TLE8366

The Demoboard

Automotive Power

Infineon

Never stop thinking

Table of Contents **Page**

1 Abstract

This Application Note is intended to provide additional information about the TLE8366Demoboard. The reader should be given some additional information for working with the demo board, for developing his own schematic, dimension the components (filter elements) and create a proper layout. Please refer to the application Note "TLE8366 Application Information" for additional information.

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

2 Introduction

The TLE8366 is a Step down Converter operating with a fixed 370 kHz switching frequency. By applying a rectangular signal to the "Sync"-Pin the switching frequency may be adjusted to an external source between 200 and 500 kHz.

The TLE8366 is deliverable in three versions:

- A fixed 5 V output voltage version, named TLE8366EV50

- A fixed 3.3 V output voltage version, named TLE8366EV33

- A variable output voltage version, named TLE8366EV

  (Output voltages adjustable between 0.60 V up to 16 V)

All versions could use the same demo board. The demo board is equipped with a TLE8366EV, if not otherwise mentioned.

3 The Demoboard

3.1 Quick start
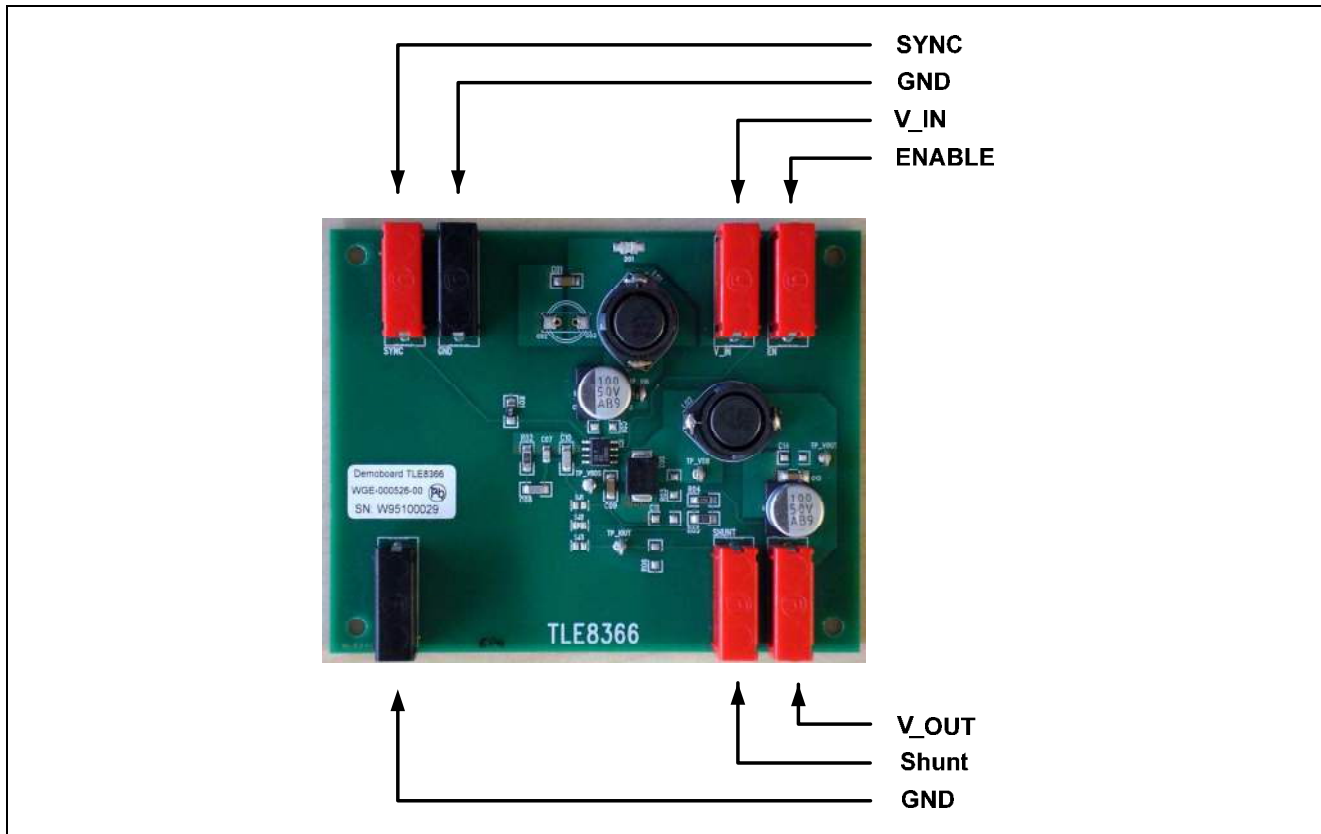
Figure 1   Quick start

- Connect **GND** to ground

- Connect **V_IN** to the voltage supply

- Connect **ENABLE** to V_IN to start the board

- With **SYNC** You may synchronize the TLE8366 to an external frequency source

- The output voltage to supply loads is present at **V_OUT**

- **SHUNT** offers You the possibility to connect an external load between the V_OUT and SHUNT and run the TLE8366 as a current source (please make sure, that only FB_3 is connected then)

