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The Use of QFETs in a Flyback Converter

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Introduction

Power supply designers face many challenges in designing more efficient and cost-effective power supplies. Efficiency is a major consideration in designing switching power supplies. Many factors in the design process such as the input filter capacitance, transformer core geometry and construction, output rectifier, and switching device etc., affect the efficiency of switching power supplies. Among the losses all components generate, switching device losses occupy about 30%. Hence, selecting MOSFETs with optimum efficiency and high reliability is very crucial in power supply design. This application note compares the key characteristics, power losses, and efficiency of the new QFET and a conventional MOSFET in a 60 watt flyback converter operated at 180 to 265 VAC.

QFET Characteristics

Almost all the power supplies used in TVs, VCRs, PCs, fax machines, and other home appliances rely on a switching circuit to convert the AC wall power to DC power or DC to AC. Thus, they are referred to as switched mode power supplies. To obtain high efficiency, it is crucial for designers to select switching MOSFETs to give very low losses in the circuits. MOSFETs must exhibit low conduction and switching losses with safety qualifications. Fairchild Semiconductor, in extending its commitment to develop high quality MOSFETs, now offers new high efficiency QFETs for switched mode power supply applications.

A power QFET, rated at 600V and used in a 60 watt flyback converter, features a gate charge rating which is 45 percent lower than existing devices for improved switching and drive efficiency. Figure 1 compares the new QFET FQP7N60 with its conventional MOSFET counterpart. By using unified singular well stripe technology, the Miller capacitance of the new QFET is reduced by about 40 percent.

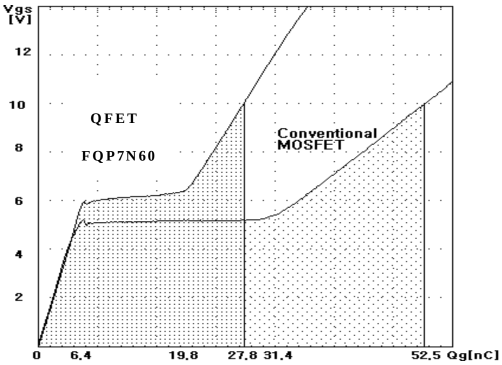

Figure 1: Gate Charge Improvement

Balanced with gate charge improvement, the on-resistance [$R_{ds(on)}$] goes down by about 20 percent with respect to previous devices versus drain current. Figure 2 shows the improvement of on-resistance in a QFET compared with a MOSFET.

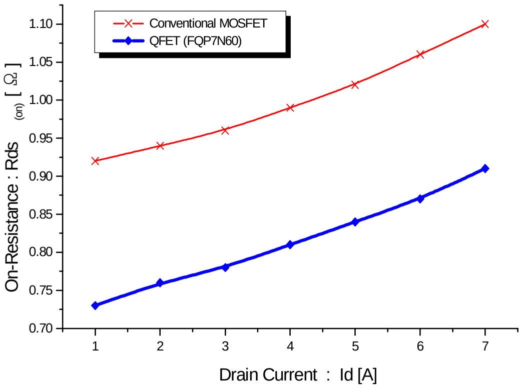

Figure 2: On-resistance Improvement vs. Drain Current

The combined improvement of gate charge and on-resistance in this 60 watt flyback converter leads to a more efficient system because of the reduced turn-off conduction loss. It is worth emphasizing that QFETs offer designers significant improvements in terms of lower overall system cost due to lower gate driver requirements, a smaller heat sink, and narrower PCB. Table 1 illustrates the features which are useful in flyback converters and other applications.

Table 1: Q_g and $R_{ds(on)}$ Improvements

Voltage Rating	Device	On-resistance	Gate Charge	Package
600V	Conventional Part	1.2 Ω	65 nC	TO-220
600V	FQP7N60(QFET)	1.0 Ω	38 nC	TO-220

Performance in a Flyback Converter

Figure 3 shows the design of a commercially available 60 watt flyback converter with two outputs (+160V, +15V), operating at a switching frequency of 80kHz and an input voltage of 220VAC. This type of switching power supply is used for applications, such as monitors, TVs, and miscellaneous instruments, requiring multiple output voltages . This discontinuous mode flyback converter, using a KA3882 current mode controller, features good voltage tracking with the use of pulse by pulse current sensing on the primary side, and an isolated secondary feedback loop. The PWM IC KA3882 directly drives the power MOSFET.

