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ThinPAK 5x6

IFAT PMM APS SE AC
René Mente, MSc

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Authors: René Mente, MSc
IFAT PMM APS SE AC
Application Engineer – HV MOSFET

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1 Introduction

“Power Density”, this phrase is becoming more and more important, not only in high power applications like server power supplies but also in the normal commercial life. Therefore, this application note is going to represent the next step in power density offered by Infineon Technologies by introducing a new package concept named “ThinPAK 5x6”. In this document the reader will find all necessary basic information about the fundamental concept of this new package design but it is also going to illustrate examples for new design possibilities. Furthermore, comparisons between already existing SMD power MOSFETs (DPAK) will be covered. In order to come to the pure technical part of this document the next chapter will cover the portfolio which will be available for ThinPAK 5x6.

2 Portfolio

In order to cover a wide spread of applications, different voltage classes and technologies will be offered in this package design as shown on Figure 1.

APPLICATIONS	Part number	Maximum Ratings		$R_{DS(on)}$(Ohm)		Q_g(nC)typ
		V_{DSS}(V)	I_D(A)	Typ@25°C	Max@25°C	
CONSUMER	IPL60R360P6S	600	30	0.32	0.36	22
	IPL60R650P6S	600	16.5	0.59	0.65	12
LIGHTING	IPL60R1k5C6S	600	7.7	1.35	1.5	9.4
	IPL60R2k1C6S	600	5.4	1.89	2.1	6.7
CHARGERS/ ADAPTERS	IPL65R650C6S	650	16.6	0.59	0.65	23
	IPL65R1k0C6S	650	12.3	0.9	1	15
	IPL65R1k5C6S	650	8.4	1.35	1.5	11

Figure 1: ThinPAK 5x6 portfolio

Figure 1 shows there are two different technologies P6 and C6 implemented in order to cover our widest spread C6 technology and our new P6 technology which guarantees better performance because of the technology based electrical characteristics (especially with respect to driving losses in light load operation due to the reduced gate charge). Furthermore, with the differentiation of 600V and 650V Infineon is fit for the future with respect to applications which need higher voltage classes like quasi resonant flyback converter which are mainly used for applications going up to around 100W output power. Only as example IPL65R1K5C6S would be a perfect fit for a 10W – 15W battery charger which is normally used for mobile or tablet solutions.

Out of the portfolio it is visible that Infineon covers within the application different types of hard switching topologies (PFC, TTF, …) and resonant switching topologies (ZVS, LLC) in the low to mid load range. Now after the portfolio and the possible applications are known the following chapter will directly describe all package related topics like package outlines and pinning.

3 Package Outlines and Pin Layout

As in the naming visible this package has an outer dimension of 5mm times 6mm and a height of 1mm with a maximum dimension tolerance of 1%. This numbers result in a volume saving possibility of around 80% in comparison to DPAK (especially if height restrictions come into place), TO-220FP is also represented in Figure 2.

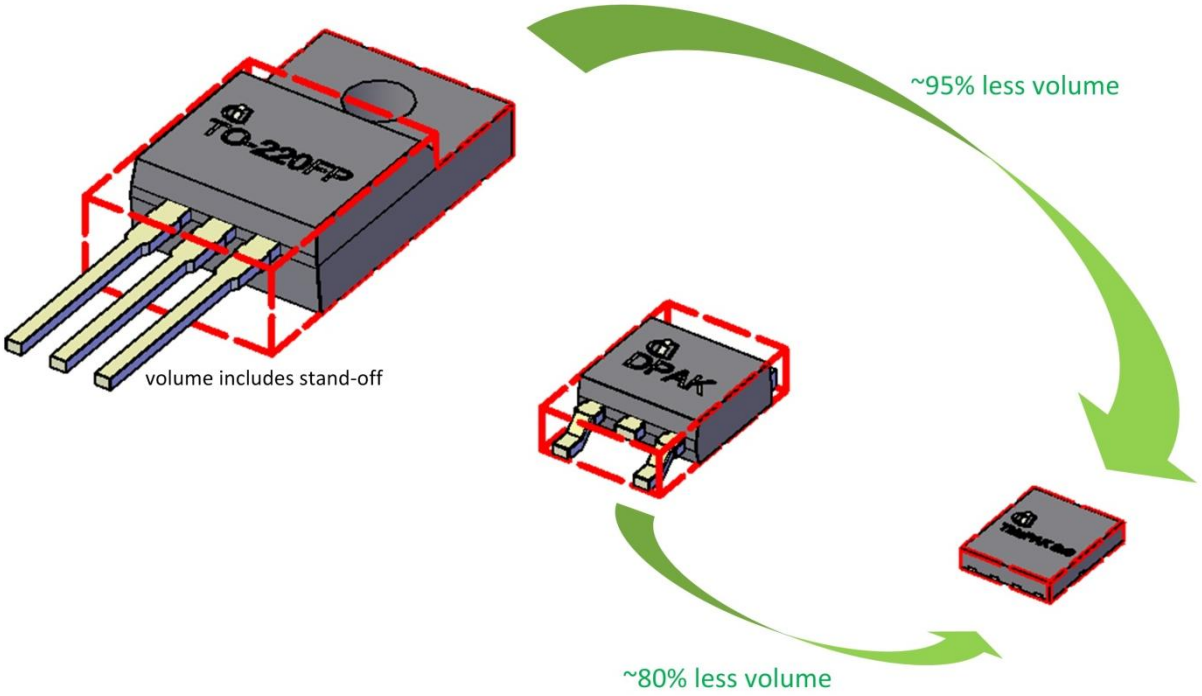
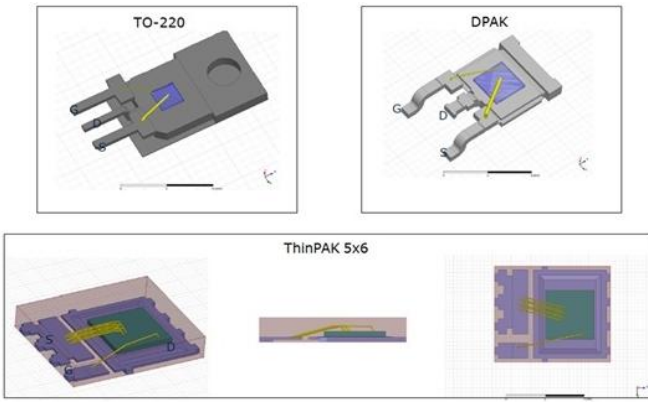


Figure 2: volume comparison TO-220FP vs. DPAK vs. ThinPAK 5x6

This general smaller dimensions result not only in a space saving advantage but also in reducing the internal and external MOSFET parasitics of the leads. Especially the source inductance which could influence on the gate drive voltages when switching with high di/dt and the drain inductance which could drive the drain source voltage internally seen on the chip over the maximum allowed break down voltage (rated in the equivalent datasheets). The following graphic is representing the parasitics comparison of TO-220FP, DPAK and ThinPAK 5x6.



TO-220FP

DC	R (mohm)	L(nH)	AC (100MH)	R (mohm)	L(nH)
Gate	32	8.2	Gate	75	7.2
Drain	0.33	5.8	Drain	10.8	5.2
Source	3.7	8.4	Source	34.7	7.4

DPAK

DC	R (mohm)	L(nH)	AC (100MH)	R (mohm)	L(nH)
Gate	28.5	6.2	Gate	71	5.8
Drain	0.002	0.09	Drain	0.53	0.1
Source	2.5	4.7	Source	25	4.5

ThinPAK 5x6

DC	R (mohm)	L(nH)	AC (100MH)	R (mohm)	L(nH)
Gate	38	4.2	Gate	75	3.8
Drain	0.003	0.05	Drain	0.25	0.02
Source	4.5	1.6	Source	12	1.46

Figure 3: parasitics comparison TO-220(FP) vs. DPAK vs. ThinPAK 5x6

These lower parasitics do not only bring the clear performance advantage with respect to switching behavior than any other high voltage package available, it also gives the designer the possibility of a more precise design in of these devices in a new project.

One of the main differences of this new package is the pin out of the leads, which need to be considered in the design phase of the application. This can be illustrated as its best in the following figure.

