MOSFET

MOSFET Gate Drive Current Setting for Motor Application

Introduction

This document describes how to decide a gate drive current in motor application.
Gate driver and pre-driver which can be selected gate drive current are controlled sink and source current individually.
The gate drive current should be decided by and the required output switching time, peripheral parts, electrical characteristics of the MOSFET.
The document shows the behavior of MOSFET with in/out current flow on half-bridge topology driving. Then, gate drive current of high/low side is derived based on the required output switching time theoretically.

Application

All types of motor application with half-bridge topology. Three phase motor driving, H-bridge motor driving.

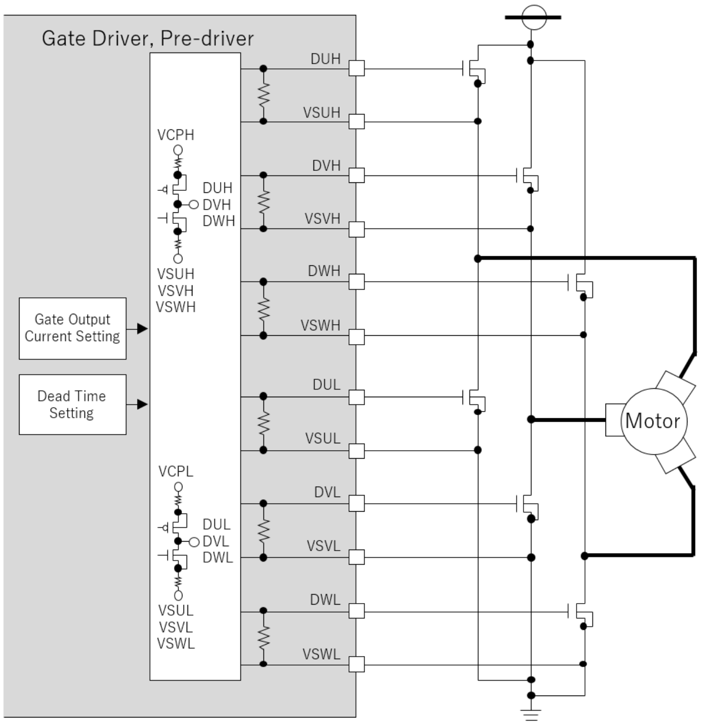

Figure 1. Motor application example:

Gate driver with constant-current gate drive for external MOSFET

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Basic MOSFET operation in a half-bridge circuit when driving a motor

In case the MOSFET flows current into the motor coil by PWM operation

① High side MOSFET Q1 turns on.
Q1 supplies the motor current Io.
The voltage at the output OUT rises to the supply voltage VM - Ron･Io. Q1 continues to supply Io.

②High side MOSFET Q1 turns off. To prevent shoot-through, there is a time to turn off the high side and low side MOSFETs at the same time.
Motor coil tries to keep Io flowing.
OUT voltage falls and the motor current Io continues to flow through the parasitic diode of the low side MOSFET Q2, which is turned off.

③Low side MOSFET Q2 turns on. The motor current Io flows through the turned-on Q2.

④Low side MOSFET Q2 turns off.
To prevent shoot-through, there is a time to turn off the high side and low side MOSFETs at the same time.
Motor current Io continues to flow through the parasitic diode of the low side MOSFET Q2

Operation returns to ①.

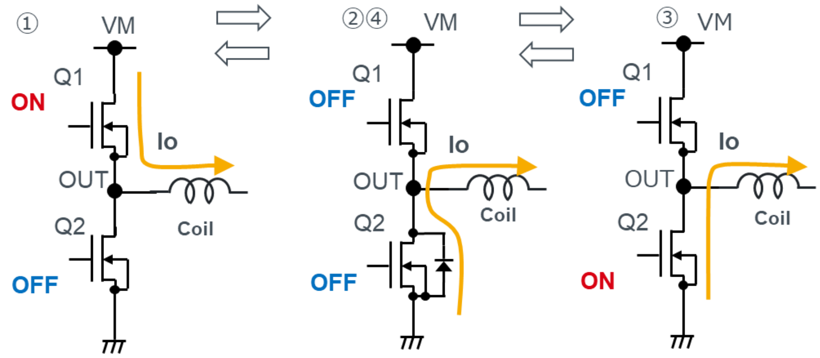

Figure 2. MOSFET operation of half-bridge circuit for coil drive during current into the motor coil.

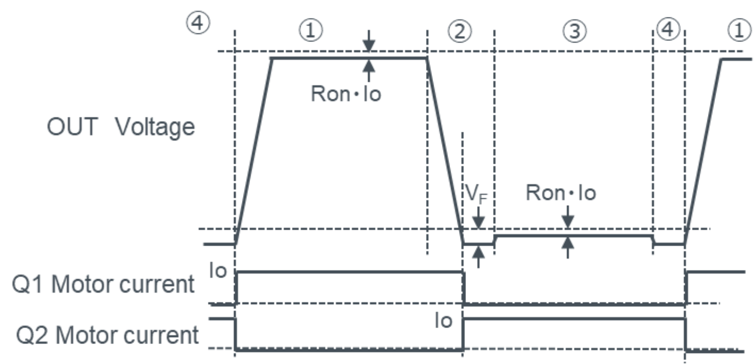

Figure 3. Half-bridge coil drive waveform during current into the motor coil.

In case the MOSFET flows current out of the motor coil by PWM operation

⑤Low side MOSFET Q2 turns on.
Q2 supplies the motor current Io.
The voltage at the output OUT falls to Ron･Io.
Q2 continues to supply Io.

⑥Low side MOSFET Q2 turns off. To prevent shoot-through, there is a time to turn off the high side and low side MOSFETs at the same time.
Motor coil tries to keep Io flowing.
OUT voltage rises and the motor current Io continues to flow through the parasitic diode of the high side MOSFET Q1, which is turned off.

⑦High side MOSFET Q1 turns on. The motor current Io flows through the turned-on Q1.