As the power MOSFET sequentially turns on and off, energy is stored in the transformer core during the on time, and is then transferred to the output capacitor during the off time. When the power MOSFET turns off, the energy stored in the leakage inductance causes a voltage spike across the drain-to-source terminal of the power MOSFET, which amounts to at least twice the input voltage (Vin + nVo + leakage inductance voltage[1]). Most applications need clamp circuits to restrict this voltage spike from exceeding the BVdss rating of a MOSFET. A power MOSFET must have high voltage capability with lower on-resistance and smaller gate charge for higher efficiency.

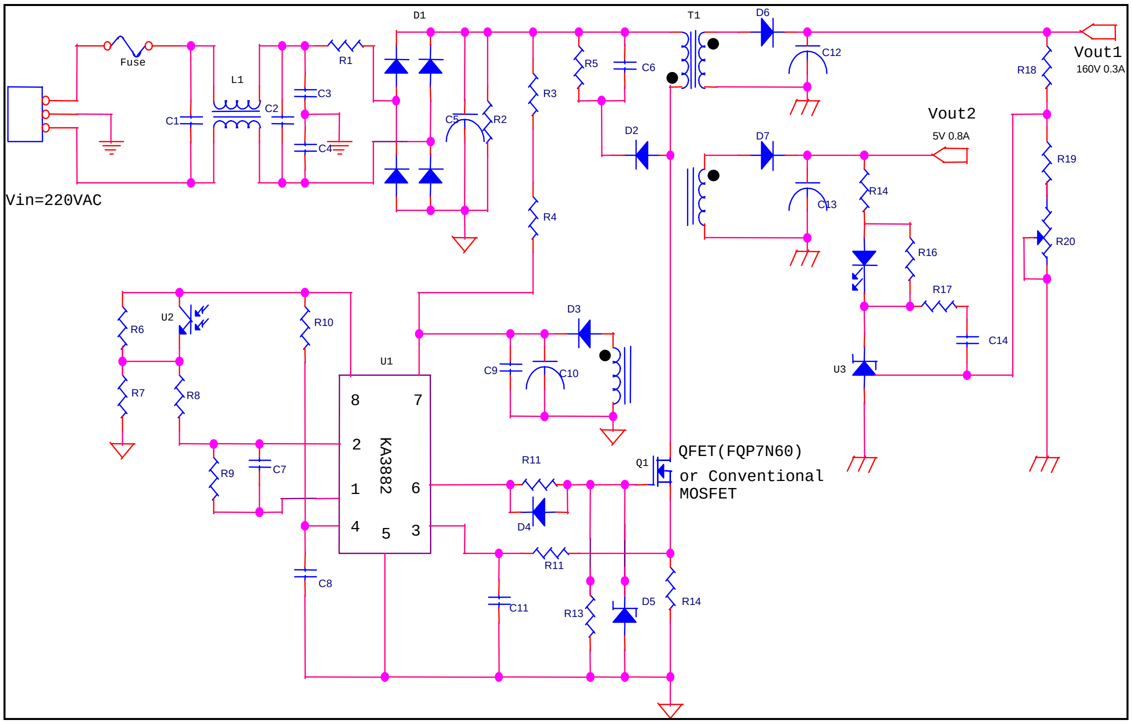

Figure 3: Flyback Converter Circuit Diagram

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[1] *'n' indicates a turns ratio of the transformer windings. The voltage of Vin + nVo + leakage inductance voltage of the transformer appears at the primary side.*

Table 2: Power Supply Specifications

1. Operating mode	:	Flyback Discontinuous Mode
2. Input voltage (V_{in})	:	180 VAC to 265 VAC (50Hz/60Hz)
3. Switching frequency (f_{sw})	:	80 kHz
4. Output voltage (V_{out})	:	A. 160V ± 5% 0.3A B. 15V ± 5% 0.8A
5. Efficiency (η)	:	75%

This flyback converter was tested in rated conditions of 220VAC input voltage, 80kHz switching frequency, and 60W output power.

Figure 4 shows the waveforms for rated operating conditions using the QFET(FQP7N60) as the switching device. The QFET is driven by a gate-source voltage of 15V and the voltage spike across the drain-source terminal is adequately clamped to about 500V by an additional clamp circuit during off-time.