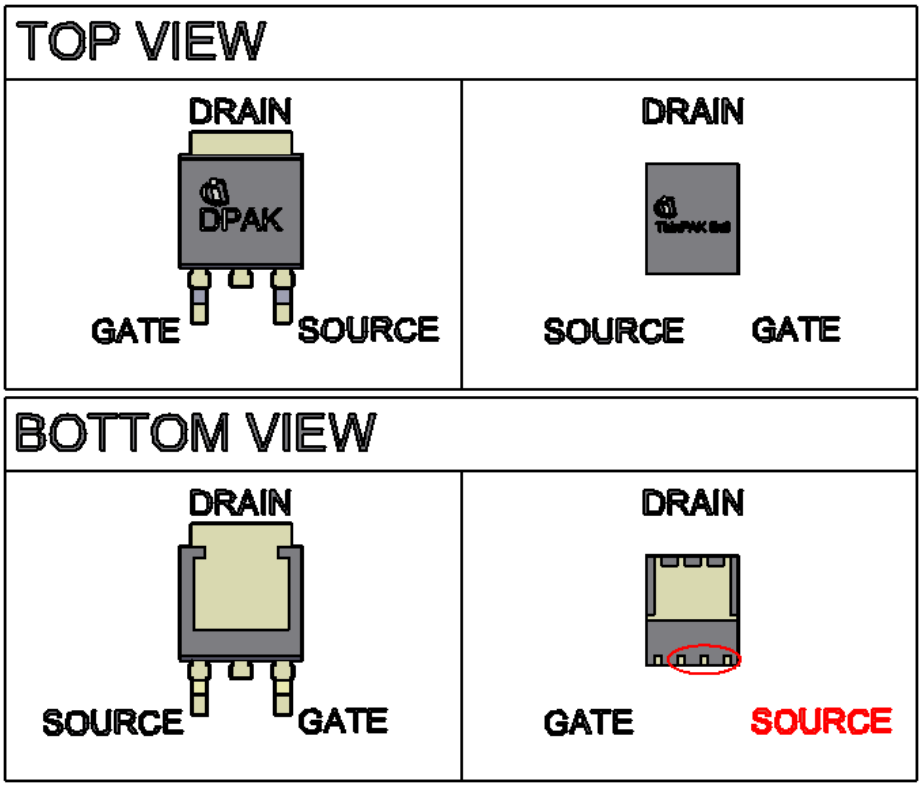


Figure 4: lead pinning DPAK vs. ThinPAK 5x6

As described the gate and the source pin of ThinPAK 5x6 are internally connected vice versa to the DPAK package. As that the package is described in detail the following chapter is going to illustrate the technology differences shortly.

4 Available technologies in ThinPAK 5x6

ThinPAK 5x6 comes available in two different CoolMOS™ price performance technologies. In order to give a clear differentiation of the technologies this chapter is included. The following picture explains the market positioning of these technologies.

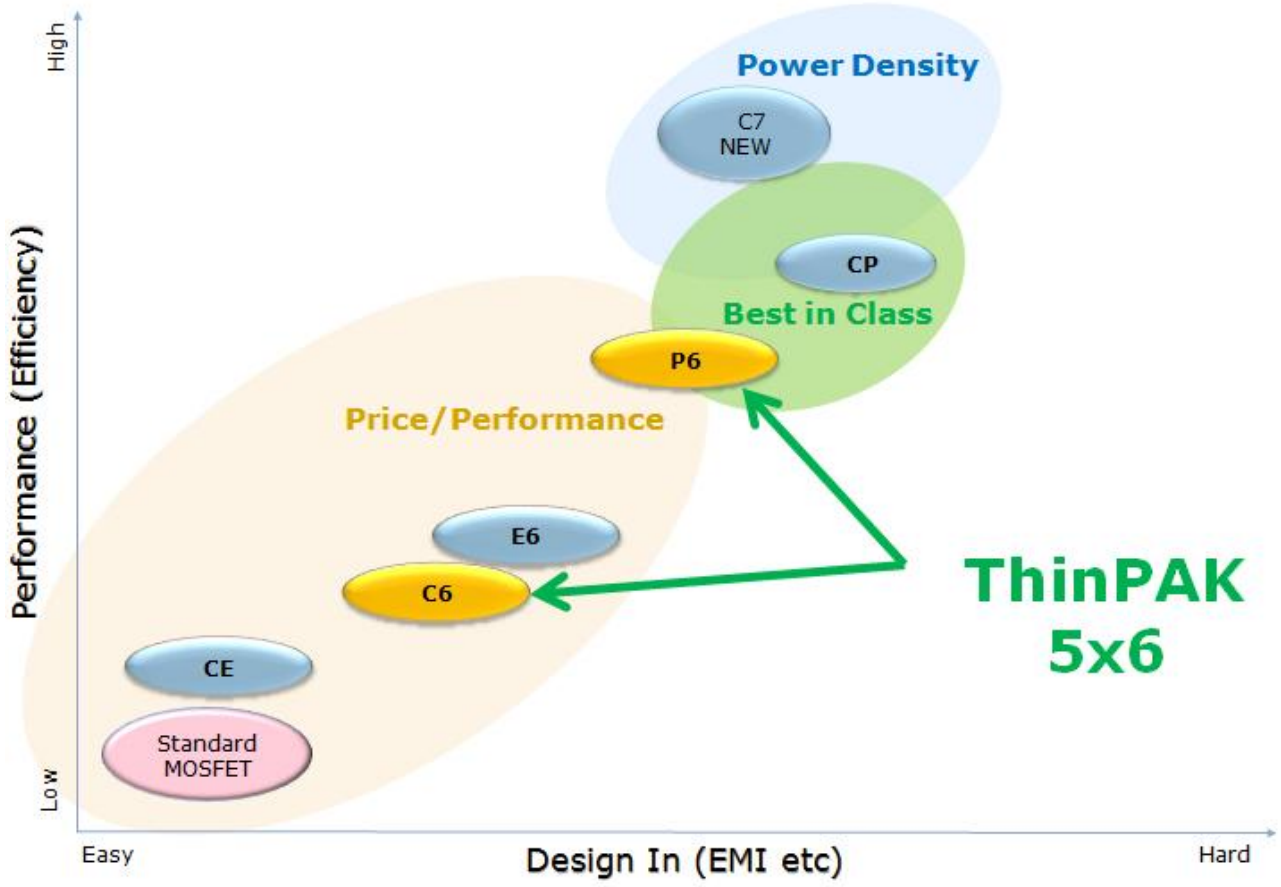


Figure 5: positioning of existing CoolMOS™ technologies

4.1 CoolMOS™ 600V P6

P6 is one of the newest technologies specialized for efficiency driven hard- and resonant switching applications. It combines the “Ease of Use” principle of a C6/E6 and the switching performance of Infineon’s fastest switching technology CP and is therefore located on the border of the price/performance and our best in class products, balancing efficiency and ease of use.

4.2 CoolMOS™ 600V C6

The difference between P6 and C6 lays with the general structure of the chip itself. The chip size of these devices is the same, but with the integration of the CP technology it is possible to further decrease the E_{on} and E_{off} losses of P6. Furthermore, C6 has around 30% higher total gate charge, making P6 also more efficient in light load operation. Nevertheless, C6 is Infineon’s widest spread CoolMOS™ technology

worldwide. This is possible due to the fact that this part has a very good price performance balance throughout its portfolio.

4.3 CoolMOS™ 650V C6

650V C6 brings a higher maximum breakdown voltage which results by the end also in around 20% bigger chips size in comparison to the 600V version. This increase of chip size is afterwards in direct correlation to the electrical parameters, which means bigger chip size gives higher switching losses due to the internal capacitances (C_{iss}, C_{oss}, C_{rss} and resulting E_{oss}, Q_{oss} and Q_g).

If there is a need for further technology comparison, please take a look to the equivalent datasheet where all necessary electrical parameters are implemented. The fundamental part of this document is now finished and will continue directly with the application measurements.

5 Application measurements

This chapter is going to show the efficiency and the thermal behavior of ThinPAK 5x6 versus DPAK and in some cases also IPAK.

5.1 150W DCM PFC (CrCM) – LCD TVs

5.1.1 System description

The DCM PFC is used in applications with an output power of smaller than 300W which fits perfectly to our $R_{DS(on)}$ classes starting with 360mOhm with the 600V P6. The used PFC is a standardized efficiency and thermal performance measurement system which runs completely automated and is illustrated in the figure below.