3.2   The Schematic

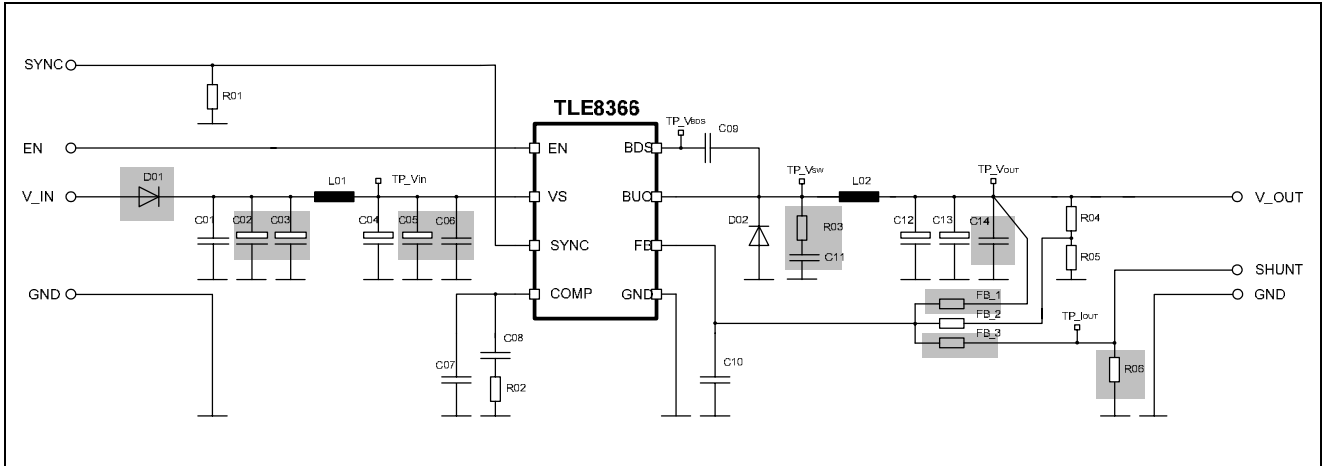**Figure 2   The schematic of the demo board (parts in grey are not mounted, but D01 is bridged)**

The demo board is equipped with a TLE8366EV. The output voltage is adjusted to 5 V by choosing R04 = 16.2 kΩ and R05 = 2.2 kΩ. (Only FB_2 is connected for the variable output voltage version TLE8366EV)

You may vary the output voltage V_OUT by changing the values of R04 and R05.

$$V\_OUT = V\_FB * \frac{R04 + R05}{R05}$$

The demo board offers the possibility of testing several configurations of input and output filters by providing additional mounting places. For decreasing the commutation voltage peak mounting places for a snubber circuit (R03 and C11) are foreseen.

 If the TLE8366EV should be used as a current source, a shunt resistor could be mounted at R06 and only FB_3 should be connected. The TLE8366EV will then drive a constant current through a load connected between V_OUT and SHUNT.

3.3 Bill of Material

Part Number	Value	Description
	TLE8366EV	
R01	47 Ω	Input resistor for synchronization signal
R02	22 kΩ	Resistor of compensation network - needs to be adjusted to output filter elements, input and output voltage and output current conditions.
R03	n.c.	Snubber resistor
R04	16.2 kΩ	Only for variable output voltage version: High side voltage divider resistor (calculated for V_OUT = 5.0V)
R05	2.2 kΩ	Only for variable output voltage version: Low side voltage divider resistor (calculated for V_OUT = 5.0V)
R06	n.c.	Only for use as current source: shunt resistor for load current measurement
FB_1	n.c.	Only for fixed voltage version: FB_2 and FB_3 must be open
FB_2	0 Ω	Only for variable voltage version: FB_1 and FB_3 must be open
FB_3	n.c.	Only for constant current version: FB_1 and FB_2 must be open
C01	220 nF	Input capacitor (for EMC reason)
C02	n.c.	Mounting place for additional input filter capacitor (only if needed)
C03	n.c.	Mounting place for additional input filter capacitor (only if needed)
C04	100 µF/ 50 V	Input filter capacitor (smoothing the alternate content of the input current)
C05	n.c.	Mounting place for additional input capacitor (only if needed)
C06	n.c.	Mounting place for additional input capacitor (only if needed)
C07	100 pF	Capacitor of compensation network - needs to be adjusted to output filter elements, input and output voltage and output current conditions.
C08	22 nF	Capacitor of compensation network - needs to be adjusted to output filter elements, input and output voltage and output current conditions.

Part Number	Value	Description
C09	220 nF	Bootstrap capacitor
C10	1 nF	Smoothing capacitor for feedback line (recommended for variable voltage version and current source)
C11	n.c.	Snubber capacitor
C12	100 µF/50V	Output filter capacitor
C13	220 nF	Output filter capacitor (ceramic to lower ESR and for EMC improvement)
C14	n.c.	Mounting place for additional output filter capacitor (only if needed)
L01	47 µH	Input Filter Inductor
L02	47 µH	Output Filter inductor
TP_Vin	Testpoint	Input voltage at pin VS
TP_Vbds	Testpoint	Bootstrap voltage
TP_Vsw	Testpoint	Output of internal Mosfet
TP_Vout	Testpoint	Output voltage
TP Iout	Testpoint	Output current signal (for current source only)
D01	0 R	Mounting place for reverse polarity protection diode (replaced by bridge)
D02	MBRS340T3 Schottky Diode	Freewheeling Diode
SYNC	4 mm Banana Jack red	
EN	4 mm Banana Jack red	
V_IN	4 mm Banana Jack red	
GND	4 mm Banana Jack black	
V_OUT	4 mm Banana Jack red	
SHUNT	4 mm Banana Jack red	
GND	4 mm Banana Jack black	

