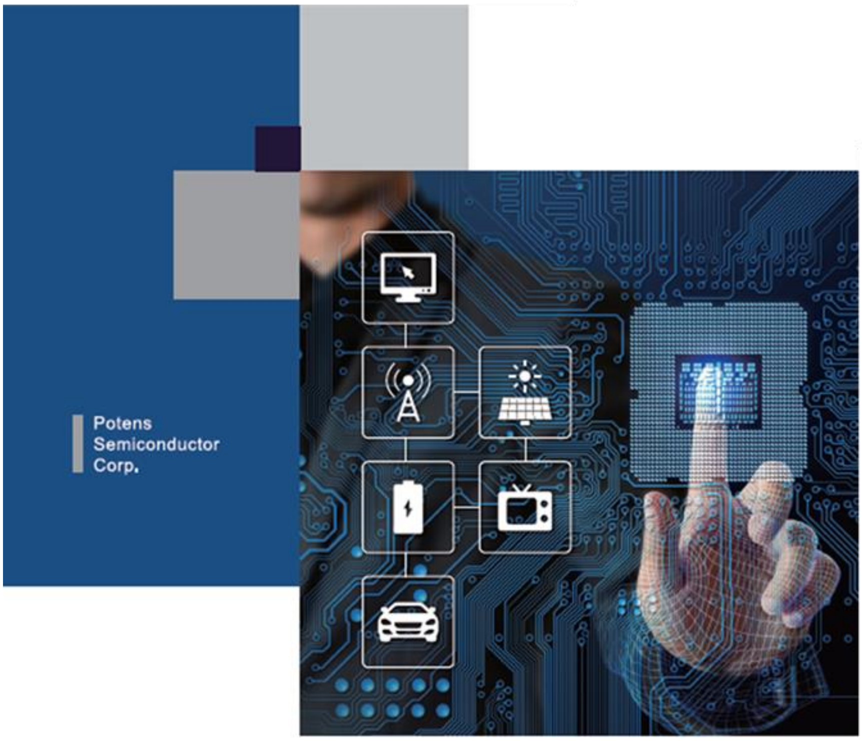
Application Information

Gate Drive Selection and Design



Enhancing everyday life

The driving of the power MOSFET is related to the switching speed of the turn-on/off and the EMI performance in the switching power supply design. It need to be consider the characteristic of the MOSFET and the capability of the gate driver at the same time. The equivalent model of the MOSFET is shown in Fig. 1. The input capacitance is

$$C_{iss} = C_{gs} + C_{gd} \tag{1}$$

The output capacitance is

$$C_{oss} = C_{ds} + C_{gd} \tag{2}$$

The reverse transfer capacitance is

$$C_{rss} = C_{gd} \tag{3}$$

where C_{gs} is the capacitance between gate and source. C_{gd} is the capacitance between gate and drain. C_{ds} is the capacitance between drain and source. R_g is the internal gate resistor.

In general, we put the external resistor R_{g_ext} to change the switching speed for efficiency or EMI optimization in the gate drive circuit. Fig. 2 shows that the gate drive circuit. V_{GS} is the external gate drive voltage. V_{gs} is the gate source voltage. Fig. 3 is the gate drive voltage, the drain current and the drain source voltage while the turn on transition. The threshold voltage transition is from $V_{GS} = 0$ to $V_{GS} = V_{th}$. Then, the t_1 transition time is as

$$t_1 = (R_{g_{ext}} + R_g) \times C_{iss} \times ln\left(\frac{1}{1-\frac{V_{th}}{V_{GS}}}\right) \tag{4}$$

The plateau voltage transition is from $V_{GS} = 0$ to $V_{GS} = V_{pl}$. Then, the t_2 transition time is as

$$t_2 = (R_{g_{ext}} + R_g) \times C_{iss} \times ln\left(\frac{1}{1-\frac{V_{pl}}{V_{GS}}}\right) \tag{5}$$

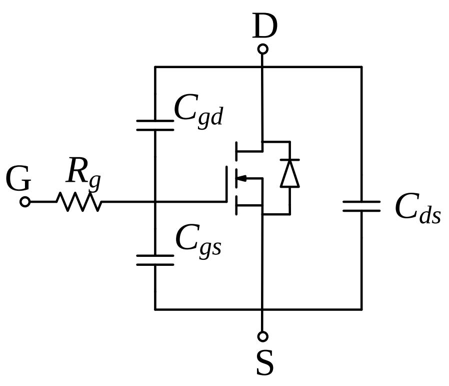


Fig. 1 The equivalent model of the MOSFET

The t_3 transition is for $V_{GS} = V_{pl}$. Then, the transition time is as

$$t_3 = (R_{g_{ext}} + R_g) \times C_{iss} \times \frac{V_{DS}}{V_{GS} - V_{pl}} \tag{6}$$

The rise time when the MOSFET switches on is related to the input capacitance or the gate charge. The gate charge can be expressed as

$$Q_g = I_g \times t \tag{7}$$

From the gate drive circuit loop in Fig.1, we can derive the gate current as

$$I_g = \frac{V_{GS} - V_{gs}}{R_{g\_ext} + R_g} \tag{8}$$

Substitute the equation (8) into the equation (7) then the rise time is derived as

$$t = \frac{Q_g}{\frac{V_{GS} - V_{gs}}{R_{g\_ext} + R_g}} \tag{9}$$

$$= \frac{1}{V_{GS} - V_{gs}} \times Q_g \times (R_{g\_ext} + R_g) \tag{10}$$

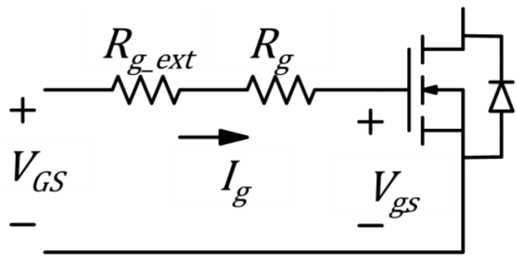


Fig. 1 The gate drive circuit.