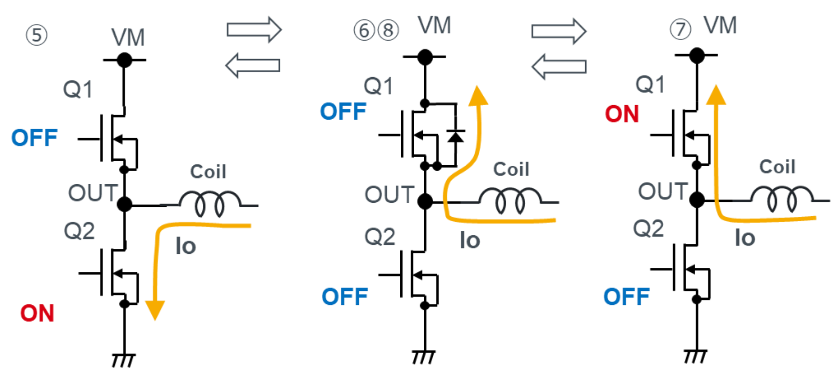

Figure 4. MOSFET operation of half-bridge circuit for coil drive during current out of the motor

⑧High side MOSFET Q1 turns off.
To prevent shoot-through, there is a time to turn off the high side and low side MOSFETs at the same time. Motor current Io continues to flow through the parasitic diode of the high side MOSFET Q1
Operation returns to ⑤.

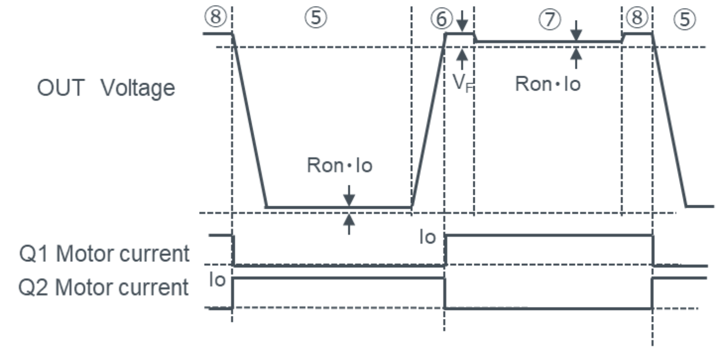

Figure 5. Half-bridge coil drive waveform during current out of the motor

Switching time and Transition time definition

Following time range should be decide based on your motor application.

-t_{SW}, $t_{SW\ OFF}$: Switching time from the beginning of Gate voltage to the end of Output voltage transition

t_{SW} and $t_{SW\ OFF}$ affect to reduce the difference between duty ratio of input PWM from controller and duty ratio of output to the motor, and reduce acoustic noise by reducing the current distortion of three phase motors.
$t_{SW\ OFF}$ should be sufficient shorter than the dead time to prevent shoot-through.

-t_{ON}, t_{OFF}: Transition time for output voltage

t_{ON} and t_{OFF} are equivalent to slew rate of output. Slew rate affect to efficiency and EMC.

Source (outflow gate) current is decided by t_{SW} and t_{ON}. Sink (inflow gate) current is decided by $t_{SW\ OFF}$ and t_{OFF}.

Figure 6 shows timing chart of half-bridge for motor driving. Motor pre-driver or gate driver outputs gate current control signal with dead time. Detailed behavior of No.1 to No.35 is as follows:

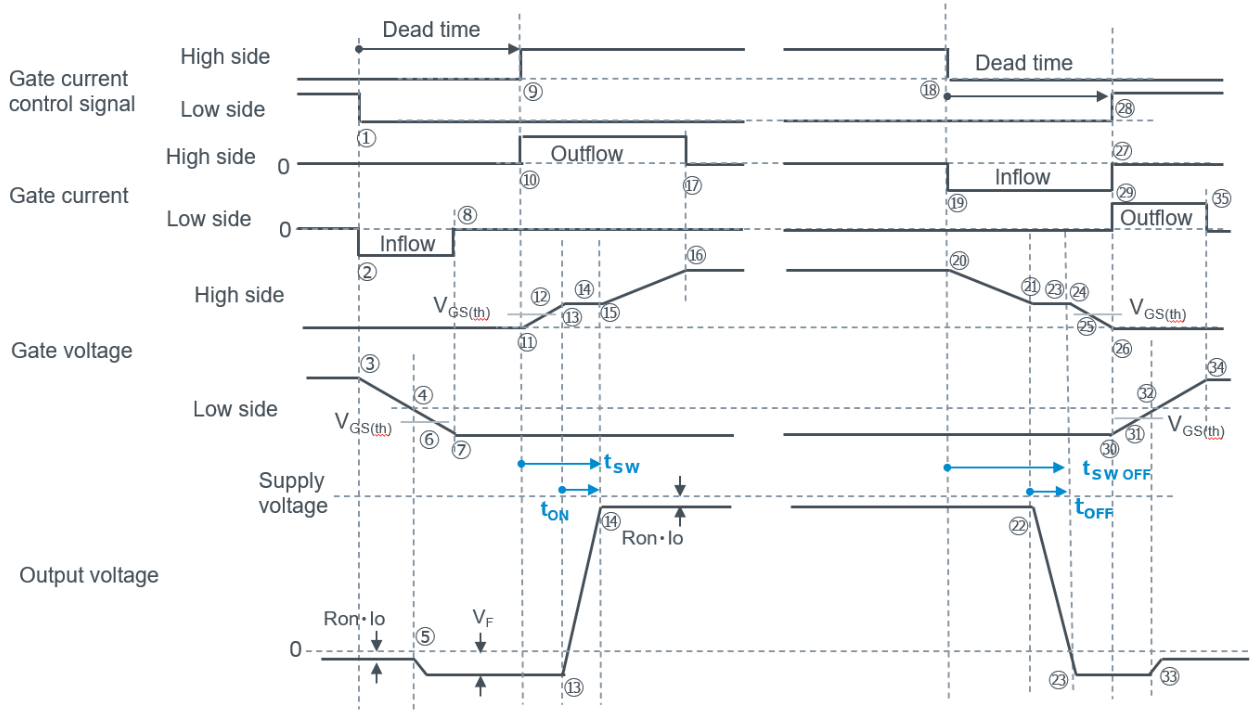

Figure 6. Timing chart for Half-bridge on motor drive application [Motor current out]

