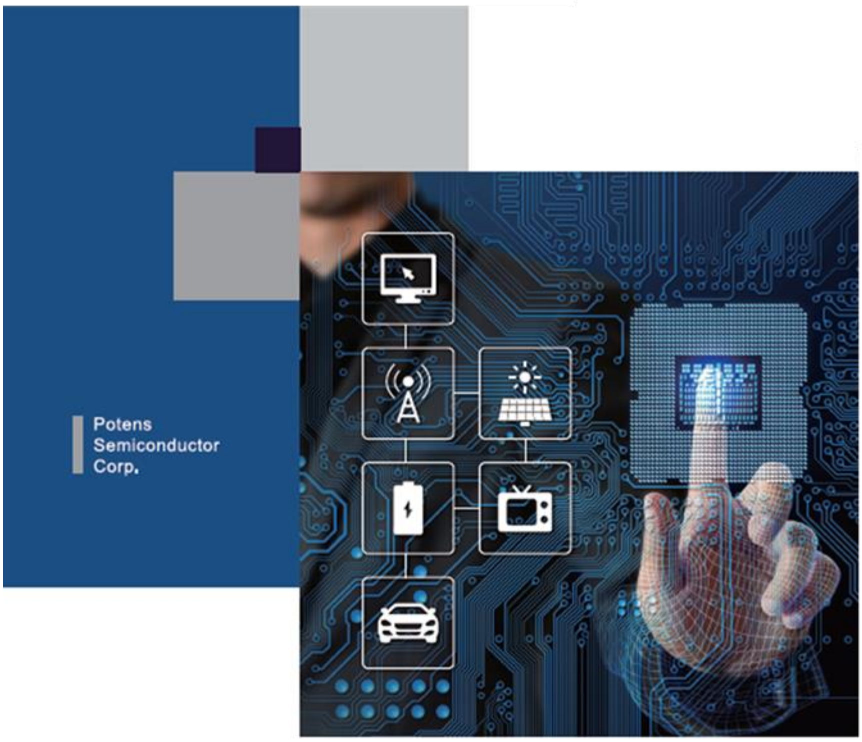
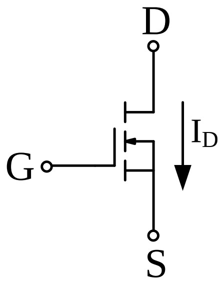
Application Information

Application for Gate Drive Operation

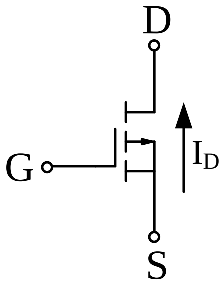


Enhancing everyday life

The MOSFET is a semiconductor device widely used for switching purposes. The main principle of the MOSFET is to control the current and voltage through the drain and source pins. It works as a switch and the gate voltage controls the operation of the MOSFET. In N-channel MOSFET, positive voltage can be applied on the gate for turning on and negative voltage for turning off. In P-channel MOSFET, negative voltage can be applied on the gate for turning on and positive voltage for turning off. Fig. 1 shows the symbols of the MOSFET.



(a) N-channel MOSFET



(b) P-channel MOSFET

Fig. 1 The symbols of the MOSFET

The switching speed of the turn-on/off is related the parasitic capacitance of the MOSFET and gate driving circuit. The basic driving circuit is shown as Fig. 2. The resistor R_{gs} is to make the gate-source voltage down to 0 V while the gate-source voltage is open. Therefore, we recommend placing 10kΩ~100kΩ resistor for reducing malfunction of the switch. The resistors R_{g_ext} and R_g and the input capacitance would affect the switching speed and the switching loss. For external R_{g_ext} selection to reduce switching loss, the following equation is recommended for the setting of V_{gs} rise/fall time by 5 time constants:

$$t_{rise/fall} = 5 \times (R_{g\_ext} + R_g) \times C_{iss} \tag{1}$$

Where C_{iss} is the input capacitance. R_g is the internal gate resistor. R_{g_ext} is the external resistor to change the switching speed for efficiency or EMI optimization in the gate drive circuit. From Potens' experience, we choose:

$$\frac{t_{period}}{t_{rise/fall}} \geq 50 \tag{2}$$

Where t_{period} is the period (cycle duration). The relation of the period and the switching frequency f_s is :

$$t_{period} = \frac{1}{f_s} \tag{3}$$

From equation (1) to (3), R_{g_ext} can be expressed as below:

$$R_{g\_ext} \leq \frac{1}{250 \times f_s \times C_{iss}} - R_g \tag{4}$$

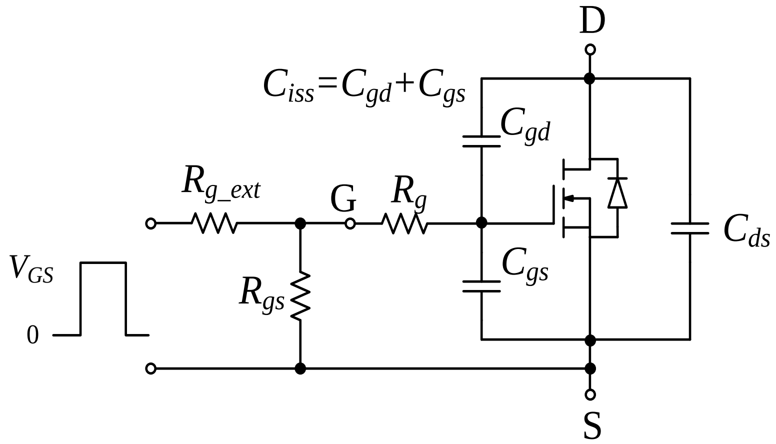


Fig. 2 The basic gate drive circuit.