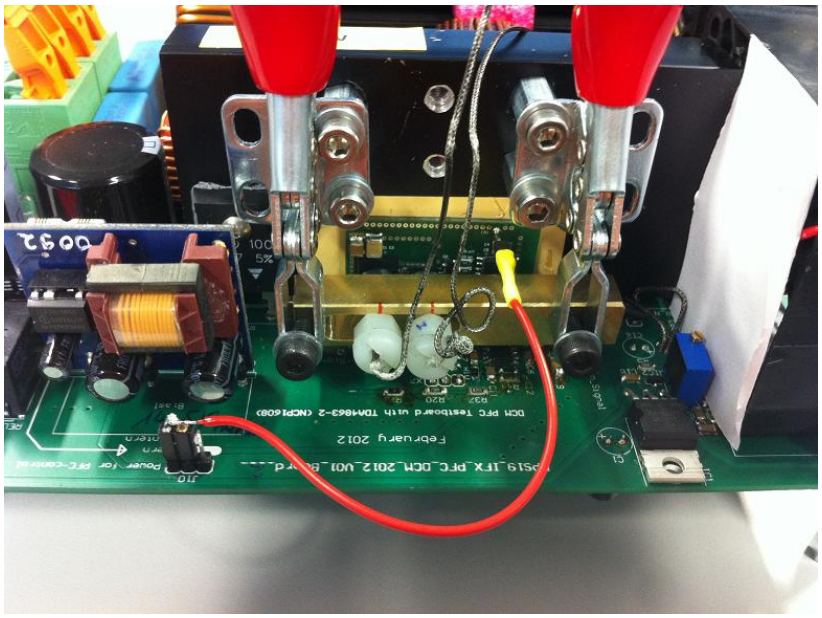


Figure 6: 150W DCM PFC

As visible in the picture this is a quite complex system and is not directly used in a real application like in a TV set. Nevertheless, this system is especially designed to test different MOSFET technologies and packages to each other. Such an exact comparison is only possible by reducing as much unknown variables in the system which can influence the performance of the device under test. That is the reason why this

setup is also temperature controlled, which means you will always have the same ambient temperature for all different DUTs and the measurement itself is completely automated.

In order to verify the efficiency and the thermal performance of DPAK and ThinPAK 5x6 the following adapter boards are obligatory.

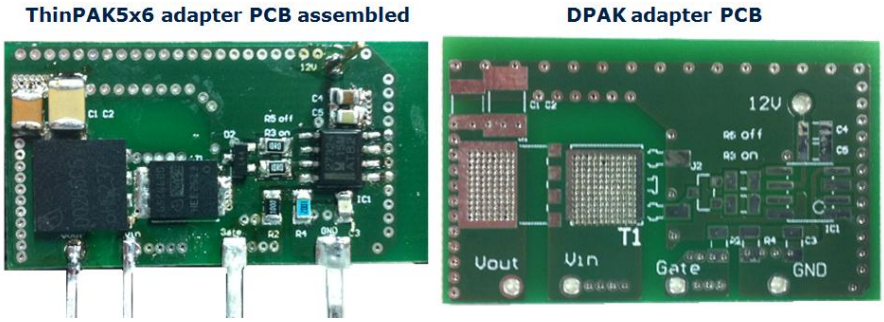


Figure 7: adapter PCBs ThinPAK 5x6 (left) and DPAK (right) for 150W DCM PFC

It is visible that also the gate drive circuit is located on the daughter PCBs which results in a gate drive control which is absolutely the same for DPAK and ThinPAK 5x6. Furthermore, the temperature is measured via thermo couples which are placed on the top side of the case of the ThinPAK 5x6 and DPAK as illustrated in the following figure.

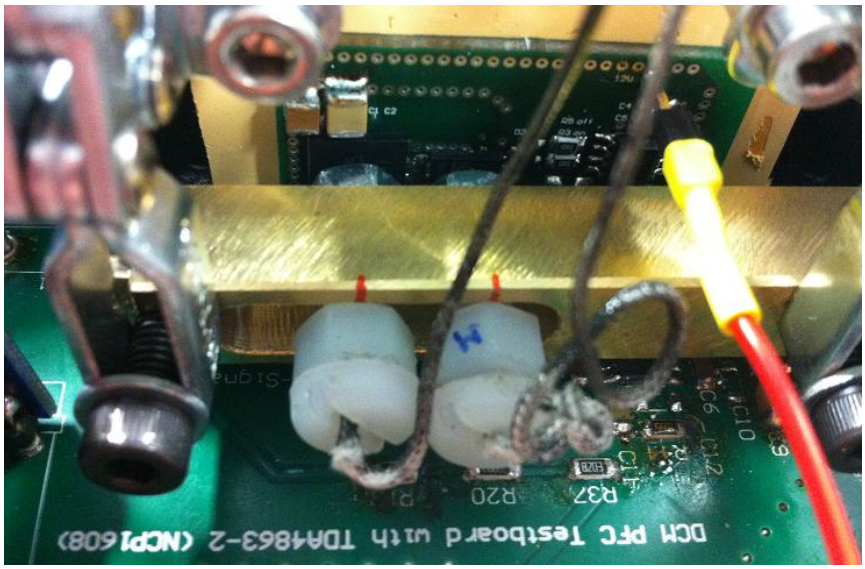


Figure 8: thermo-couples connection to package case in 150W DCM PFC

As from theoretical point of view the efficiency of ThinPAK 5x6 in comparison to DPAK can be on the same level when the thermal behavior of the package is nearly the same due to the usage of the same technology. The following section of this document will describe the resulted efficiency and the thermal difference between ThinPAK 5x6 and DPAK.

5.1.2 Efficiency and thermal performance comparison in 150W DCM PFC

This chapter is going to show the differences between IPL65R650C6S and IPD65R600C6S. The setup characteristics are represented in the following table.

V_{IN}	90 VAC (worst case situation -> thermals are most important for the analysis)
V_{OUT}	400 VDC
$R_{G,ext}$	10 Ω
f_{sw}	variable
heat sink	pre-heated to 60 °C

With this setup the following system efficiency was reached.

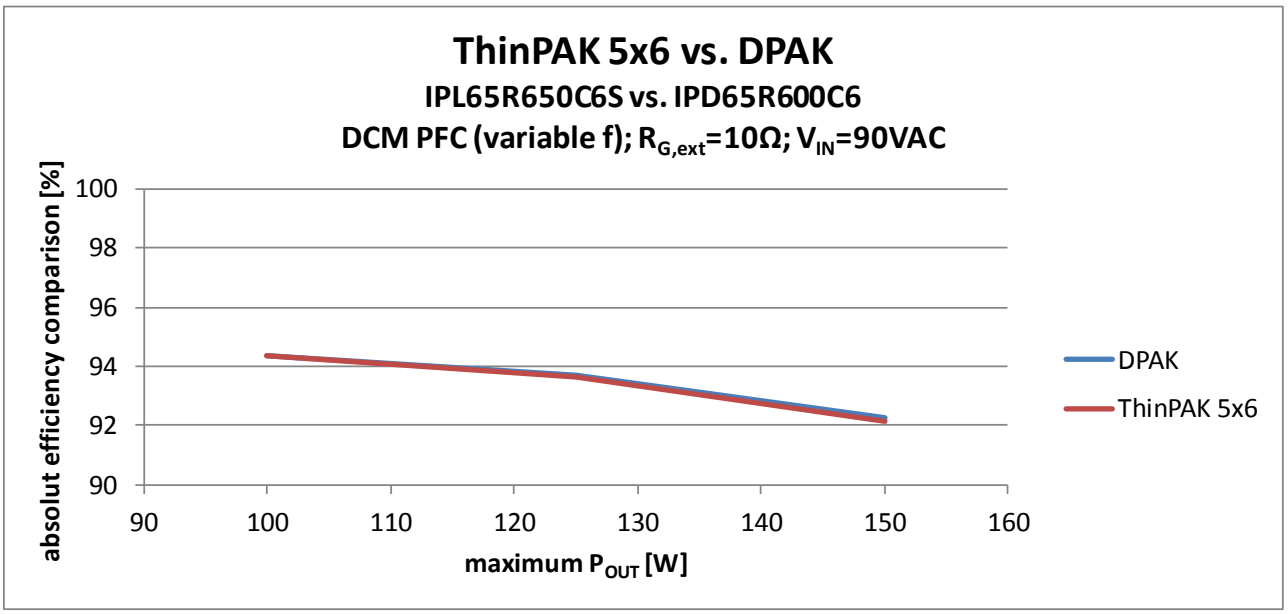


Figure 9: efficiency comparison ThinPAK 5x6 vs. DPAK in 150W DCM PFC

It is clearly visible that the efficiency is within the 0.1% measurement tolerance, which means these two matched devices lead to the same system efficiency over the whole load range.