Figure 3   Bill of Material TLE8366EV Demo board

3.4 The most important parts

Compensation Network C07, C08 and R02

Feedback (smoothing) Capacitor C10

Input Filter Capacitor C04

Input Filter Inductor L01

Output Filter Inductor L02

Feedback line connectors
FB_1 above
FB_2 in the middle
FB_3 below

Bootstrap Capacitor C09

Freewheeling Diode D02

Resistor Divider For Variable Output Voltage, R04 above, R05 below

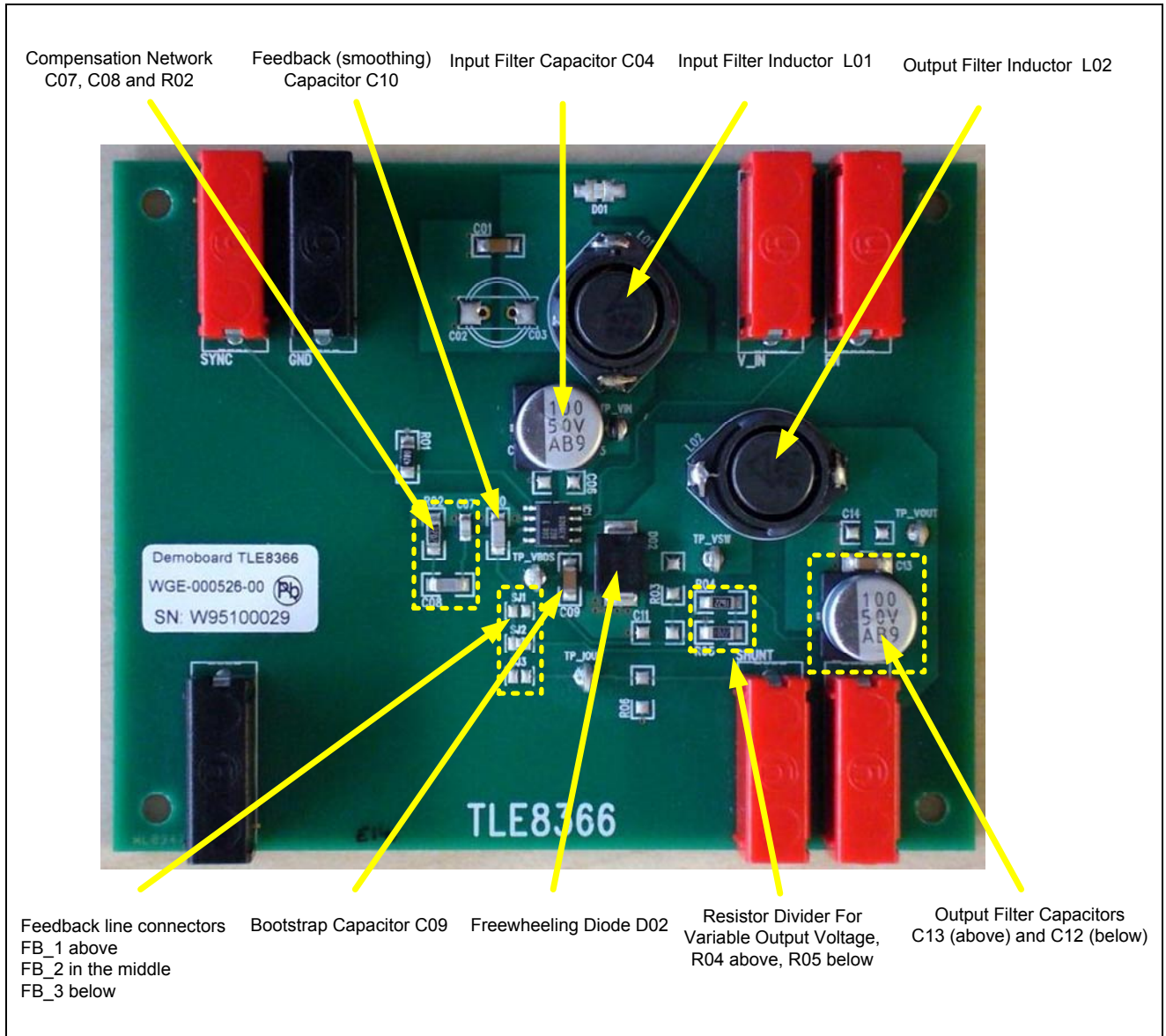Output Filter Capacitors C13 (above) and C12 (below)

Figure 4   TLE8366 Demo board

4 Dimensioning

For the following chapter please refer to the relating chapter 3 of the application note "TLE8366 Application Information".

4.1 Calculating the output filter elements C12, C13 (C_{OUT}) and L02 (L_{OUT})

The demo board shall be designed for a nominal input voltage V_{In} = 13.5 V with a maximum value of 45 V (maximum rating of the TLE8366), an output voltage V_{Out} = 5.0 V and a maximum load current I_{Out} = 1.8 A.