① Low side gate current control signal goes to 'L'
↓
② Driver (Gate driver or pre-driver) draws a current from gate of low side MOSFET [Sink current]
↓
③ Gate voltage of the low side MOSFET decrease from maximum voltage.
↓
④ Gate voltage of the low side MOSFET decrease to stop drain current.
↓
⑤ Output voltage continuously dropped due to low side MOSFET flows motor current with body diode after stop drain current of itself.
↓
⑥ Low side MOSFET turns off by decreasing gate voltage to under $V_{GS(th)}$.
↓
⑦ Gate voltage of the low side MOSFET goes to 0V.
↓
⑧ Gate current of the low side MOSFET to driver decreases to 0A,because gate charge has been to zero.
↓
⑨ High side gate current control signal goes to 'H' after the dead time to prevent shoot through.
↓
⑩ Driver supplies a current to gate of the high side MOSFET [Source current]
↓
⑪ Gate voltage of high side MOSFET increases.
↓
⑫ High side MOSFET turns on by increasing gate voltage to over $V_{GS(th)}$.
↓
⑬ Output voltage starts to rise, because V_{GS} of high side MOSFET increases to be able to flow current same as path for the body diode of low side MOSFET.
↓
⑭ Output voltage rises to near the supply voltage. During the period, V_{GS} of high side MOSFET is not changed.
↓
⑮ V_{GS} of high side MOSFET increases again after output voltage reaches to near supply voltage.
↓
⑯ Gate Voltage of high side MOSFET reaches to output high voltage of driver.
↓
⑰ Gate current of high side MOSFET is to 0A, because gate charge is full.

⑱ High side gate current control signal goes "L"
↓
⑲ Driver draws a current from gate of high side MOSFET [Sink current]
↓
⑳ Gate voltage of the high side MOSFET decrease from maximum voltage.
↓
㉑ V_{GS} of the high side MOSFET decrease to stop drain current.
↓
㉒ Output voltage falls.
↓
㉓ Output voltage go to -Vf due to draw a current from the body diode of low side MOSFET. During the period, V_{GS} of high side MOSFET is not changed.
↓
㉔ After the output voltage goes to -Vf, V_{GS} decreases again.
↓
㉕ High side MOSFET turns off by decreasing gate voltage to under $V_{GS(th)}$.
↓
㉖ Gate voltage of the high side MOSFET goes to 0V.
↓
㉗ Gate current of high side MOSFET is to 0A, because gate charge is empty.
↓
㉘ Low side gate current control signal goes to 'H' after the dead time to prevent shoot through.
↓
㉙ Driver supplies a current to gate of the low side MOSFET. [Source current]
↓
㉚ Gate voltage of low side MOSFET increases.
↓
㉛ Low side MOSFET turns on by increasing gate voltage to over $V_{GS(th)}$.
↓
㉜ Gate voltage of low side MOSFET increases to be able to flow current same as path for the body diode of low side MOSFET.
↓
㉝ Low side MOSFET flows a current from its body diode had flowed.
↓
㉞ Gate Voltage of low side MOSFET reaches to output high voltage of driver.
↓
㉟ Gate current of low side MOSFET is to 0A, because gate charge is full.

Source current setting of low side MOSFET gate drive

This parameter affects to the low side Nch MOSFET is on.
The source current value (I_{source}) can be calculated by deciding either following value on your demand. (See p.4 and Fig. 8,9):

(1) t_{ON}: Transition time for output voltage(V_{DS})
(2) t_{SW}: Switching time from the beginning of V_{GS} to the end of V_{DS} transition.

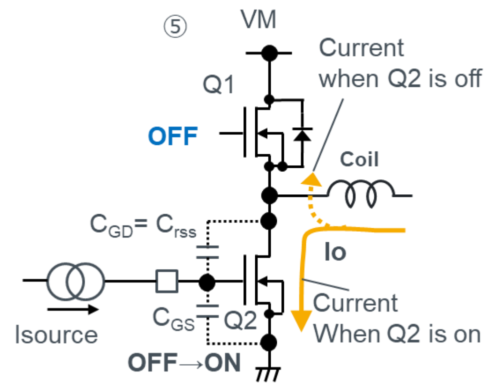

Figure 7. Equivalent circuit at low side on

(1) Calculate low side source current with t_{ON}

Source current I_{source} is calculated by the electrical charge Q_{gd} and the time t_{ON}.

$$I_{source} = \frac{Q_{gd}}{t_{ON}} \qquad (1)$$

Q_{gd} : the required electrical charge from high to low of V_{DS}.

[Example]

ROHM Nch Dual MOSFET (HPLF5060, V_{DSS}=40V, I_D=40A)
- Specification (Tentative):
  Q_{gd}=2.0nC(typ)(conditions: V_{DD}≈20V, I_D=10A, V_{GS}=6V)
- User Required: (Applicable value for motor application)
  t_{ON}＝200ns

Required low side source current is:

$$I_{sourse} = \frac{2.0nQ}{200ns} = 20mA \quad (2)$$

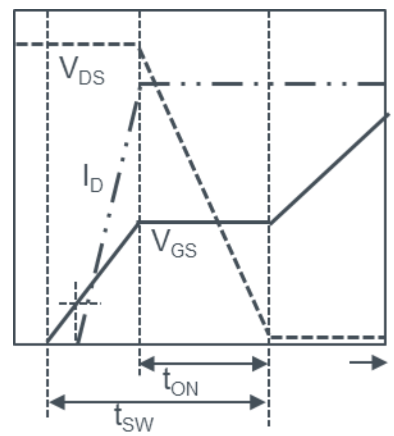

Figure 8. Switching transient waveform

(2) Calculate low side source current with t_{SW}

Source current I_{source} is calculated by the electrical charge Q_{gd}, Q_{gs} and the time t_{SW}.

$$I_{source} = \frac{Q_{gs}+Q_{gd}}{t_{SW}} \qquad (3)$$

Q_{gd} : the required electrical charge from high to low of V_{DS}.
Q_{gs} : the required electrical charge from zero to flat of V_{GS}.