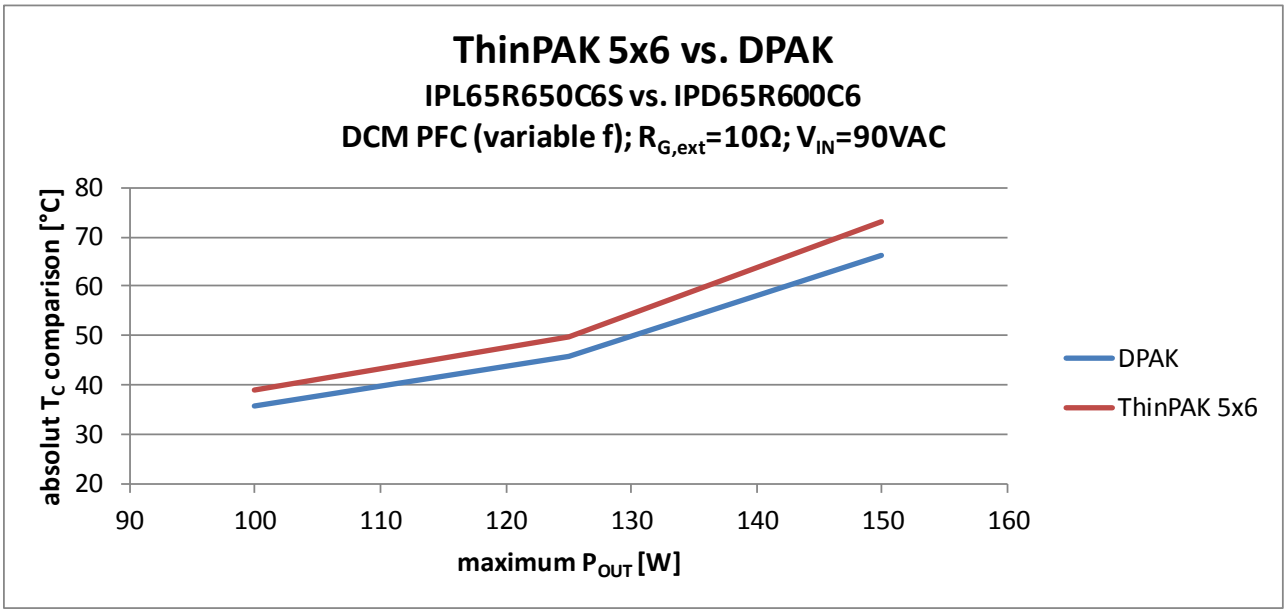


Figure 10: case temperature comparison ThinPAK 5x6 vs. DPAK in 150W DCM PFC

For the thermal behavior the conclusion of this measurement is that ThinPAK 5x6 will have around 3°C – 5°C higher case temperature than DPAK. The following chapters will discuss the usage and performance of ThinPAK 5x6 in lower power adapters for net book applications.

5.2 QR Flyback (35W) – Net Book Adapter

5.2.1 System description

This chapter will show the efficiency comparison and the thermal performance of ThinPAK 5x6 in comparison to DPAK in a 35W quasi resonant flyback converter which is commonly used as adapter for net books. In this case two technologies will be compared.

The adapter looks like in the following figure.

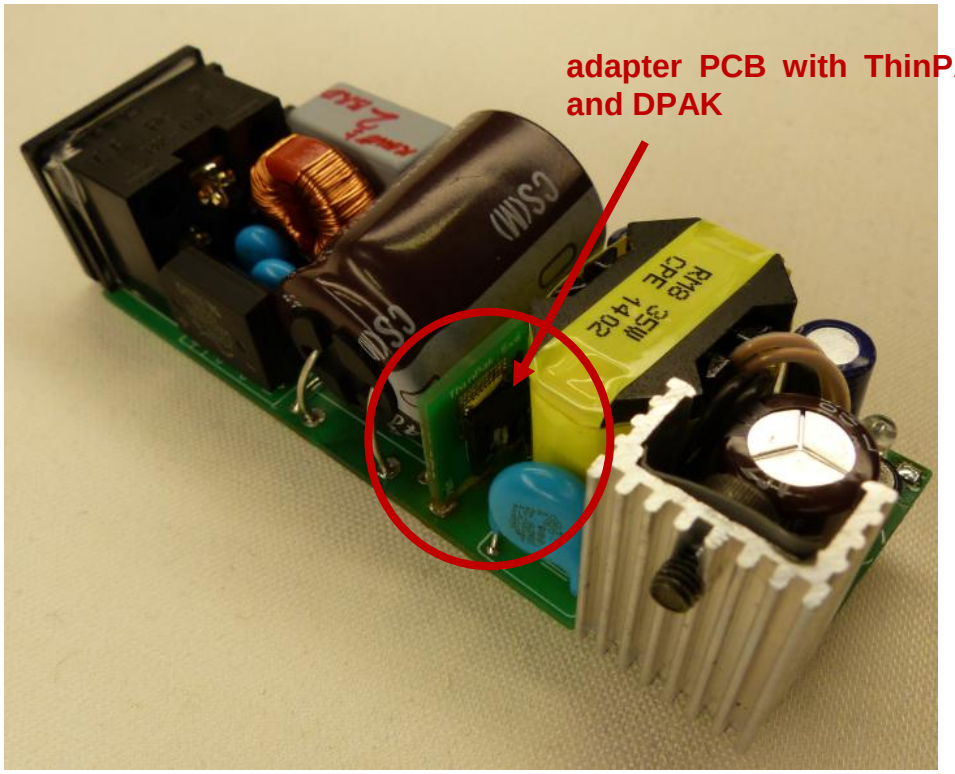


Figure 11: 35W quasi resonant flyback converter for net books

As visible in Figure 11 also here adapter PCBs are used to compare the two packages. The reason for this can be easily explained. In order to have a real comparison of the devices the system needs to be the same all the time. If there is a usage of two main boards with a dedicated footprint for DPAK and ThinPAK 5x6 due to the production tolerances of for example the transformer which has a tolerance of around ±20% this could also influence the system efficiency and could lead to wrong device assumptions. Also in this comparison it is obligatory to eliminate as much as possible unknown variables. Therefore the following adapters were used.

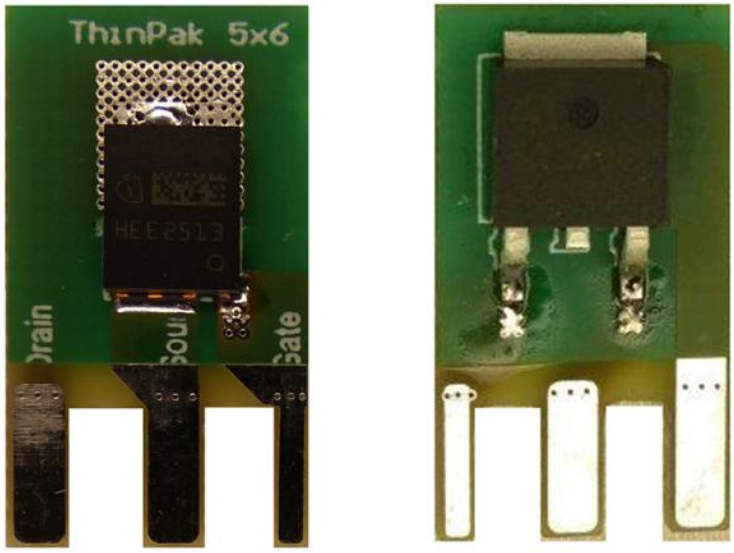


Figure 12: adapter PCBs ThinPAK 5x6 (left) and DPAK (right) for 35W QR flyback

5.2.2 Efficiency and thermal performance comparison 35W QR flyback

As mentioned earlier this measurement will compare two technologies first IPL65R650C6S vs. IPD65R600C6 and second IPL60R600P6S vs. IPD60R600P6 to each other with the following test conditions.

For the efficiency comparison

V_{IN}	90 VAC
V_{OUT}	19 VDC
I_{OUT}	up to 1.85 A
$R_{G,ext}$	10 Ω
f_{sw}	variable

and for the thermal comparison

V_{IN}	115 VAC
V_{OUT}	19 VDC
I_{OUT}	1.85 A
$R_{G,ext}$	10 Ω
dwell time	30 min

The efficiency comparisons of both technologies are represented in the following figures at 25%, 50%, 75% and 100% of the output power.