To calculate the output capacitor we got the formula:

$$V_{Ripple,total} = \Delta I \cdot (\frac{1}{8 \cdot C_{OUT} \cdot fs} + R_{ESR})$$

To calculate the output inductor we have:

$$L_{OUT} = \frac{(V_{IN} - V_{OUT}) \cdot V_{OUT}}{\Delta I \cdot fs \cdot V_{IN}}$$

Where we know:

- V_{In} = 13.5 V
- V_{Out} = 5.0 V
- I_{Out} = 1.8 A.
- f_S = 370 kHz (nominal switching frequency)

Now we have to make assumptions for the desired ripple current ΔI and the voltage ripple $V_{Rippletotal}$.

For ΔI we take 10% of the maximum output current 1.8 A, which is 0.18 A. The current ripple value ΔI is peak to peak, it will increase with increasing input voltage.

This delivers**:**

L02 = 47 µH

The voltage ripple $V_{Rippletotal}$ consists of two parts, the one related to the capacitance value, the other to the ESR of the capacitance.

We assume 50 mΩ for the ESR and allow 10 mV voltage ripples.

Using the equation from above, we get C12 = 60.81 µF. Taking the next technical value, 68 µF would be sufficient for this requirement. Having a look to the equation we recognize, that the voltage ripple is mainly depending on the ESR value of the output capacitor. Therefore the use of a parallel ceramic capacitor is recommended.

For the demo board we decided to use a bigger output capacitor as energy storage to allow higher load stepping. We take

C12 = 100 µF

And for the parallel ceramic capacitor:

C13 = 220 nF

The resonant frequency of the output filter is given by:

$$f_{RES} = \frac{1}{2\pi\sqrt{L_{OUT}C_{OUT}}}$$

With L02 = 47 µH and C12 = 100µF (we neglect C13) we get

f_{RES} = 2.3 kHz

This is far below the switching frequency.

4.2 Choosing the output filter elements C12, C13 and L02

To avoid magnetic fields we recommend to use magnetically shielded inductors with a so-called "closed iron core".

Figure 5   Magnetically shielded inductor from EPCOS

We choose the SMT power inductor series B82479G1 from EPCOS

Characteristics and ordering codes

L_R μH	Tolerance	f_L MHz	I_R A	I_{sat} A	R_{max} Ω	Ordering code
10	±20% ≙ M	0.1	3.90	8.00	0.040	B82479G1103M000
22		0.1	3.10	6.00	0.059	B82479G1223M000
33		0.1	2.80	5.00	0.075	B82479G1333M000
47		0.1	2.40	4.00	0.097	B82479G1473M000
68		0.1	2.00	3.00	0.138	B82479G1683M000
100		0.1	1.70	2.40	0.207	B82479G1104M000

Figure 6   Data Inductor - Extract from EPCOS datasheet

- f_L is the frequency, where the inductance was measured.

- I_R is the rated current. This is the maximum permissible current with temperature increase of ≤ 40 K at rated temperature. I_R = 2.40 A, which is above the maximum output current $I_{Out,Max}$ = 1.80 A

- I_{Sat} is the saturation current. This is the maximum permissible current with an inductance decrease of approximately 10%. I_{Sat} = 4.00 A, which is above the maximum buck over current I_{BUOC} = 3.6 A (please refer to spec line in TLE8366 data sheet)

- The rated current and the saturation current of the inductor must be higher than the real output current and the real peak current through the switcher.

- If the regulator is designed for less than the maximum current capability, the values of the rated current and the saturation current may also be decreased accordingly to have the benefit of using smaller parts, but it must be ensured for any mode of operation, that neither I_R nor I_{Sat} will be exceeded.

We choose the Aluminum electrolytic SMD capacitor series B41121 from EPCOS

Technical data and ordering codes

V_R V DC	C_R 120 Hz 20 °C µF	Case dimensions $d \times l$ mm	tan δ_{max} 120 Hz 20 °C	$I_{AC,R}$ 120 Hz 105 °C mA	Ordering code
50	0.1	4 × 5.4	0.12	0.7	B41121A6104M000
	0.22	4 × 5.4	0.12	1.6	B41121A6224M000
	0.33	4 × 5.4	0.12	2.5	B41121A6334M000
	0.47	4 × 5.4	0.12	3.5	B41121A6474M000
	1.0	4 × 5.4	0.12	7	B41121A6105M000
	2.2	4 × 5.4	0.12	11	B41121A6225M000
	3.3	4 × 5.4	0.12	13	B41121A6335M000
	4.7	5 × 5.4	0.12	16	B41121A6475M000
	10	6.3 × 5.4	0.12	24	B41121A6106M000
	10	6.3 × 5.8	0.12	24	B41121B6106M000
	22	6.3 × 7.7	0.12	51	B41121A6226M000
	33	6.3 × 7.7	0.12	60	B41121A6336M000
	47	6.3 × 7.7	0.12	63	B41121A6476M000
	100	8 × 10	0.12	155	B41121A6107M000
	150	10 × 10	0.12	300	B41121A6157M000

Figure 7   Data Capacitor - Extract from EPCOS datasheet

- We decided to use on type of capacitor for input and output filter, therefore we took the 50 V type.

- For the use on a demo board a load life of 1000 h @ +105°C is sufficient, for use in other applications we recommend to check the life time.

- The specified ripple current capability or voltage ripple capability must be higher than the values, which may occur on the application in worst case.