[Example]

ROHM Nch Dual MOSFET (HPLF5060, V_{DSS}=40V,I_D=40A)
- Specification (Tentative):
  Q_{gs}=1.2nC(typ), Q_{gd}=2.0nC(typ)(conditions: V_{DD}≈20V, I_D=10A, V_{GS}=4.5V)
- User Required: (Applicable value for motor application)
  t_{SW}=500ns (1/100 for general PWM frequency 20 kHz)

Required low side source current is:

$$I_{source} = \frac{1.2nC+2.0nC}{500ns} = 6.4mA \qquad (4)$$

However, since Qgs and Qgd change with the voltage and current used, correction is necessary in such cases.

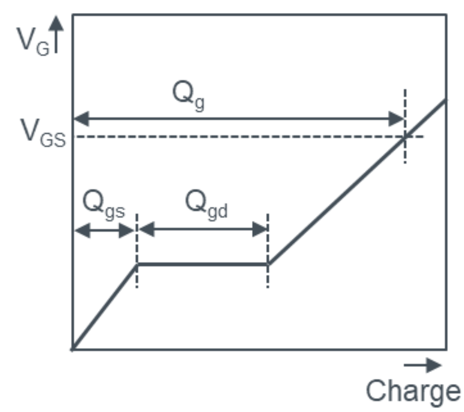

Figure 9. Gate voltage vs. gate charge characteristics

Sink current setting of low side MOSFET gate drive

This parameter affects to the low side Nch MOSFET is off.
The sink current value (I_{sink}) can be calculated by deciding either following value on your demand. (See p.4 and Fig.11,12):

(3) $t_{SW\,OFF}$: Switching time from the beginning of V_{GS} to the end of V_{DS} transition.

(4) t_{OFF} : Transition time for output voltage

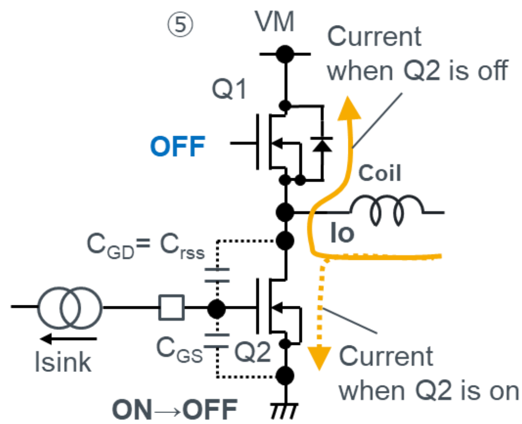

Figure 10. Equivalent circuit at low side off

(3) Calculate low side sink current with $t_{SW\,OFF}$

Electrical charge Q_{GS2} calculated by the voltage V_{GSDL}, V_{PLT} and the capacitance C_{iss}.

$$Q_{GS2} = (V_{GSDL}-V_{PLT}) \times C_{iss} \quad (5)$$

Q_{GS2} : the required electrical charge from maximum to flat of V_{GS}.
V_{GSDL} : the maximum voltage of the output circuit that drives the gate.
V_{PLT} : the flat voltage when the gate voltage changes.
C_{iss} : input capacitance of MOSFET

Sink current I_{sink} is calculated by the electrical charge Q_{GS2}, Q_{gs} and the time $t_{SW\,OFF}$.

$$I_{sink} = (Q_{GS2}+Q_{gd})/t_{SW\,OFF} = \{(V_{GSDL}-V_{PLT})\times C_{iss} + Q_{gd}\}/t_{SW\,OFF} \quad (6)$$

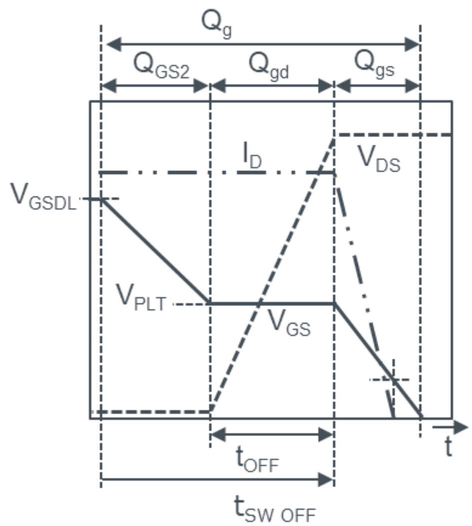

Figure 11. Switching transient waveform

[Example]

ROHM Nch Dual MOSFET (HPLF5060, V_{DSS}=40V, I_D=40A)
- Specification (Tentative):
  C_{iss}=700pF(typ) (conditions: V_{DS}≈20V, V_{GS}=0V, f=1MHz)
  Q_{gd}=2.0nC(typ) (conditions: V_{DD}≈20V, I_D=10A, V_{GS}=6V)
  V_{PLT}=2.1V(typ) (conditions: V_{DD}≈20V, I_D=10A, V_{GS}=10V)

ROHM Three phase sensor-less motor pre-driver
- Specification (Tentative):
  V_{GSDL}=9.5V(typ) (conditions: VCC = 5.5V to 18V, I_O=-20mA at I_{SOURCE}=-31mA setting)
- User Required: (Applicable value for motor application)
  t_{SW}=500ns (1/100 for general PWM frequency 20 kHz)

Required low side sink current is:

$$I_{sink}=\{(9.5V-2.1V)\times 700pF+2.0nC\}/500ns$$
$$=(5.18nC+2.0nC)/500nC=14.4mA \quad (7)$$

(4) Calculate low side sink current with t_{OFF}

Sink current I_{sink} is calculated by the electrical charge Q_{gd} and the time t_{OFF}.

$$I_{sink}=Q_{gd}/t_{OFF} \quad (8)$$

Q_{gd} : the required electrical charge from low to high of V_{DS}.

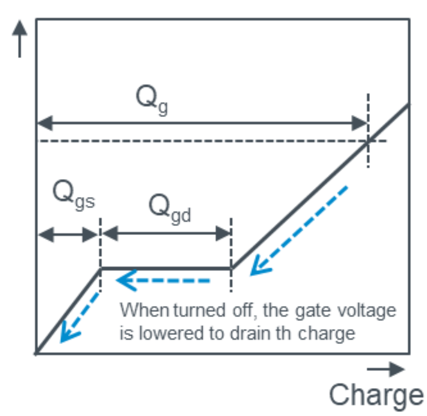

Figure 12. Gate voltage vs. gate charge characteristics

[Example]

ROHM Nch Dual MOSFET (HPLF5060, V_{DSS}=40V, I_D=40A)
- Specification (Tentative):
  Q_{gd}=2.0nC(typ) (conditions: V_{DD} ≈20V, I_D=10A, V_{GS}=6V)
- User Required: (Applicable value for motor application)
  t_{ON}=200ns

Required low side sink current is:

$$I_{sink} = 2.0nC/200ns = 10.0mA \quad (9)$$

Recalculated t_{OFF} by 14.4mA of equation (7) is:

$$t_{OFF} = Q_{gd}/I_{sink} = 2.0nC/14.4mA = 139ns \quad (10)$$

Confirm that there is no ringing in the output waveform.

