

Super Junction MOSFET series

Double-pulse test substantiated advantages of PrestoMOS[™]

Inverters and Totem pole type PFC (Power Factor Correction) include more than two transistors. In this circuits, short-circuit current penetrating through high and low arms deteriorates turn-on losses in some cases. How this event behaves is heavily affected by the recovery characteristics of a diode (body diode) parasitic to the transistor that is not driven, and therefore you must choose transistors with body diodes having excellent recovery features in a bridge circuit topology. The PrestoMOSTM series ROHM are most suitable for bridge circuits, because the transistors in the series are equipped with body diodes whose recovery attributes are top-level in this application filed. This application note describes how excellent the switching and recovery behaviors of PrestoMOSTM by using the double-pulse-test results of the series.

Double-pulse test

Double-pulse test is widely and commonly used to evaluate the characteristics of switching devices such as the super junction MOSFET (SJMOS) and the insulated gate bipolar transistor (IGBT). This measurement is capable of providing not only the switching characteristics of devices under test but also the recovery features of the transistor-parasitic body diodes and of the fast recovery diode (FRD) commonly used with IGBTs. Thus this test is very useful for estimating circuit losses caused by the recovery that happens when the switching devices used in the circuits turn on. This application note describes the switching and recovery features of PrestoMOS[™] SJMOS equipped with high-speed recovery body diodes, which features are measured by double-pulse test.

The basic circuit topology of the double-pulse test is depicted in Figure 1.





Figure 2 shows the 3 major categories of the basic operation of the double-pulse test. Here Q1 in Figure 1 is free-wheel MOSFET, while Q2 is the driven-side MOSFET. In this figure, V_{Pulse} , I_L , V_{DS_L} , I_{D_L} denote pulse-generator voltage, the current flowing through *L*1, the drain-source voltage of Q2, the drain-current of Q2, respectively.



Figure 2. Three major categories of the operation in double-pulse test

In category (III), the red-line in I_{D_L} is short-circuit current at the timing of Q2 turning on. This is caused by the recovery of the body diode in Q1. When body diodes transition from ON to OFF, the body diodes must throw out the charge storing during their on-state. If Q_{rr} , I_{rr} , and P_{d_L} denote here the amount of these charges, the peak of the current during emitting the charges, and the power loss of Q2, respectively, the ON transition of Q2 can be exhibited in Figure 3. The area of the filled triangles delineated by I_{D_L} curves corresponds to Q_{rr} , and the height of the triangles I_{rr} .





Generally speaking, as can be seen in Figure 3, the turn-on related power loss of Q2 increases if the recovery characteristic of the body diode of Q1 is not good, or large Q_{rr} . Therefore, in applications in which free-wheeling currents flow like inverters and Totem Pole PFC, you must choose transistors with their body diodes equipped with excellent recovery features. PrestoMOSTM has the top-level recovery and switching attributes in this industry, and thereby power applications such as inverters and Totem Pole PFC can achieve very low switching losses.

Results of double-pulse test

The double-pulse test is performed to confirm the recovery characteristics of a several SJMOS's. For PrestoMOSTM and conventional SJMOS without high-speed recovery characteristics, the waveforms of $I_{D_{-}L}$ in category-(III) operation are shown in Figure 4, while $E_{on_{-}L}$, turn-on loss, are shown as the curves in Figure 5. For all cases, both Q1 and Q2 are replaced.



Figure 4. Observed waveforms for $I_{D_{\perp}}$ of PrestoMOSTM and conventional SJMOS's.



Figure 5. Observed waveforms for $E_{on_{L}}$ of PrestoMOSTM and conventional SJMOS's.

As can be seen in Figure 4 and 5, larger Q_{rr} of Q1 leads to larger switching loss. However, turn-on losses worsen in some cases even if SJMOS with high-speed recovery are used. For example, we take the case that self-turn-on is the cause of large losses. Whether the self-turn-on happens or not is determined by the ratio of the gate-drain capacitance C_{gd_H} and the gate-source capacitance C_{gs_H} of Q1. PrestoMOSTM has the optimized capacitance ratio to inhibit self-turn-on, as detailed in the next section. In addition, PrestoMOSTM and some competitors' SJMOS's are evaluated under the same measurement conditions as used for Figure 4 and 5 in the double-pulse test. The waveforms of these I_{D_L} , E_{ON_L} gate-source voltage V_{GS_H} of Q1 are compared in Figure 6, 7, and 8, respectively. As clearly shown in Figure 6, Q_{rr} and I_{rr} of the body diode of PrestoMOSTM leads to a low peak height of I_{D_L} . As a result of which, E_{ON_L} is the smallest for PrestoMOSTM as can be seen in Figure 7. Furthermore, as shown in Figure 8, an unintentional increase in V_{gs_H} is small for PrestoMOSTM, which is very effective to inhibit self-turn-on. This sufficiently hampers short-circuit current, and therefore E_{ON_L} can be reduced more than reference devices.



Figure 6. Observed waveforms for $I_{D_{\perp}}$ of SJMOS with high-speed recovery.



Figure 7. Observed waveforms for *E*on_L of SJMOS with high-speed recovery.





The mechanism of self-turn-on

In the transition from category-(II) to (III) as defined in Figure 2, the drain-source voltage (V_{DS_H}) of Q1 steeply changes from 0 to V (V). This generates the time-derivative of dV_{DS_H}/dt , which charges C_{gd_H} and C_{gs_H} . In the equivalent circuit of a MOSFET, C_{gd_H} and C_{gs_H} is serially connected, and thereby the ratio of these capacitances determines V_{GS_H} by $V_{GS_H} = V_{DS_H} \times \{1+(C_{gs_H}/C_{gd_H})\}^{-1}$. If this V_{GS_H} goes over the threshold voltage of a MOSFET, the MOSFET unintentionally turns on, which is self-turn-on, and thus short-circuit current penetrates through both arms. Figure 9 shows the current generated by the recovery of the body diodes and also the one created by self-turn-on.



Figure 9. The paths of the currents generated by the recovery and self-turn-on (R_{g_H} : gate resistance for Q1, C_{ds_H} : Drain-source capacitance of Q1)

Bridge circuits such as inverters and Totem Pole PFC includes the serial connection of transistors, and thus turn-on losses often increase by the currents generated not only by the recovery of body diodes but also by short-circuit. PrestoMOS[™] has the device structure optimized for the excellent recovery features of body diodes and inhibiting self-turn-on through the appropriately designed capacitance ratios.

Summary

• The recovery characteristics of switching devices play an important role in bridge topology circuits such as inverters and Totem Pole PFC.

•PrestoMOSTM is capable of realizing high power conversion efficiency and the lowest power loss in bridge circuits than the SJMOS with high-speed recovery provided by other sources, because the SJMOS series of ROHM shows excellent recovery features and has the structure to inhibit self-turn-on.

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