4.3 Choosing the Freewheeling diode

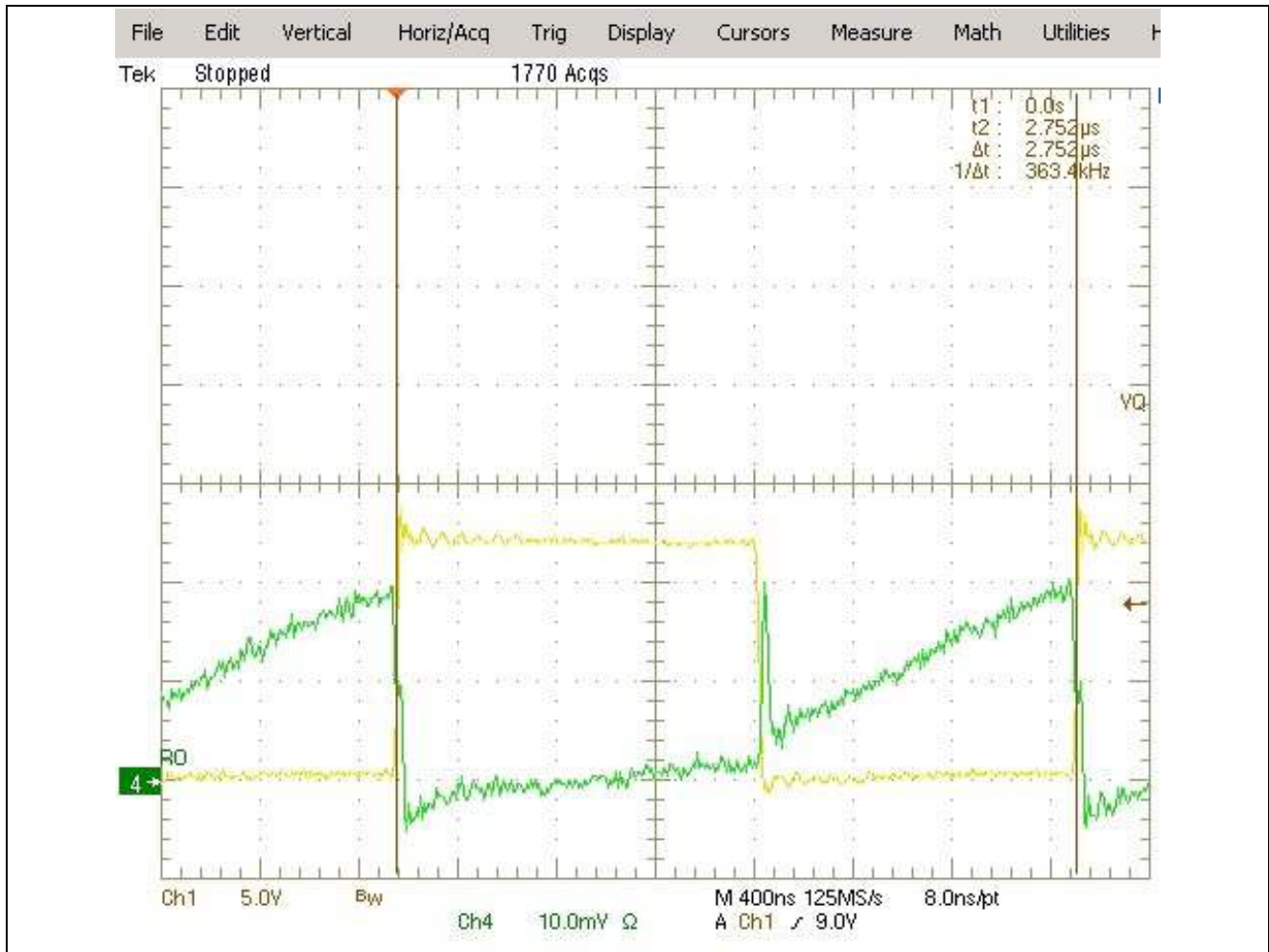We choose a Schottky diode, the MBRS340T3

Figure 8   Voltage and current at switch node

- The yellow curve shows the voltage curve at the cathode of the diode

- The green curve shows the current through the internal Mosfet of the TLE8366

- The red circle shows the "commutation voltage peak", which is caused by random inductances and capacitances. It is undesired, but inevitable. This peak should be kept as small as possible, below 0.5 V. An ultrafast diode may cause a very voltage peak there. If this peak should exceed the maximum rating of pin BUO, it will lead to destruction.

- The blue ellipse shows the "commutation current peak", when the diode starts to lead current

4.4 Choosing the input filter elements C01, C04 and L01

The use of an input capacitor is mandatory; however this capacitor may be divided into several single capacitors. The capacitor(s) shall have a low ESR to provide current for a fast load response.

For C04 we choose the Aluminum electrolytic SMD capacitor series B41121 from EPCOS, the same value as the capacitor in the output filter. The voltage ratio has to be higher than the maximum input voltage, which is 45 V – so we took 50 V.

The average current through the capacitor could be calculated:

$$\boxed{I_{RMS} = I_{OUT}\sqrt{D}}$$

The input capacitor has to offer a low ohmic path for the alternate content of the input current. During a load step the first charge for the output filter capacitor will be taken from the input capacitor. Therefore it has to be large enough to contain enough energy.