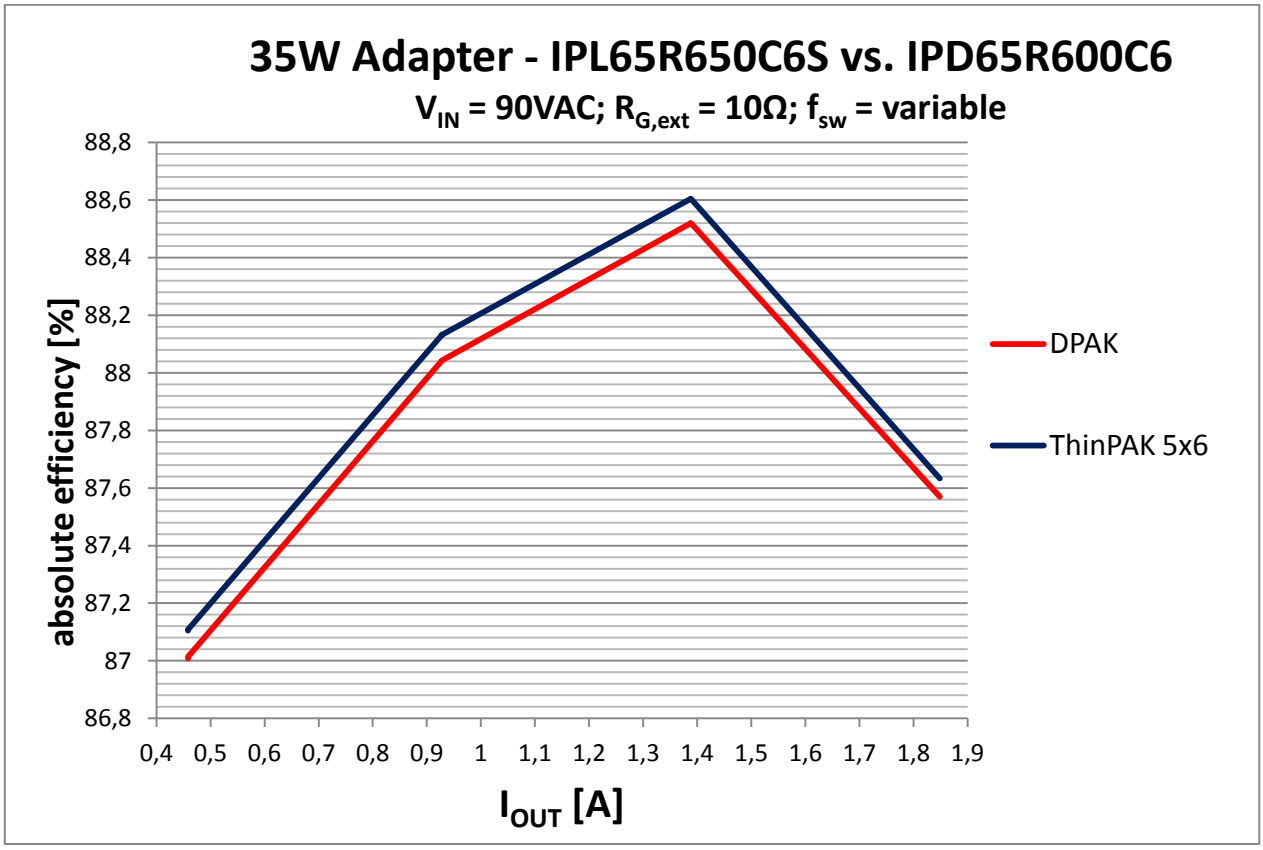


Figure 13: efficiency comparison ThinPAK 5x6 vs. DPAK in 35W QR flyback (C6 technology)

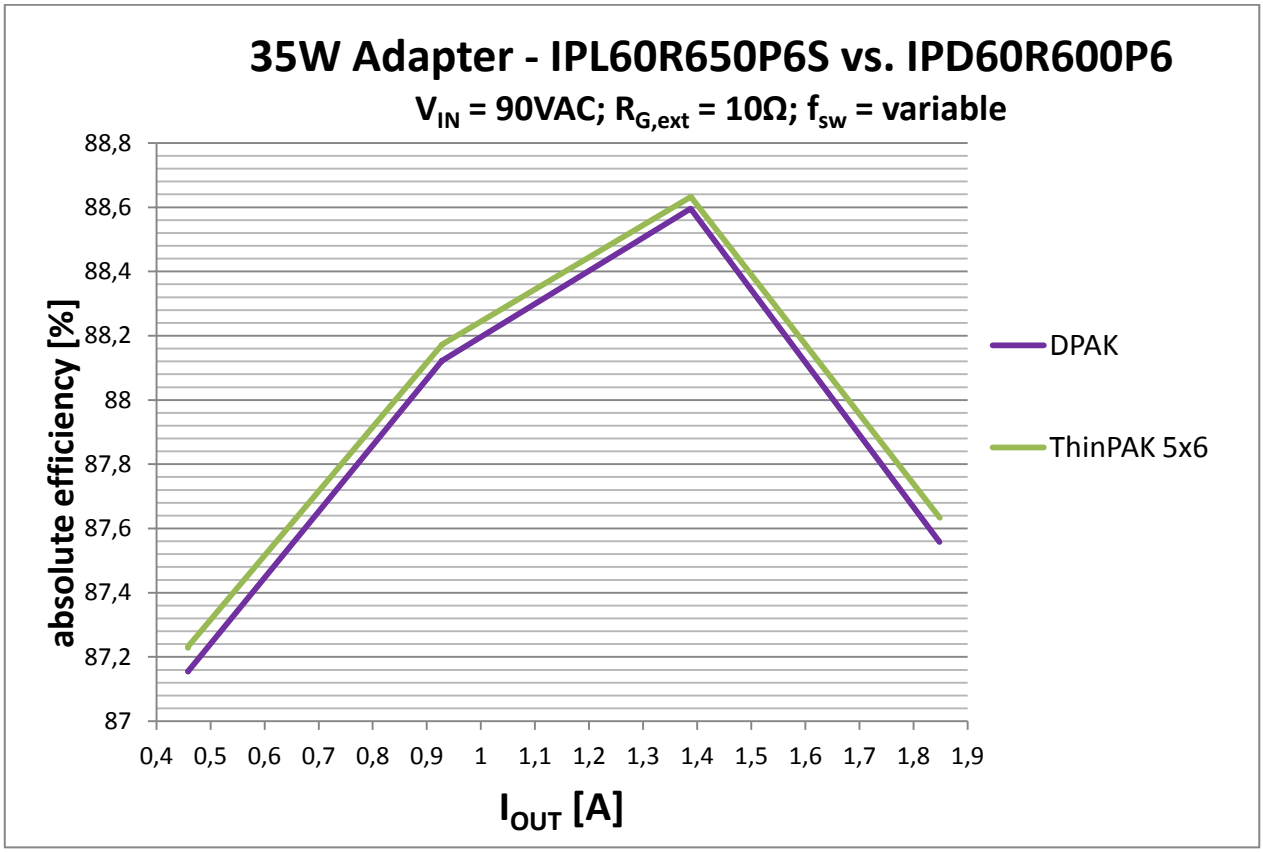


Figure 14: efficiency comparison ThinPAK 5x6 vs. DPAK in 35W QR flyback (P6 technology)

As visible in both diagrams the measurement tolerance stays in between the 0.1% which gives the conclusion that ThinPAK 5x6 gives the same electrical performance as DPAK.

Also in this case the thermal performance needs to be addressed. Therefore the following measurement was realized. It was visible that the temperature on the case of the MOSFET package was already constant after 5 minutes; nevertheless the case temperature for comparison was taken after 30min dwell time.

	IPD60R600P6	IPL60R650P6S
Tcase (°C)	74.2	78.1

	IPD65R600C6	IPL65R650C6S
Tcase (°C)	76.7	79.1

Figure 15: case temperature comparison ThinPAK 5x6 vs. DPAK in QR flyback (C6 and P6 technology)

The temperature difference is nearly the same as mentioned before in the PFC analysis which brings here a case temperature difference of around 3°C – 4°C. Because the thermal behavior of this package is very important the following short section will describe a thermal runaway test with this 35W adapter.

5.2.3 Thermal runaway test

In this test the 35W adapter is placed in a thermal chamber with were the ambient temperature is slowly increased from 25°C to 75°C. In this case also after some runtime of the adapter the MOSFET temperature should not runaway leading to a destruction of the MOSFET and/or the whole system. The following table describes the test conditions and a picture from the test setup including the thermal chamber and the measurement equipment:

V_{IN}	90 VAC
V_{OUT}	19 VDC
I_{OUT}	1.85 A
$R_{G,ext}$	10 Ω
dwell time	30 min
temperature	Ambient temperature is increased from 25°C to 75°C (1°C per minute)

Figure 16: thermal runaway test equipment

There are several possibilities in order to test a thermal runaway, therefore the following two analysis are represented. First of all the temperature over time which is shown in the following diagram.