Output voltage transition when turned off does not become steeper than a certain point even if Isink is increased.

When current is applied to the motor coil by PWM drive, the coil part can be regarded as a constant current load. When Q2 is turned off and the output voltage rises by constant current, the capacitor connected to the Q2 drain is charged to change the voltage.
Output current Io charges C_{oss} of high side and low side MOSFET and output-to-GND capacitor C_{OUT} for noise rejection.
the output voltage transition dV_{DS}/dt is as follows.

$$dV_{DS}/dt = Io/(C_{oss(Q1)}+C_{oss(Q2)}+C_{out}) \quad (11)$$

Output voltage transitions cannot be greater than this, even if gate sink current increases.

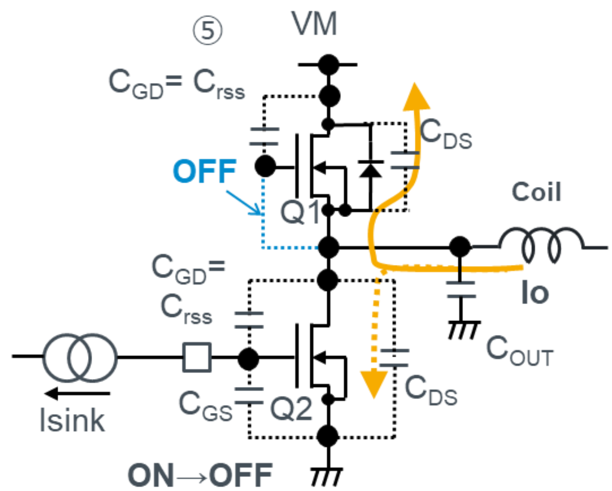

Figure 13. Equivalent circuit 2 at low side off

[Example]
ROHM Nch Dual MOSFET (HPLF5060, V_{DSS}=40V, I_D=40A)
- Specification (Tentative):
  C_{oss}=900pF (conditions: V_{DS}=0V, V_{GS}=0V, f=1MHz)
  C_{oss}=430pF (conditions: V_{DS}=12V, V_{GS}=0V, f=1MHz)
- Output-to-GND capacitor
  C_{OUT}=0nF
- Output current
  Io=5A
- Supply voltage
  VM=12v

Output voltage transition is:

$$dV_{DS}/dt = 5A/(0.90nF+0.43nF+0nF) = 3.76V/ns \quad (12)$$

Output transition time is:

$$t_{OFF} = VM/(dV_{DS}/dt) = 12V/3.76V/ns = 3.19ns \quad (13)$$

Output voltage transition when turned off is The later of the value determined by output current and output capacitor or the value determined by gate sink current and C_{rss}.

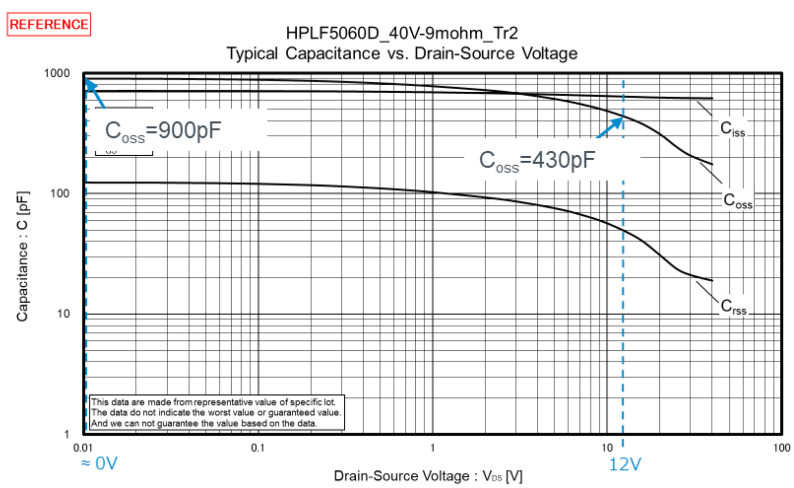

Figure 14. MOSFET Capacitance vs. Drain- Source voltage characteristic

Sink current setting of low side MOSFET drive to prevent self-turn-on

To prevent self-turn-on, changes in drain-source voltage must be such that the current charging the gate-drain capacitor C_{rss} raises the gate-source voltage and does not exceed the gate threshold voltage.

If the change in drain-source voltage is dV_{DS}/dt, the current $I_{Crss\text{-}Cgs}$ flowing from C_{rss} through C_{GS} is:

$I_{Crss\text{-}Cgs} = (C_{rss} \times C_{GS}) / (C_{rss} + C_{GS}) \times dV_{DS}/dt$ (14)

If the gate current Isink is flowed out of the connection point between C_{rss} and C_{GS}, the current I_{Cgs} flowing into C_{GS} is:

$I_{Cgs} = I_{Crss\text{-}Cgs} - Isink = (C_{rss} \times C_{GS})/(C_{rss}+C_{GS}) \times dV_{DS}/dt - Isink$ (15)

Approximating that VDS varies from 0V to the supply voltage VM during time t1, dV_{DS}/dt is:

$dV_{DS}/dt = VM/t1$ (16)

The voltage V_{Cgs} generated at C_{GS} is:

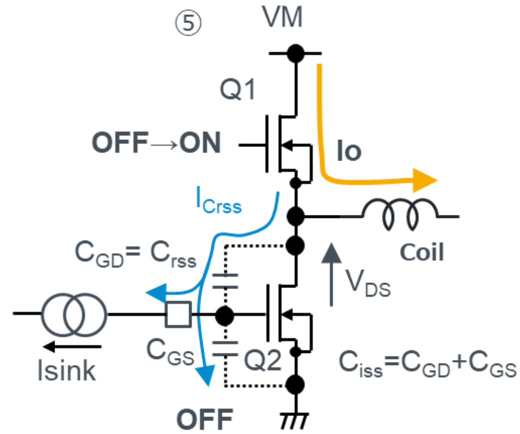

Figure 15. Equivalent circuit at self-turn-on

$$V_{Cgs} = \frac{1}{C_{GS}}\int_0^{t1} I_{Cgs}\,dt = \frac{1}{C_{GS}}\int_0^{t1}\left(\frac{C_{rss}\times C_{GS}}{C_{rss}+C_{GS}} \times \frac{VM}{t1} - Isink\right)dt = \frac{C_{rss}}{C_{rss}+C_{GS}} \times VM - \frac{1}{C_{GS}} \times Isink \times t1 \qquad (17)$$

Because Q2 is not turned on when V_{Cgs} is less than Vth of Q2,

$$Vth \geq \frac{C_{rss}}{C_{rss}+C_{GS}} \times VM - \frac{1}{C_{GS}} \times Isink \times t1 \qquad (18)$$

$$Isink \geq \left(\frac{C_{rss}}{C_{rss}+C_{GS}} \times VM - Vth\right) \times \frac{C_{GS}}{t1} \qquad (19)$$

[Example]

ROHM Nch Dual MOSFET (HPLF5060, V_{DSS}=40V, I_D=40A)

- Specification(Tentative):
  - C_{iss} =700pF, C_{rss}=120pF (conditions: $V_{DD} \approx$ 0V, V_{GS}=0V, f=1MHz)
  - $C_{GS} = C_{iss} - C_{rss}$ = 580pF
  - $V_{GS(th)}$ =2.0V(min) (conditions: $V_{DS}=V_{GS}$, I_D=1mA)
  - Assuming 0.63V drop at Tj=150°C due to temperature characteristics, $V_{GS(th)}$=1.37V(Min)
- The supply voltage
  - VM =12V.
- t1 is the time to the point where the tangent line of the steepest point of V_{DS} and the supply voltage intersect in actual operation. Set t1 to 1/2 of t_{ON}. (See Fig.16)
  - t1=100ns

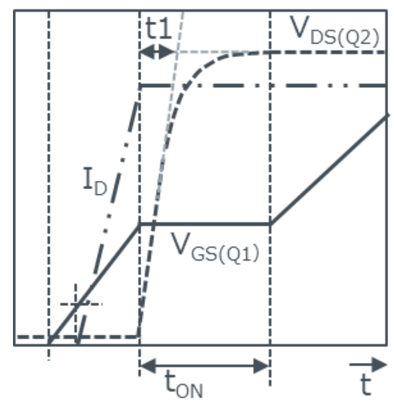

Figure 16. Q2 V_{DS} actual waveform when Q1 is on

$$Isink \geq \left(\frac{120pF}{700pF} \times 12V - 1.37V\right) \times \frac{580pF}{100ns}$$

$$= (2.06V - 1.37V) \times \frac{580pF}{100ns}$$

$$= 4.0mA \qquad (20)$$

If sink=10mA, V_{Cgs} is:

$$V_{Cgs} = \frac{120pF}{700pF} \times 12V - \frac{1}{580pF} \times 10mA \times 100ns$$

$$= 2.06V - 1.72V$$

$$= 0.34V \qquad (21)$$

Because V_{Cgs} is under $V_{GS(th)}$ [1.37V(min) (at Tj=150°C)], Self-turn-on does not occur.

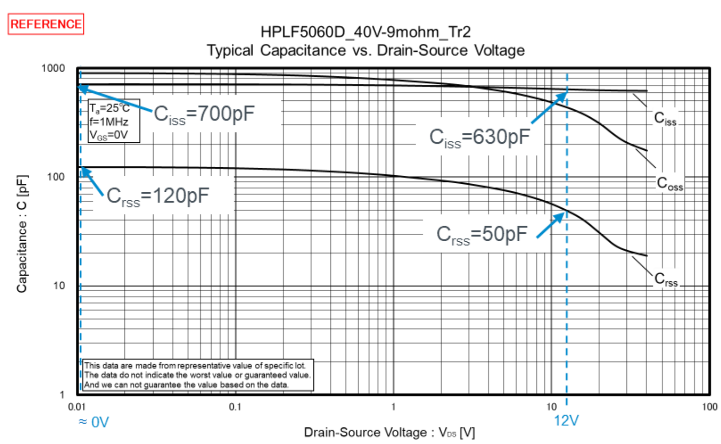

Figure 17. MOSFET capacitance - Drain-source voltage characteristics

Source current setting of high side MOSFET gate drive

When current flows into the gate of the high side Nch MOSFET, the gate voltage rises and reaches V_{GS}, which allows the motor current to flow, the source voltage V_S of Q1 rises, and the gate voltage V_G rises with it.
The drain voltage V_D is constant. For this reason, the relative gate-source voltage V_{GS} and the drain-source voltage V_{DS} are similar to the operation of the low side MOS-FET.

This parameter affects to the high side Nch MOS-FET is on.
The source current value (I_{source}) can be calculated by deciding either following value on your demand. (See p.4 and Fig. 20):
(1) t_{ON}: Transition time for output voltage
(2) t_{SW}: Switching time from the beginning of V_{GS} to the end of V_{DS} transition.

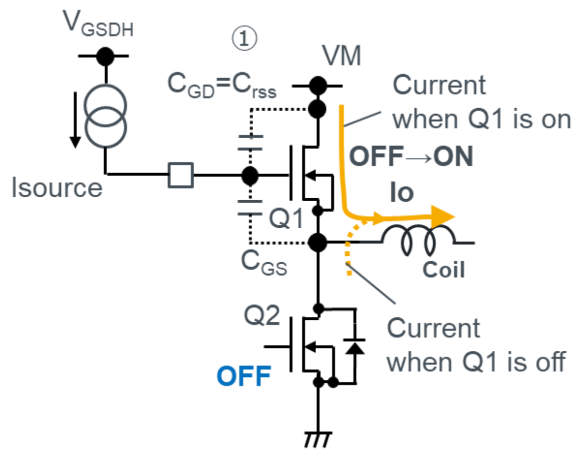

Figure 18. Equivalent circuit at high side on

(1) Calculate low high source current with t_{ON}

Source current I_{source} is calculated by the required electrical charge Q_{gd} and the time t_{ON}.

$$I_{source} = \frac{Q_{gd}}{t_{ON}} \quad (22)$$

Q_{gd} : the required electrical charge from high to low of V_{DS}.