Table I. Main Electrical Characteristics of PDC6986BZ-5

Dynamic and switching Characteristics

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
C_{iss}	Input Capacitance	V_{DS}=30V, V_{GS}=0V, f=1MHz		820	1600	pF
R_g	Gate Resistance	V_{GS}=0V, V_{DS}=0V, f=1MHz	---	1	---	Ω

For example, the switching frequency of the circuit is 400kHz. The switching device PDC6986BZ-5 is applied in the circuit and the main parameter is shown in table I. The suggestion for R_{g_ext} can be easily obtained

$$R_{g\_ext} \leq \frac{1}{250 \times 400k \times 820p} - 1 \quad (5)$$

$$\Rightarrow R_{g\_ext} \leq 11$$

Potens' suggestion is that choosing 10Ω for R_{g_ext} in this driving circuit.

The gate threshold voltage is another key parameter for the gate driving. It is the lowest V_{GS} at which a specified small amount of I_D flows. For the voltage applied to the gate, refer to the test condition voltage for drain-source on-state resistance in the datasheet. Therefore, our recommendation is that the gate driving voltage from the protection IC or general purpose I/O of MCU should be 1.5~2 times higher than the maximum gate threshold voltage to ensure that the MOSFET is operating in the linear/ohmic region. For example, there is a LED driver that the supply voltage of GPIO is 1.8V and the MOSFET (PDEN69A8S) is driven by this GPIO to turn on/off the LED. This circuit is shown in Fig. 3. Then we check the gate driving is suitable for this circuit by using superposition theorem in Fig. 4(a) and assume that $I_{gss} = 0.1\mu A$. First, find the current flowing through R_{g_ext}. Let us find the current flowing through a circuit by considering only the voltage source. The current source can be open-circuited, hence, the modified circuit diagram is shown in Fig.

4(b). The current flowing through R_{g_ext} can be found using the following equation:

$$I_{g1} = \frac{1.8\text{V}}{10k+100k} = 16.4\mu\text{A} \tag{6}$$

Now let us find out the current flowing through R_{g_ext} considering only the current source. We eliminate the voltage source by short-circuiting it. The modified circuit, therefore, is given as Fig. 4(c). The current flowing through R_{g_ext} can be determined using the current division principle.

$$I_{g2} = 0.1\mu\text{A} \times \frac{100k}{10k+100k} = 0.09\mu\text{A} \tag{7}$$

The summation of currents I_{g1} and I_{g2} will give us the current flowing through R_{g_ext}. Mathematically, this is represented as follows:

$$I_g = I_{g1} + I_{g2} = 16.49\mu\text{A} \tag{8}$$

Then the gate driving voltage can be expressed as:

$$V_{gs} = V_{GPIO} - I_g \times R_{g\_ext} = 1.8\text{V} - 16.49\mu\text{A} \times 10k = 1.635\text{V} \tag{9}$$

And we check the typical gate threshold voltage of PDEN69A8S is 1.8V and is larger than V_{gs}. Therefore, it would cause the brightness of LED is dimmed due to the low V_{GPIO} and the R_{g_ext} voltage drop would cause the MOSFET can NOT operate in suitable area. For power tool, BMS and motor applications, we suggest using high gate threshold type MOSFET to reduce noise interference from high speed switching.

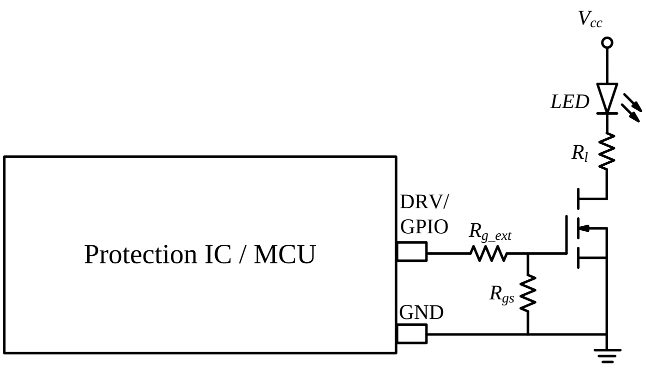
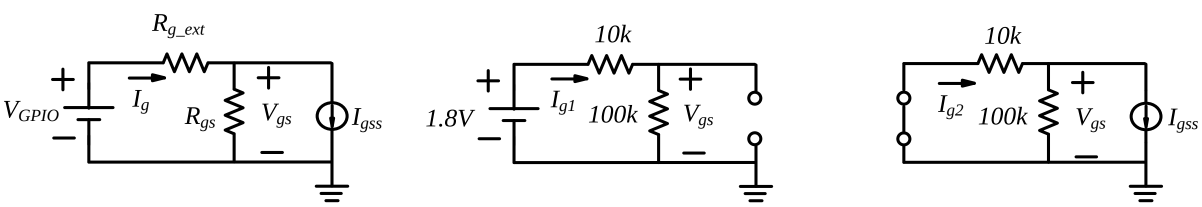


Fig. 3 The gate drive circuit for LED.



(a) the equivalent circuit (b) current source with open circuit (c) voltage source with short circuit

Fig. 4 the gate driving circuit using superposition theorem

Reference

[1] Potens Semiconductor, “65V N-channel MOSFET,” PDC6986BZ-5 datasheet. https://www.potens-semi.com/upload/product/PDC6986BZ-5.pdf.

[2] Potens Semiconductor, “60V N-channel MOSFET,” PDEN69A8S datasheet. https://www.potens-semi.com/upload/product/PDEN69A8S.pdf.