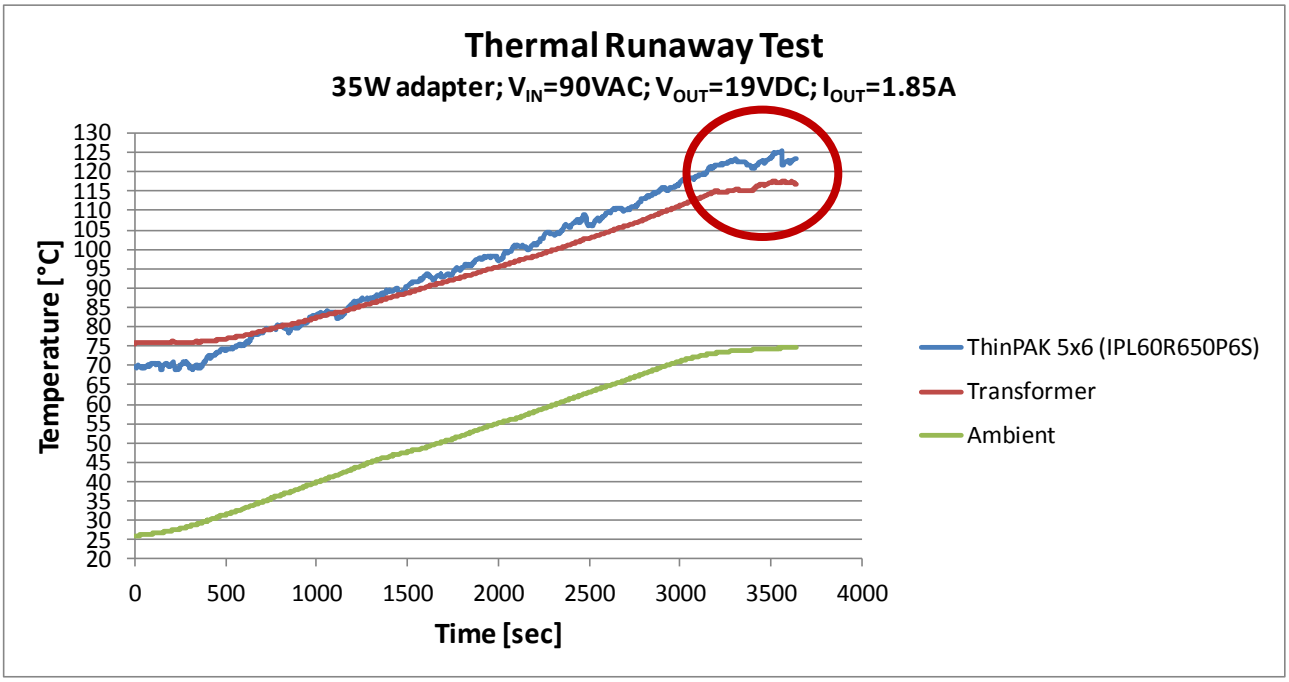


Figure 17: thermal runaway test - temperature over time

It is illustrated that after 75°C ambient temperature is reached the case temperature will stabilize at around 125°C and no additional temperature increase of the MOSFET and transformer is visible. The second way to represent the thermal runaway test is by exemplify the MOSFET and transformer temperature over the ambient temperature.

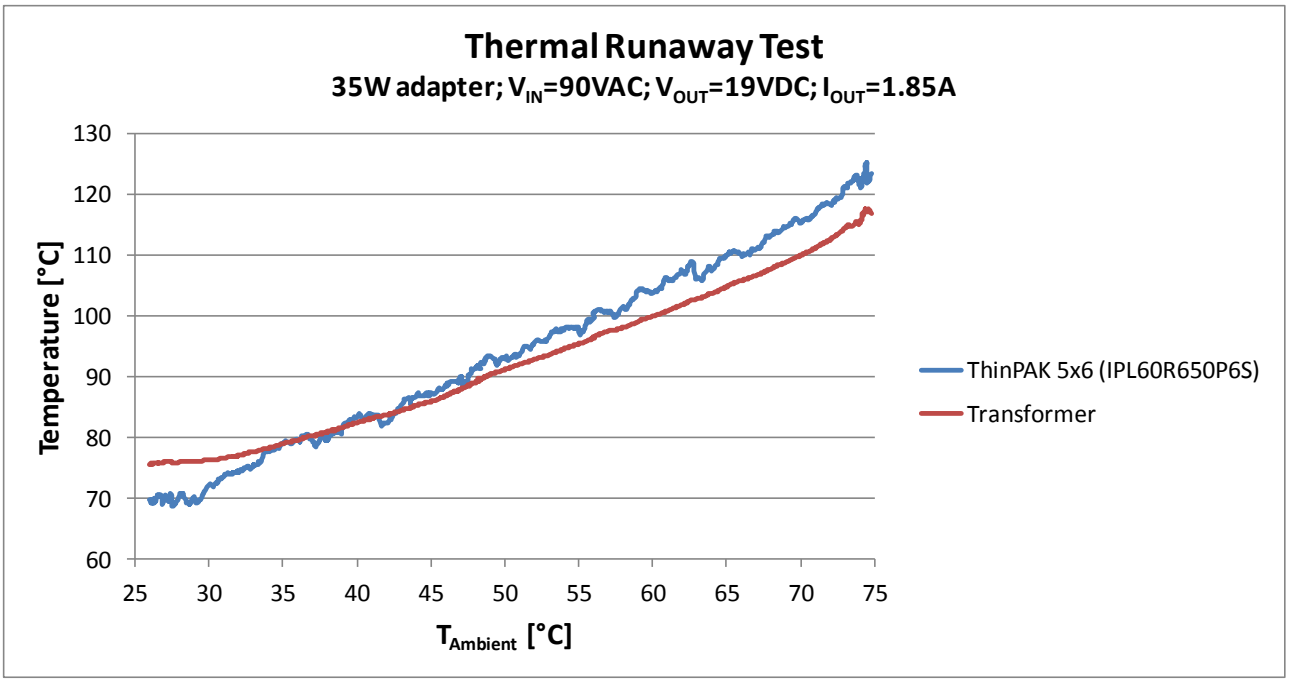


Figure 18: thermal runaway test - MOSFET and transformer temperature over ambient temperature

Figure 18 describes that the temperature of the MOSFET and the transformer are following on average a straight line over the increased ambient temperature. Only the transformer shows a slight exponential factor starting from 70°C ambient temperature which can be an indicator for a thermal runaway and saturation of the transformer. Nevertheless, the used MOSFET is absolutely fitting for these requirements. In order to also see the performance of higher $R_{DS(on)}$ classes is implemented in this document. The next chapter will concentrate on a low power battery charger which can be used as tablet or smart phone charger.

5.3 QR Flyback (10W) – Battery Charger

5.3.1 System description

This charger is a design for tablet and/or smart phones and was realized by Infineon Korea design house KPOS. It is dedicated for using ThinPAK 5x6 which means that in this case only the performance of the IPL65R1K5C6S will be illustrated according to specification limits. These specification limits, especially the case temperature of the MOSFET is needed and limited to 90°C. Another limit is the average efficiency which is set to 80% efficiency average. The design is illustrated in the following figure.

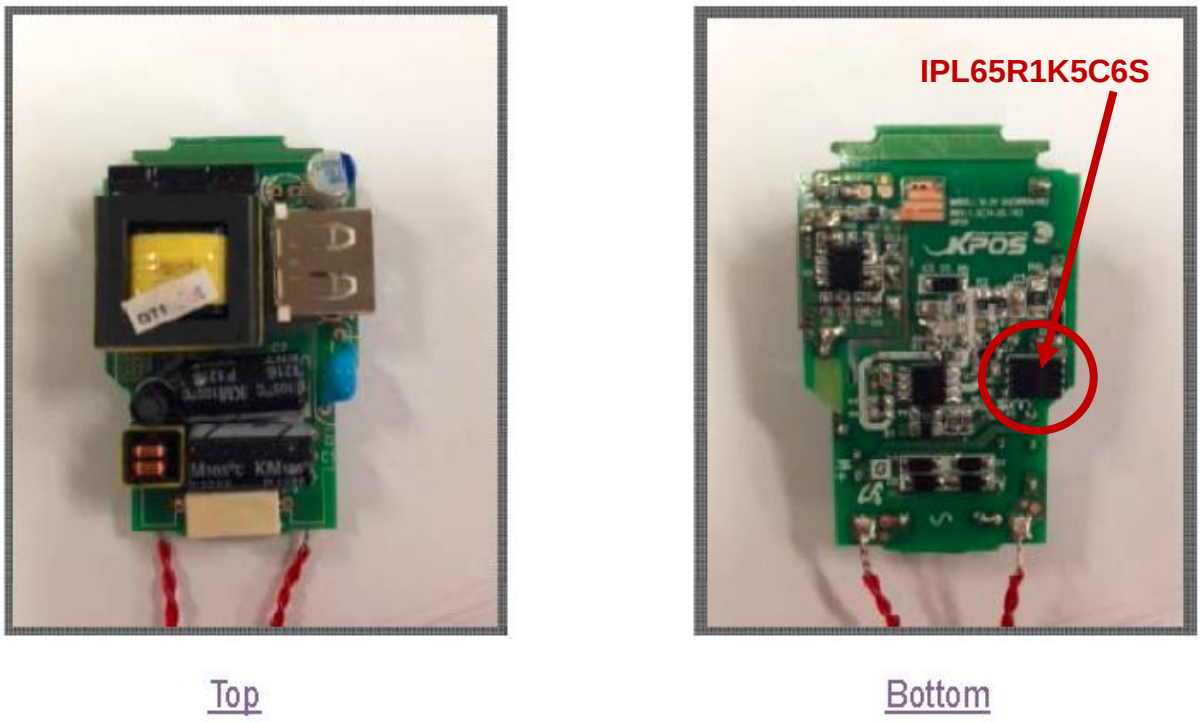


Figure 19: 10W quasi resonant flyback converter for tablet or/and smart phone charger

