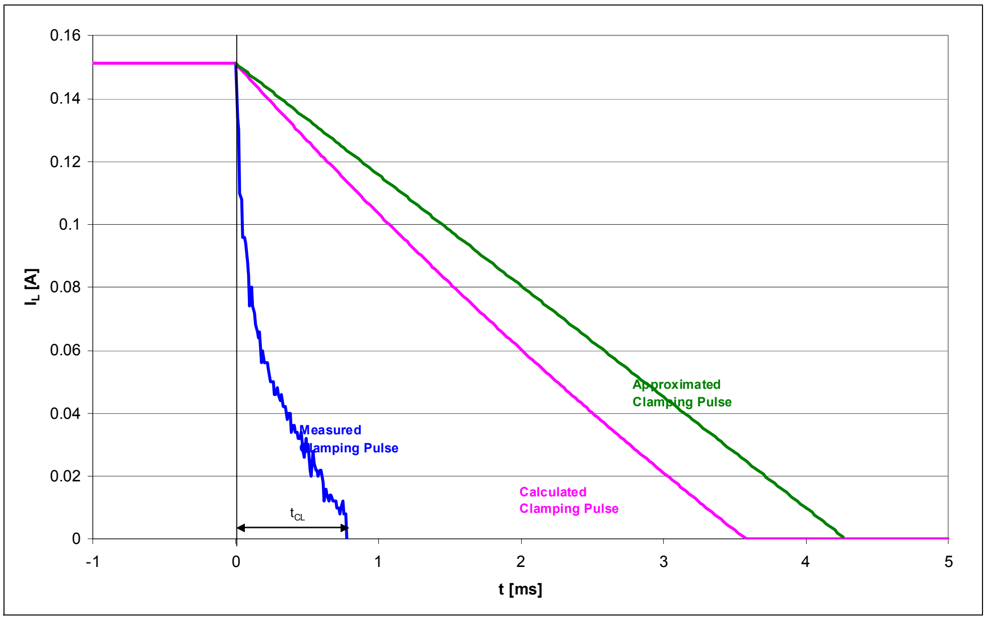

Figure 9 E_A measurement (R_L=89.3Ω, L_L=920mH, V_{BAT}=13.5V)

The measurement results are following:

$V_{DS(CL)}$ = 46V

I_L = 0.151A

t_{CL} = 0.78ms

E_A = 1.35mJ

4.2 E_A Calculations

The integral in **Chapter 4.1** leads to following equation:

$$E_A = V_{DS(CL)} \times \left[\frac{V_{BAT} - V_{DS(CL)}}{R_L} \times \ln\left(1 - \frac{R_L \times I_L}{V_{BAT} - V_{DS(CL)}}\right) + I_L\right] \times \frac{L_L}{R_L}$$

If the integral function requires to much effort, a linear approximation of the current shape could be used:

$$E_A = \frac{1}{2} \times L_L \times {I_L}^2 \times \left(1 - \frac{V_{BAT}}{V_{BAT} - V_{DS(CL)}}\right)$$

Figure 9 is showing the current during switch-OFF phase from the measurement as well as the calculated and approximated values.

Table 3 Measured vs. Calculated values (R_L=89.3Ω, L_L=920mH, V_{BAT}=13.5V, V_{CL}=46V)

	I_L [A]	E_A [mJ]	t_{CL} [ms]
Measured Values	0.151	1.35	0.78
Calculated Values	0.151	11.79	3.56
Approximated Values	0.151	14.95	4.26

The measured value is much lower than the calculated value due to the relay properties. At a certain current level the relay coil goes into saturation and the inductance starts to decrease. The saturation current is depending on the temperature and is lower for higher temperatures. Additonally, the mechanical part of the relay will influence the permeability of the relay core during the switching event, also resulting in a changed inductance value.

5 Conclusion

The calculation of the energy, based on the LCR-measurement of the relay, leads usually to a much higher value than measured in the application. Therefore it is recommended to measure the switch-OFF characteristic to ensure the right selection of the device. Otherwise it is possible, that a more expensive device is choosen which will not be neccessary from the application point of view.

Furthermore, the repetitive pulse energy is specified at a certain current. For applications with lower current requirement, the energy can be higher for the same device and number of cycles.

6 Additional Information

- For further information you may contact **http://www.infineon.com/**

7 Revision History

Switching Inductive Loads with TLE724xSL

Revision History: Rev. 1.1, 2011-09-19

Page	Subjects (major changes since last revision)
3	Table 2, typing error corrected, load current for E_{AR} of TLE7240SL changed to 0.3A

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