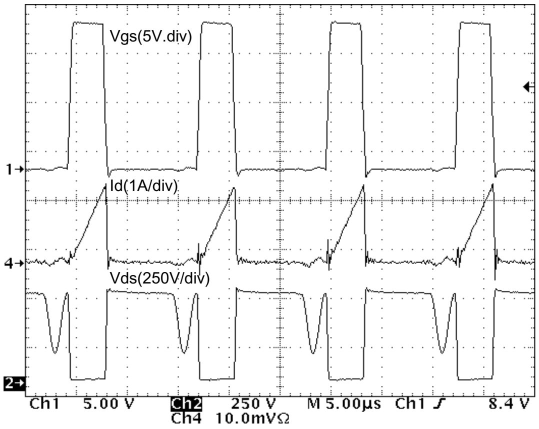


Figure 4: Operating Waveforms at Rated Conditions (V_{in}=220VAC, P_{out}=60W)

Figure 5 compares the waveforms of a conventional MOSFET with the new QFET(FQP7N60) at turn-off without the additional clamped circuit (R5, C6, and D2), and the high conduction diode (D4) for gate discharging (refer to Figure 3).

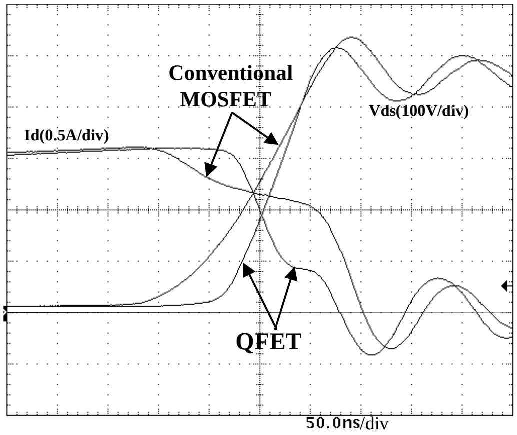


Figure 5: Turn-off Improvement at Rated Conditions (V_{in}=220VAC, P_{out}=60W)

Note that the switching time of the QFET is faster than that of the conventional MOSFET because of the reduction of gate charge by at least 45 percent. Figure 6 shows the difference in turn-off loss between both MOSFETs without clamped circuits and the conduction diode, D4. The turn-on loss in the crossover losses is very small and can be negligible. The turn-off loss period is due to the finite switching time of the MOSFET which is directly related to the gate charge.

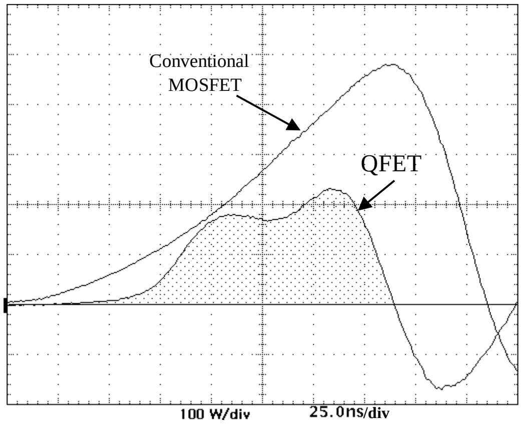


Figure 6: Turn-off Loss Improvement

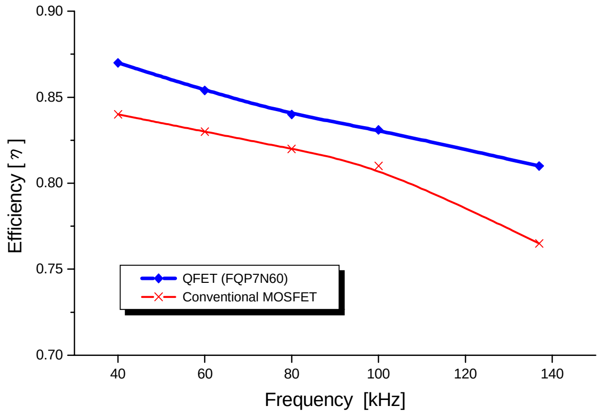


Figure 7: Efficiency vs. Frequency (40~140 kHz, @ V_{in}=220VAC, P_{out}=60W)

The turn-off loss area of QFET(FQP7N60) is half that of of the MOSFET.