As visible ThinPAK 5x6 is optimal placed on the back side of the PCB with additional margin to the outer case of the charger. This additional space from case to outer case of the charger reduces a possible hot spot on the outer case.

Design specifications:

Description	Min	Typ	Max	Units	Conditions
Input					
Voltage	85		264	VAC	
Frequency	47	50/60	63	Hz	
No Load Input Power			20	mW	@ 230V 50Hz
Output					
Output Voltage	5.05	5.30	5.55	V	
Output Ripple & Noise Voltage			150	mVp-p	20MHz Bandwidth
Output Current	0		2.0	A	
Over Current Protection			2.5	A	
Output Power (Pno)			10.6	W	
Output Voltage Undershoot	4.3V			V	0A to 2A at 230Vac
Short Circuit Protection	2.0		3,5		HICCUP
Startup Time			1	S	
Efficiency					
Average Efficiency	80			%	At the end Of PCB

Figure 20: general design specifications 10W QR flyback

Now that the design specifications are known the next section directly shows the efficiency measurement and the thermal performance.

5.3.2 Efficiency and thermal performance of IPL65R1K5C6S

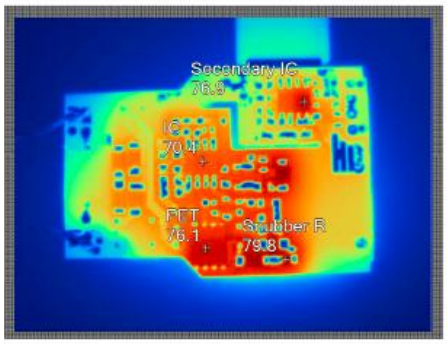
Figure 21 describes the efficiency at different load points, input voltage, output connections and last but not least the average efficiency over the whole load range.

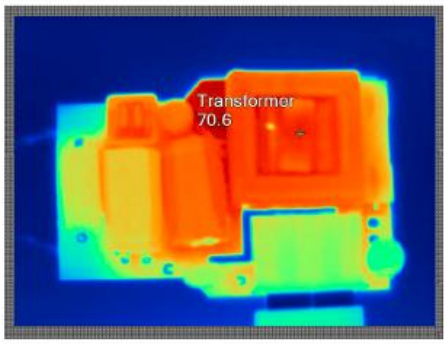
기초특성	입력전압	85V			110V			230V		264V		대기전력		
	0mA	5.271V			5.274V			5.275V		5.276V		230V 50Hz		
	2A (PCB)	5.634V			5.623V			5.634V		5.640V				
	INPUT WATT	13.220W			13.430W			13.170W		13.240W		7mW		
	효율	85.23%			83.74%			85.56%		85.20%				
	RIPPLE	91.0mV			78.0mV			80.0mV		90.0mV				
	OCP	2.194A			2.187A			2.179A		2.174A				
효율 (USB)	INPUT 조건	Load 조건	200mA		500mA		1000mA		1500mA		2000mA		AVE	
	115V 60Hz	입력 Watt	1.28W	85.55%	3.11W	86.27%	6.37W	85.01%	9.77W	84.60%	13.35W	84.31%	85.36%	
		출력 전압	5.475V		5.366V		5.415V		5.510V		5.628V			
	230V 50Hz	입력 Watt	1.34W	80.01%	3.18W	84.36%	6.33W	85.47%	9.68W	85.49%	13.17W	85.57%	85.22%	
		출력 전압	5.361V		5.365V		5.410V		5.517V		5.635V			
효율 (CABLE)	115V 60Hz	입력 Watt	1.28W	84.92%	3.11W	84.66%	6.37W	81.87%	9.77W	79.99%	13.35W	78.32%	81.21%	
		출력 전압	5.435V		5.266V		5.215V		5.210V		5.228V			
	230V 50Hz	입력 Watt	1.34W	79.42%	3.18W	82.78%	6.33W	82.31%	9.68W	80.84%	13.17W	79.50%	81.36%	
		출력 전압	5.321V		5.265V		5.210V		5.217V		5.235V			

Figure 21: efficiency of 10W QR flyback; avarage efficiency (marked in dark red)

It is clearly visible that the average efficiency stays over 80% system efficiency in all test conditions. This makes the ThinPAK 5x6 ideal with respect to space saving and power density even in this low power designs. Especially for designers ThinPAK 5x6 can be the best choice when implementing fully automated production lines which could also improve the price positioning to competitors.

The following analysis will show the case temperature of the MOSFET after 2 hours dwell time at 110VAC and 220VAC input voltage.



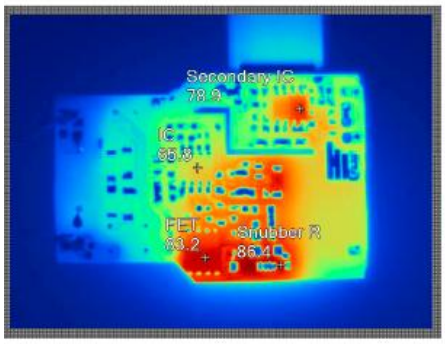


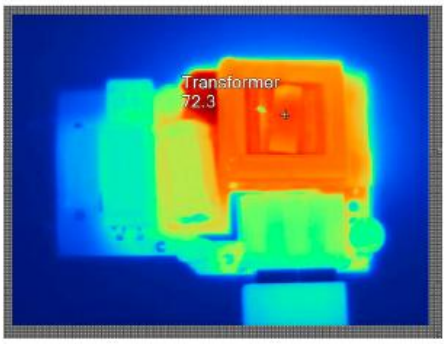
Result	Thermal
IC	70.4 °C
Secondary IC	76.9 °C
FET	76.1 °C
Snubber R	79.8 °C

Result	Thermal
Transformer	70.6 °C

➔ **76.1°C < 90°C specification limit**

Figure 22: thermal performance VIN = 110VAC





Result	Thermal
IC	65.8 °C
Secondary IC	78.9 °C
FET	83.2 °C
Snubber R	86.4 °C

Result	Thermal
Transformer	72.3 °C

➔ **83.2°C < 90°C specification limit**

Figure 23: thermal performance VIN = 220VAC

To conclude on this measurement ThinPAK 5x6 shows the same efficiency as the corresponding IPAK version IPS65R1K4C6 and from thermal performance ThinPAK 5x6 has around 2°C – 4°C higher case temperature (as in all other measurements).

5.4 Ease of use

The “Ease of use” measurement is a qualification measurement for the gate oscillation provoked by high di/dt over the source inductance during the switching phase of the MOSFET. All Infineon datasheets

represent a dynamic switching voltage of ±30V on the gate. The following figure represents such a measurement with a good and a bad example.