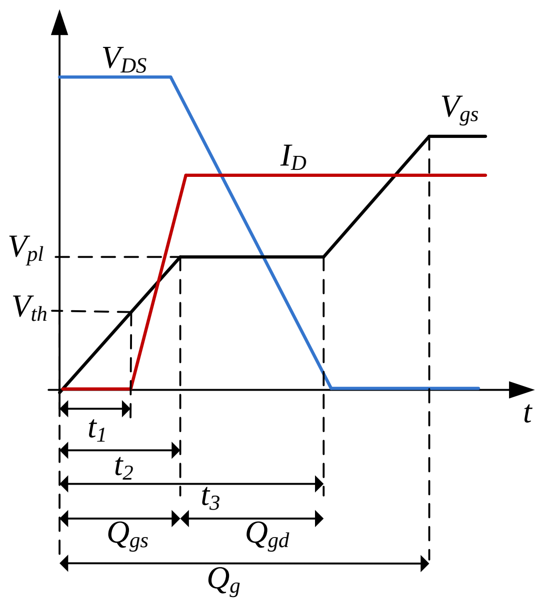


Fig. 2 The turn on transition of the MOSFET.

From the above calculation, we can conclude that the rise time is related to the product of Q_g and $R_{g\text{-}ext}$+R_g. Take the SR MOSFET on the 2nd side of Flyback circuit as an example. The power loss can be derived as

$$P_{loss} = I_{srms}{}^2 \times R_{dson} + Q_g \times V_{cc} \times f_s + I_d \times V_f \times t_d \times f_s + \frac{1}{2} \times I_{spk} \times \left(\frac{V_{in}}{n} + V_{o1}\right) \times t_r \times f_s + I_g{}^2 \times (R_{g\_ext} + R_g) \quad (11)$$

The summary of the key parameters and the power loss for Potens' Products PDEC69F0BBZ-5 and PDC6988Z-5 is shown as Table I. Although there is a big difference between the internal gate resistors of these two parts, the power losses are very close for this charger circuit application and EMI solution with $R_{g\_ext} = 100\Omega$. By using the equation (10), the rise time of these two parts can be summarized as Table II. The rise time can be expressed by Q_g and $R_{g\text{-}ext}$+R_g. Therefore, the rise time of these two examples is close. Fig. 3 shows the rise time of PDEC69F0BZ-5 and PDC6988Z-5. The channel 1 is V_{GS} waveform, the channel 2 is V_{gs} waveform and the channel 3 is V_{DS} waveform. On the contrary, the fall time can also be derived by the same analysis.

Table I The summary of the key parameters and the power loss

Parametres	PDEC69F0BZ-5	PDC6988Z-5
Rdson(mΩ)	18.24	24.2
Qg(nC)	6.6	10.6
td(μs)	46.78	38.28
tr(μs)	32.03	46.1
Rg(Ω)	95.6	0.9
Rg_ext(Ω)	100	
Ig(uA)	1	
Isrms(A)	3.5	
Vcc(V)	5	
fs(kHz)	57	
Id(A)	2	
Vf(V)	1	
Ispk(A)	12	
Vin(V)	110	
n (turn ratio)	14	
Vo1(V)	5	
Power loss(W)	0.15	0.21

Table II The rise time of the MOSFETs

Parametres	PDEC69F0BZ-5	PDC6988Z-5
Qg(nC)	6.6	10.6
Rg(Ω)	95.6	0.9
Rg_ext(Ω)	100	
Rise time(ns)	$1290 \times (V_{GS} - V_{gs})$	$1070 \times (V_{GS} - V_{gs})$

Test condition: Input: 110V/60Hz Output: 5V/2A

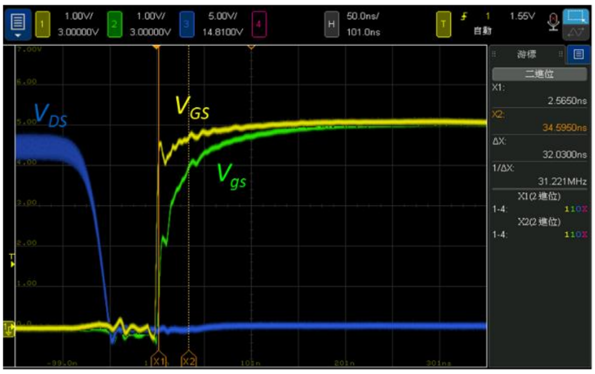
PDEC69F0BZ-5	PDC6988Z-5
	

Fig. 3 The turn on waveforms of the MOSFET.

Reference

[1] Potens Semiconductor, “65V N-channel MOSFET,” PDC6988Z-5 datasheet. https://www.potens-semi.com/upload/product/PDC6988Z-5.pdf.