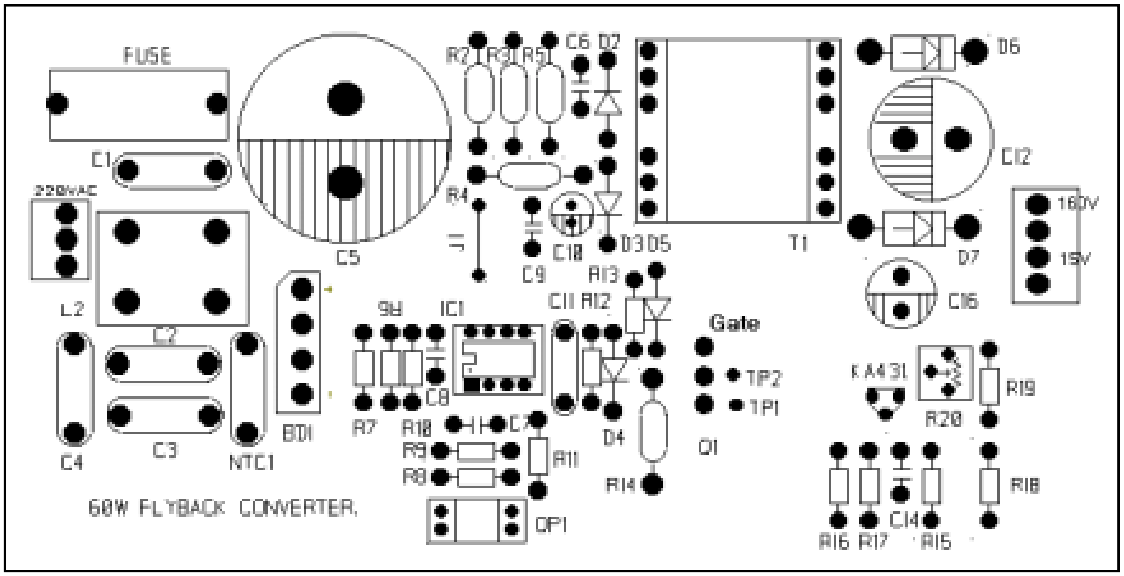
During turn on and off, there is a short period when there is a significant overlap of voltage and current across the MOSFET. Figure 5 shows that the QFET(FQP7N60) has a shorter overlap period than the conventional MOSFET, resulting in a lower loss (Figure 6). In Figure 7 the efficiencies of the converter are calculated without D4 (high conduction diode, refer to Figure 3) operating at rated conditions of 220 VAC input voltage and 60 watt output as a function of frequency. As shown in Figure 7, the QFET (FQP7N60) design is more efficient than its conventional MOSFET counterpart. The advantage of QFET design is more pronounced as the switching frequency of the power supply increases. These waveforms clearly demonstrate that faster switching translates into lower switching loss and much better efficiency.

Summary

To ensure high efficiency and reliable performance of the flyback converter, or any other converter, the designer must ensure that the MOSFET operates effectively with lower on-resistance and gate charge in the system. In this application note, that QFET(FQP7N60) flyback design demonstrates higher efficiency than the previous MOSFET design because of the improvement of on-resistance and gate charge. The other series of Fairchild's QFETs with high voltage ratings (600, 800, and 900 V) allow designers to improve the performance of a switching mode power supply by a significant reduction in gate charge and on-resistance.

Appendix:

A. The printed circuit board layout



B. Parts List

Designator	**Value**	**Designator**	**Value**	**Designator**	**Value**
C1, C2, C3, C4	0.0047 µF	R1	NTC	R19	1.9 kΩ(1/4W)
C5	220 µF	R2	220 kΩ(1W)	R20	500 Ω (variable)
C6	0.0022 µF	R3	220 kΩ(1W)	L1	BSF2125
C7	0.0033 µF	R4	220 kΩ(1W)	T1	Transformer
C8	0.0022 µF	R5	68 kΩ(1W)	U1	KA3882
C9	100 µF	R6	12 kΩ(1/4W)	U2	PC817 (Photocoupler)
C10	10 nF	R7	2.7 kΩ(1/4W)	U3	KA431
C11	560 pF	R8	100 kΩ(1/4W)	Q1	FQP7N60
C12	33µF	R9	100 kΩ(1/4W)		
C13	1000 µF	R10	9 kΩ(1/4W)		
C14	10 nF	R11	50 kΩ(1/4W)		
D1	Bridge Diode	R12	1 kΩ(1/4W)		
D2	1N4937	R13	100 kΩ(1/4W)		
D3	1N4937	R14	0.5 kΩ(1W)		
D4	1N4148	R15	5 kΩ(1/4W)		
D5	1N4744	R16	1 kΩ(1/4W)		
D6	FR304	R17	33 kΩ(1/4W)		
D7	UF5404	R18	120 kΩ(1/4W)		

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