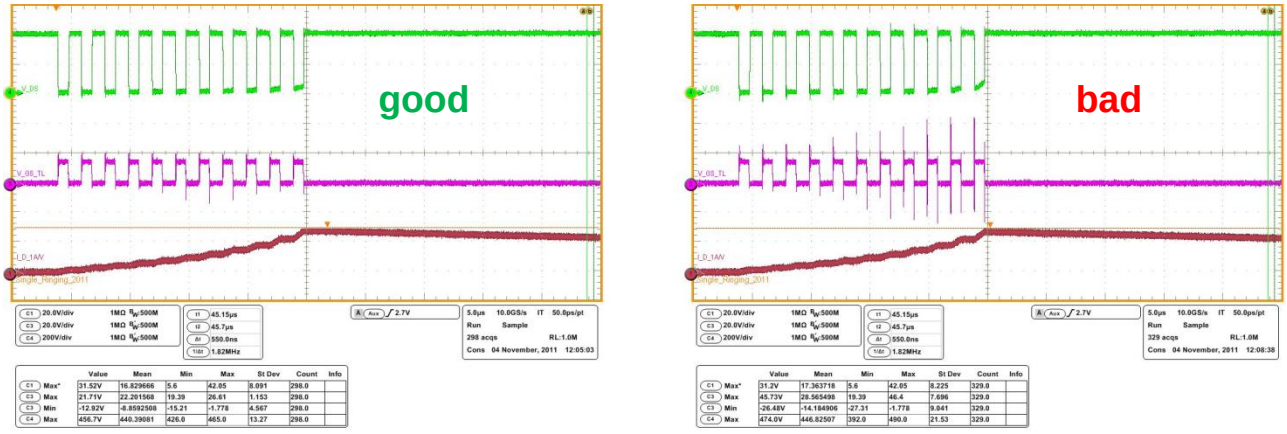


Figure 24: gate oscillation example (V_{DS} ... green; V_{GS} ... magenta; I_{choke} ... dark red)

With this setup it is possible to additionally add parasitic capacitances ($C_{GD,ext}$) in the range of 5pF - 13pF and inductances to the source path of around 7nH. This simulates a not ideal gate drive loop of PCB designs. Infineon wants to deliver the best quality devices available worldwide and therefore such a test is obligatory. The following diagram is going to illustrate the maximum gate source voltage peak depending on the current which is flowing through the MOSFET based on the smallest and biggest chip available in the portfolio.

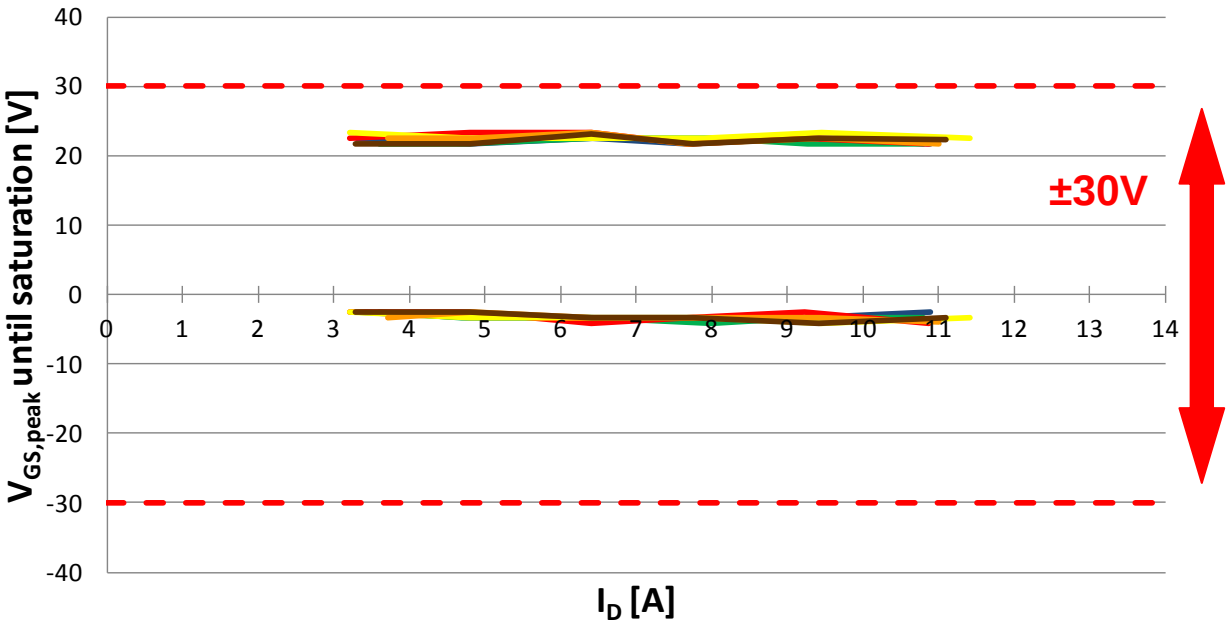


Figure 25: maximum gate voltage peak of IPL60R2K1C6S vs. IPD60R2K0C6 ($R_{G,ext}$=0.5Ω; $C_{GD,ext}$=7.2pF)

The example above shows the comparison between the IPL60R2K1C6S and IPD60R2K0C6 which represents the smallest chip available. It is visible that the maximum voltage peak during turn-ON (positive y-axis) and turn-OFF (negative y-axis). In this case it is shown that ThinPAK 5x6 gives the same “Ease of use” level as DPAK.

The next diagram will compare IPL60R360P6S and IPP60R330P6. In this case the influence of the source inductance of a through the whole device will be dramatically increased.

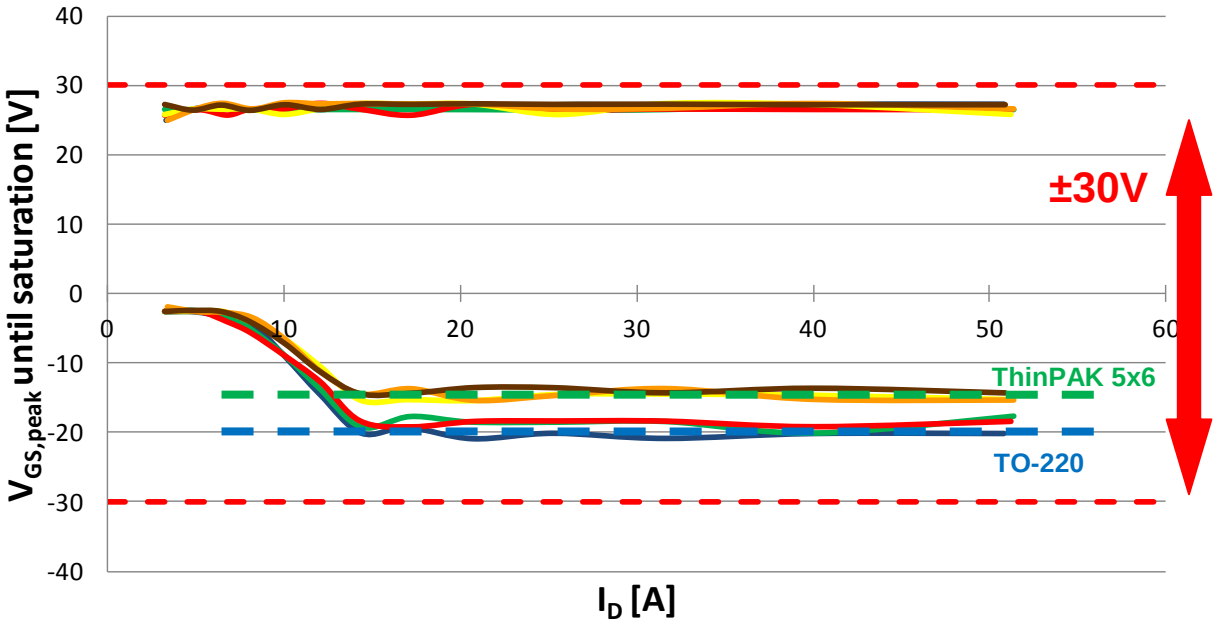


Figure 26: maximum gate voltage peak of IPL60R360P6S vs. IPP60R330P6 ($R_{G,ext}$=0.5Ω; $C_{GD,ext}$=5pF)

As can be seen especially during the turn-OFF the ThinPAK 5x6 shows a maximum voltage peak on the gate which is around 7V lower than the TO-220 version. By the end this could lead to the assumption to decrease the external gate resistor during turn-OFF for the ThinPAK 5x6 to come to the same gate oscillation as the TO-220 package but would by the end result in a higher system efficiency due to the reduction of the E_{off} losses.

This brings us to the end of this document were all the relevant points will be summarized.

6 Summary

ThinPAK 5x6 represents a 2nd generation of surface mounted devices, it is a new package conceived for higher power density in low to mid power ranger. The only 1mm profile of the package makes the device perfect for applications with height restrictions and gives designers the option to place the MOSFET on the backside of the PCB. Another very important factor is the reduction of the internal MOSFET parasitics such as the source inductance which results in an improvement to switching behavior than any other high voltage package done by Infineon Technologies. This effect was visible in the “Ease of use” measurements. One design change must be considered during the design in phase of a project, the gate and source pins are exchanged to each other.

According to the applications measurements ThinPAK 5x6 is a suitable replacement to traditional IPAK and DPAK which has only around 2°C – 5°C higher case temperature but absolutely the same efficiency.