[Example]
ROHM Nch Dual MOSFET (HPLF5060, V_{DSS}=40V, I_D=40A)
- Specification (Tentative):
  Q_{gd}=2.0nC(typ)(conditions: V_{DD}≈20V, I_D=10A, V_{GS}=6V)
- User Required: (Applicable value for motor application)
  t_{ON}=200ns

Required low side source current is:

$$I_{sourse} = \frac{2.0nQ}{200ns} = 20mA \quad (23)$$

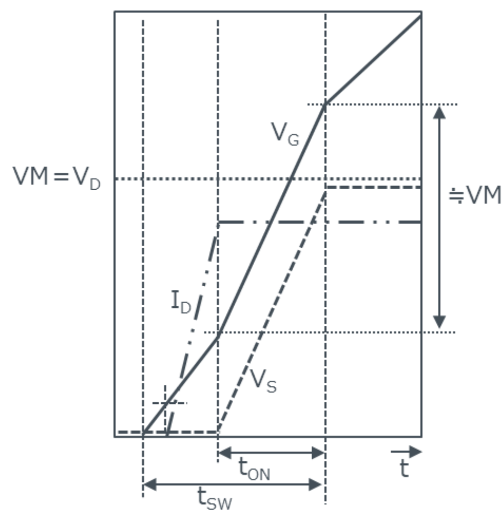

Figure 19. Switching transient waveform (Absolute value)

(2) Calculate high side source current with t_{SW}

Source current I_{source} is calculated by the required electrical charge Q_{gd}, Q_{gs} and the time t_{SW}.

$$I_{source} = \frac{Q_{gs}+Q_{gd}}{t_{SW}} \quad (24)$$

Q_{gd} : the required electrical charge from high to low of V_{DS}.
Q_{gs} : the required electrical charge from zero to flat of V_{GS}.

[Example]
ROHM Nch Dual MOSFET (HPLF5060, V_{DSS}=40V, I_D=40A)
- Specification (Tentative):
  Q_{gs}=1.2nC(typ), Q_{gd}=2.0nC(typ)(conditions: V_{DD}≈20V, I_D=10A, V_{GS}=4.5V)
- User Required: (Applicable value for motor application)
  t_{SW}=500ns (1/100 for general PWM frequency 20 kHz)

Required low side source current is:

$$I_{source} = \frac{1.2nC+2.0nC}{500ns} = 6.4mA \quad (25)$$

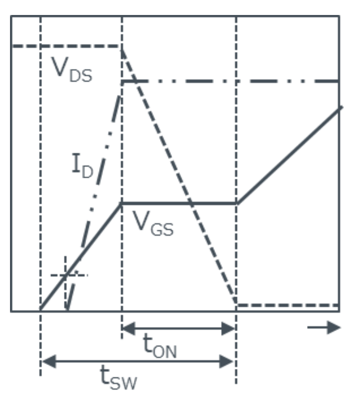

Figure 20. Switching transient waveform (Relative value)

However, since Qgs and Qgd change with the voltage and current used, correction is necessary in such cases.

Sink current setting of high side MOSFET gate drive

The operation from full on to off is the same as the operation of the low side MOS-FET.
This parameter affects to the high side Nch MOSFET is off.
The sink current value (I_{sink}) can be calculated by deciding either following value on your demand. (See p.4 and Fig.23) :

(3) $t_{SW\,OFF}$: Switching time from the beginning of V_{GS} to the end of V_{DS} transition.

(4) t_{OFF} : Transition time for output voltage

(3) Calculate high side sink current with $t_{SW\,OFF}$

Electrical charge Q_{GS2} is calculated by the voltage V_{GSDL}, V_{PLT} and the capacitance C_{iss}.

$$Q_{GS2}=(V_{GSDL}-VM-V_{PLT})\times C_{iss} \quad (26)$$

Q_{GS2} : the required electrical charge from maximum to flat of V_{GS}.
V_{GSDL} : the maximum voltage of the output circuit that drives the gate.
VM : power supply voltage
V_{PLT} : the flat voltage when the gate voltage changes.
C_{iss} : input capacitance of MOS-FET

Sink current I_{sink} is calculated by the required electrical charge Q_g, Q_{gs} and the time $t_{SW\,OFF}$..

$$I_{sink}=(Q_{GS2}+Q_{gd})/t_{SW\,OFF}=\{(V_{GSDL}-V_{PLT})\times C_{iss}+Q_{gd}\}/t_{SW\,OFF} \quad (27)$$

[Example]

ROHM Nch Dual MOSFET (HPLF5060, V_{DSS}=40V, I_D=40A)
- Specification (Tentative):
  C_{iss}=700pF(typ) (conditions: V_{DS}≈20V, V_{GS}=0V, f=1MHz)
  Q_{gd}=2.0nC(typ) (conditions: V_{DD}≈20V, I_D=10A, V_{GS}=6V)
  V_{PLT}=2.1V(typ) (conditions: V_{DD}≈20V, I_D=10A, V_{GS}=10V)

ROHM Three phase sensor-less motor pre-driver
- Specification (Tentative):
  V_{GSDL}=VM+9.5V(typ) (conditions: VM = 5.5V to 18V, I_O=-20mA at I_{SOURCE}=-31mA setting)
- User Required: (Applicable value for motor application)
  t_{SW}=500ns (1/100 for general PWM frequency 20 kHz)

Required low side sink current is:

$$I_{sink}=\{(9.5V-2.1V)\times 700pF+2.0nC\}/500ns$$
$$=(5.18nC+2.0nC)/500nC=14.4mA \quad (28)$$

(4) Calculate low side sink current with t_{OFF}

Sink current I_{sink} is calculated by the required electrical charge and the time t_{OFF}.
Q_{gd} is determined as the required electrical charge from low to high of V_{DS}.