We choose the same value for this capacitor as for the output filter capacitor.

We choose **C04 = 100 µF**

The input filter inductor L01 forms together with C04 a low pass input filter to smoothen the input current and keep the alternate content away from the rest of the application. It is recommended to use an input filter inductor, however some applications may allow to work without this device. Similar to the output inductor L02 the input inductor L01 has to be chosen, that the rated current must be higher than the real input current and the saturation current must be higher than the maximum real peak current occurring.

We choose **L01 = 47 µH**

The resonance frequency of the input filter must be well below the switching frequency.

With L01 = 47 µH and C04 = 100µF we get

f_{RES} = 2.3 kHz

This is well below the switching frequency.

To suppress conducted emissions an additional input filter capacitor **C01 = 220 nF** (ceramic) is mounted at the entrance.

4.5 Choosing the other parts

4.5.1 Compensation Network

The compensation network consisting of R02, C07 and C08 shall compensate the voltage ripple on the output of the error amplifier, which is caused by the switching of the internal Mosfet. The compensation network needs to be adapted to the real configuration of the regulator. A simulation tool provides a proposal for the values of the elements. The proposal must be evaluated by hardware, because the simulation tool can not consider stray effects in the application circuit like random inductances or resistors.

To create the proposal for the compensation network, the following must be known:

- Nominal input voltage

- Output voltage

- Maximum output current

- Inductance value of the output filter inductor L02

- ESR of the output filter inductor L02

- Capacitance value of the output capacitor C14 (and other capacitors)

- ESR of the output filter capacitor C14 (and other capacitors)

4.5.2 Reverse polarity protection diode

Insert if necessary. Please dimension according maximum input voltage and maximum inrush current

4.5.3 Further elements

- The use of a smoothing capacitor (C10) for feedback line is recommended for variable voltage version and current source. A value of 1 nF close to pin FB is sufficient. The capacitor should not be too large not to slow down the feedback signal

- The bootstrap capacitor C09 is supplying the internal Mosfet driver. A value of 220 nF is recommended

4.6 General recommendation

- The demo board was designed to demonstrate the functionality and the maximum current capability of the TLE8366

- For testing specific applications it may be necessary to exchange the elements originally mounted on the board by the elements, which will be used in the specific application.

- This chapter gives the background, how the demo board was calculated. Every calculation has to be verified by hardware. The design is only valid, if this evaluation is successful

5 The Layout

For the following chapter please refer to the relating chapter 4 of the application note "TLE8366 Application Information".
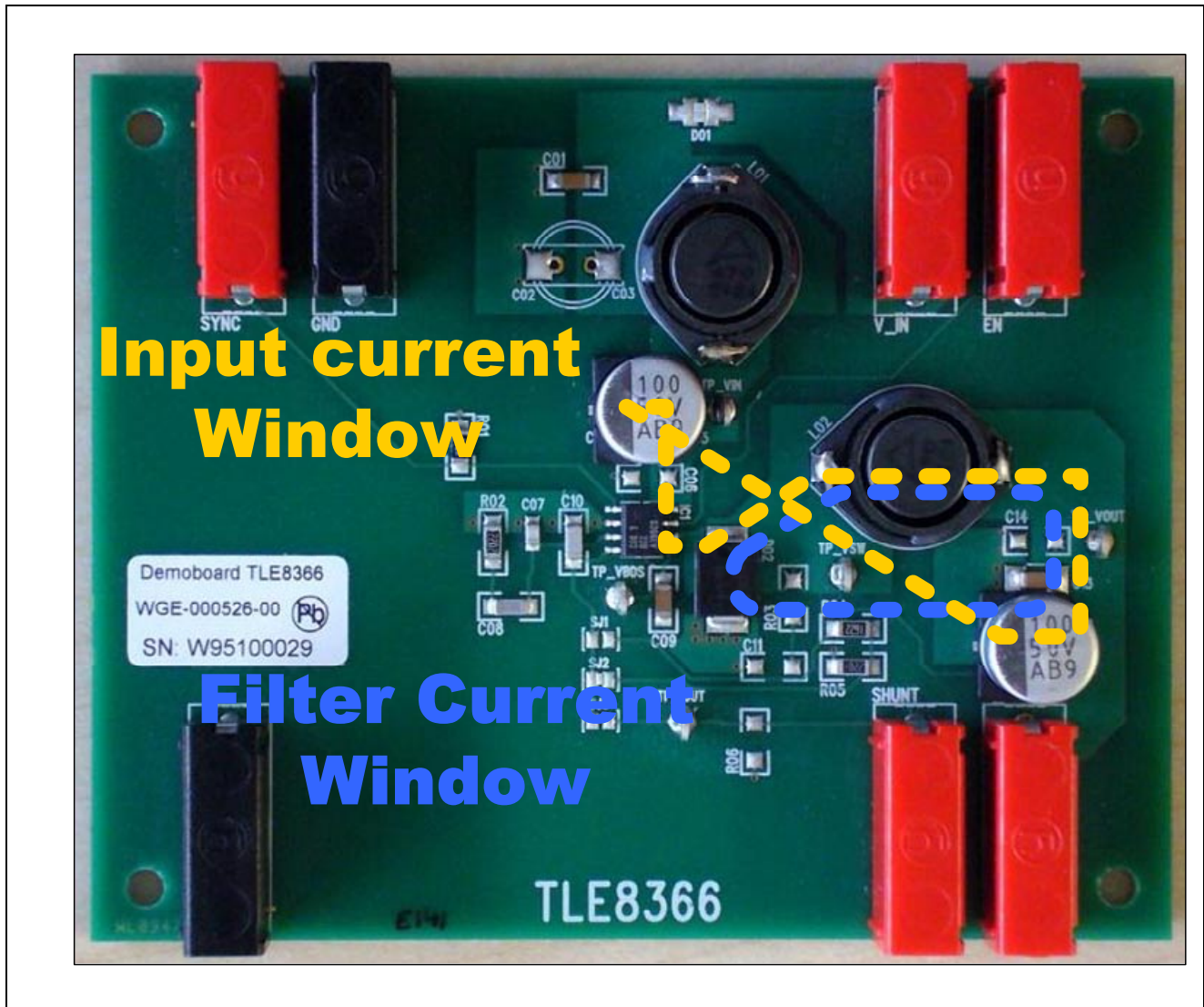
5.1 Radiated Magnetic Emissions:

Figure 9   Circular current windows

- The size of the so-called "Input current window" and "Filter current window" were kept as small as possible to reduce the size of the emitting loop

- To achieve this, the elements of the filter current window circuit freewheeling diode D02, output filter inductor L02 and output filter capacitorsC12 and C13 were located close together

- The same for the input current window: The elements are C04, the internal switcher, again L02, C12 and C13

- In addition there is aground layer on the bottom side of the board to cover the remaining windows.
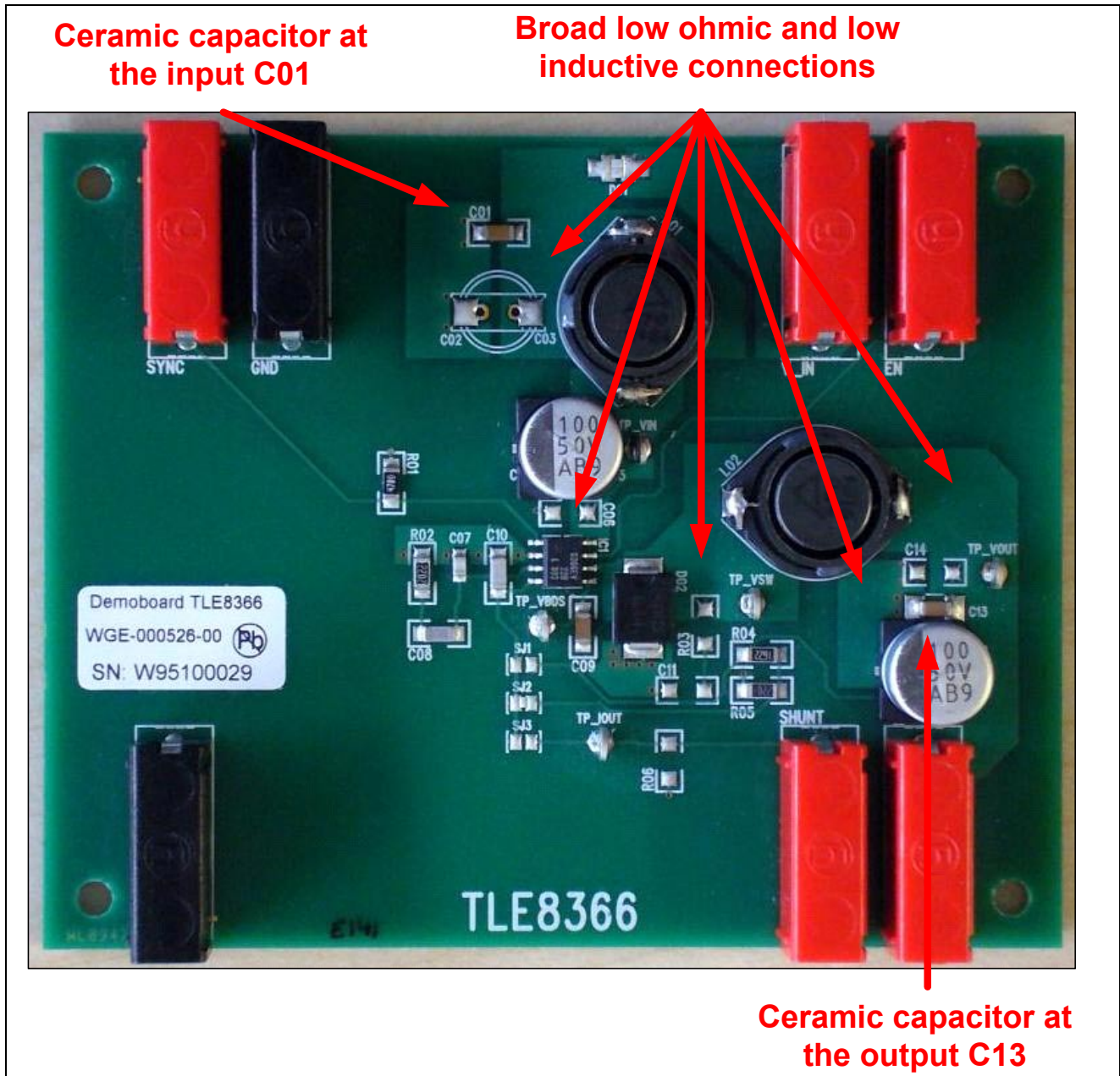
5.2 Conducted and Radiated Disturbances:

Figure 10   Counter measures against electromagnetic disturbances

- Use of broad low resistive and low inductive connections in the "high current" paths

- Ceramic capacitors at input and output to suppress high frequent emissions

- Feedback line without vias and away form switching lines to avoid disturbances

- Ground layer at the bottom side

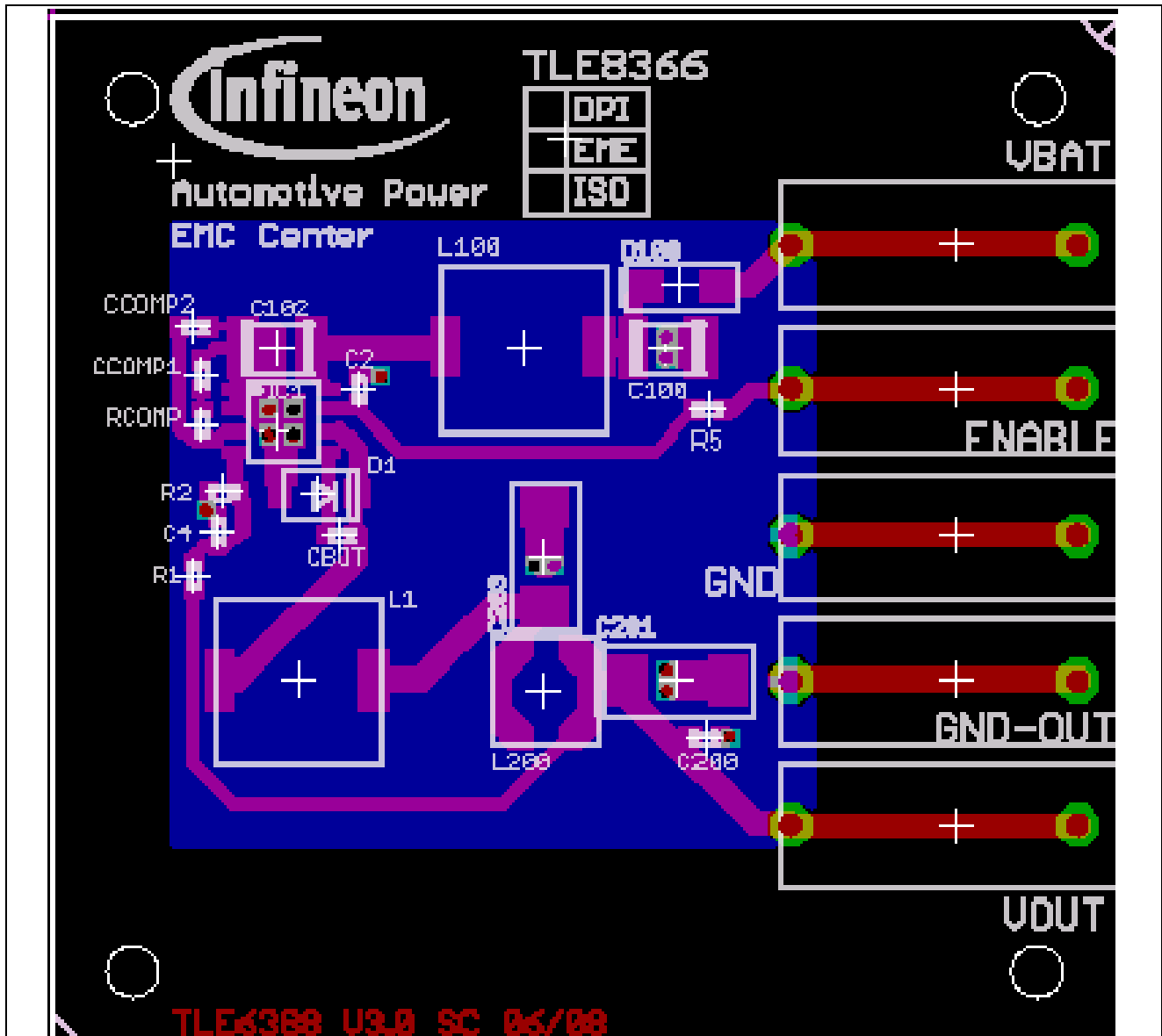- Ground connections from top to bottom layer with a couple of vias to reduce ohmic and inductive content

Figure 11 Additional layout proposal from EMC-Center

- This image offers an additional design proposal for an EMI-optimized Layout

- A ground layer (blue) should cover the complete converter area

- Switch node connections are a source of EMI and should be as short as possible and located as close as possible to the TLE8366

- Avoid to open "large windows" with these lines

- Filter capacitors with a very low ESR should be placed at the converter input and output to reduce conducted emissions on input and output lines

- The feedback line should be connected directly to the output capacitor and kept free of the switch node connections, a filter capacitor directly at the pin is recommended

6 Additional Information

- Please contact your local Infineon representative for further assistance and additional information
- For further information you may also contact **http://www.infineon.com/**

AP Number

Revision History:	2010-11-20	Rev 1.0
Version 1.0:	Initial release	

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Information

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