$$I_{sink}=Q_{gd}/t_{OFF} \quad (29)$$

【Example】

ROHM Nch Dual MOSFET (HPLF5060, V_{DSS}=40V, I_D=40A)
- Specification (Tentative):
  Q_{gd}=2.0nC(typ) (conditions: V_{DD} ≈20V, I_D=10A, V_{GS}=6V)

User Required: (Applicable value for motor application)
  t_{ON}=200ns

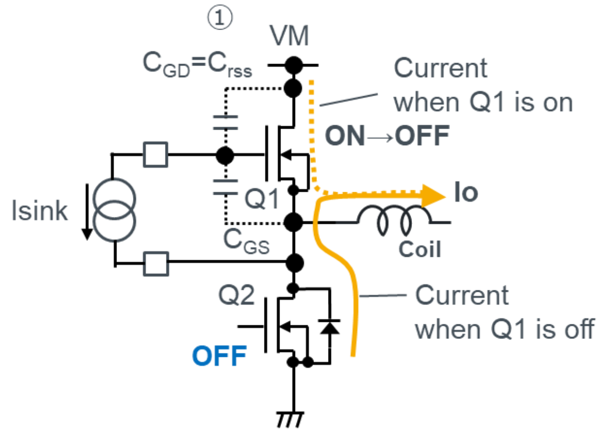

Figure 21. Equivalent circuit at high side off

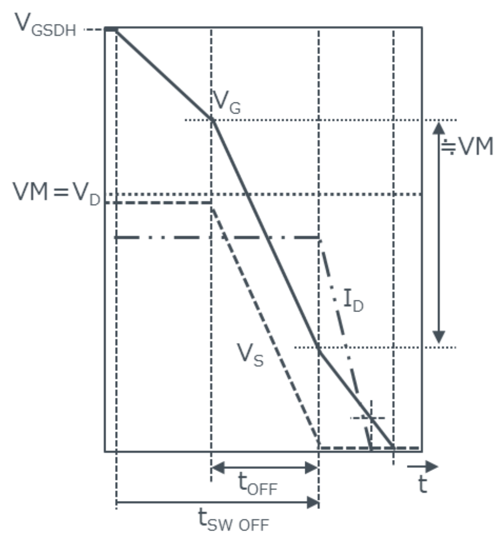

Figure 22. Switching transient waveform (Absolute value)

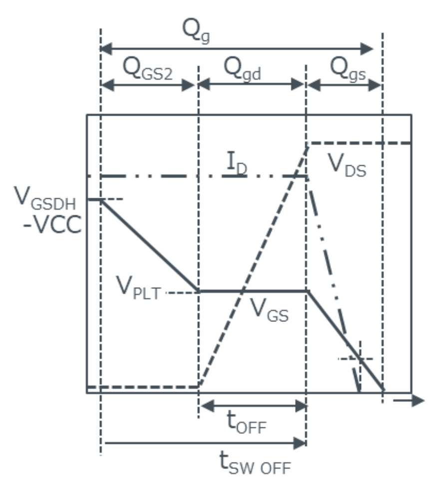

Figure 23. Switching transient waveform (Relative value)

Required low side sink current is:

I_{sink} = 2.0nC/200ns = 10.0mA (30)

Recalculated t_{OFF} by 14.4mA of equation (28) is:

t_{OFF} = Q_{gd}/ I_{sink} = 2.0nC/14.4mA = 139ns (31)

Confirm that there is no ringing in the output waveform.

Sink current setting of high side MOS-FET drive to prevent self-turn-on

Even in the case where the high side MOSFET is turned off, when the low side MOSFET is turned on, the gate voltage of the high side MOSFET falls steeply. Since the drain of the high side MOSFET is constant by the supply voltage VM, current flows through the gate-to-drain capacitor C_{rss}. To prevent self-turn-on, the gate-source voltage of high side MOSFET must be prevented from rising above the gate threshold voltage by C_{rss} current. Set the sink current using the same approach as for the low side MOSFET. (See Page 9.)

Additional external capacitors to adjust transition time

An external capacitor between gate and drain may use for adjusting switching and transition time (C_{GDEX} of Fig.24) .

t_{ON} (Output voltage transient time) of low side MOSFET with external capacitor is as follows:

t_{ON} = (VM× C_{GDEX}+Q_{gd}) /I_{source} (32)

t_{ON} : Output voltage transition time from VM[V] to 0V.

C_{GDEX} : Capacitance of external capacitor

Q_{gd} : Required electrical charge from high to low of V_{DS}

I_{source}: Supply current from driver to gate of MOSFET

t_{ON} of high side MOSFET with external capacitor is as the same.

[Example]

ROHM Nch Dual MOSFET (HPLF5060, V_{DSS}=40V, I_D=40A)

- Specification (Tentative):

Q_{gd}=2.0nC(typ) (conditions: V_{DD} ≈20V、I_D=10A、V_{GS}=6V)

-Supply voltage

VM=12V

-External capacitor between Gate and Drain

C_{GDEX}=330pF

-Source current setting (Using previous setting, see page 6)

I_{source}=10mA

Output voltage transient time is:

t_{ON} = (12V× 330pF+ 2.0nC)/10mA=596ns (33)

t_{ON} is (596ns-200ns =) 396ns slower than the first value.

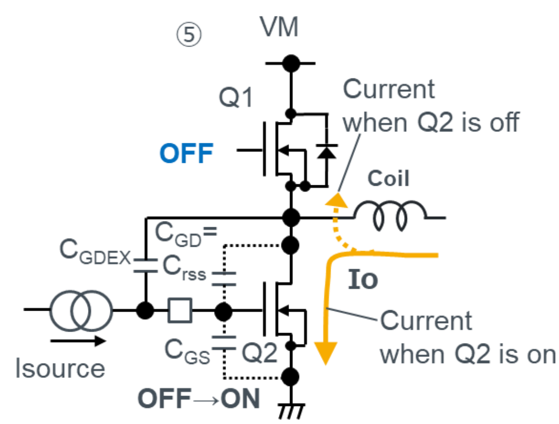

Figure 24. Equivalent circuit with external capacitor added between low side MOSFET gate and drain

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