

Power MOS FET

Structure and Features

R07ZZ0007EJ0200
(Previous: REJ27G0014-0100)
Rev.2.00
Aug 18, 2014

Renesas has two types of Power MOS FETs, D Series (vertical structure) and S Series (lateral structure), as shown in Figure 1 and Figure 2. Although there are some differences in their characteristics, both have the following advantages.

- Good frequency response and high switching speed due to absence of carrier storage effect.
- Free from current concentration, and hence have high resistance to destruction.
- Require a very low driving power as they are voltage controlled devices.

To understand the structure and features of Power MOS FETs, we would like to show the N-channel MOS FET.

Figure 3 shows the basic structure of the n-channel MOS FET. This is called a MOS (metal–oxide–semiconductor) structure because the metallic gate electrodes are covered by an oxide film. The source is so called because it is the source of the charged carriers (in this case, electrons), which flow out of the structure via the drain.

A positive voltage on the gate electrode drives inversion in the p layer directly under the gate, forming an n-channel through which current flows from drain to source. This is how the power MOS FET operates (the opposite is true of the p channel).

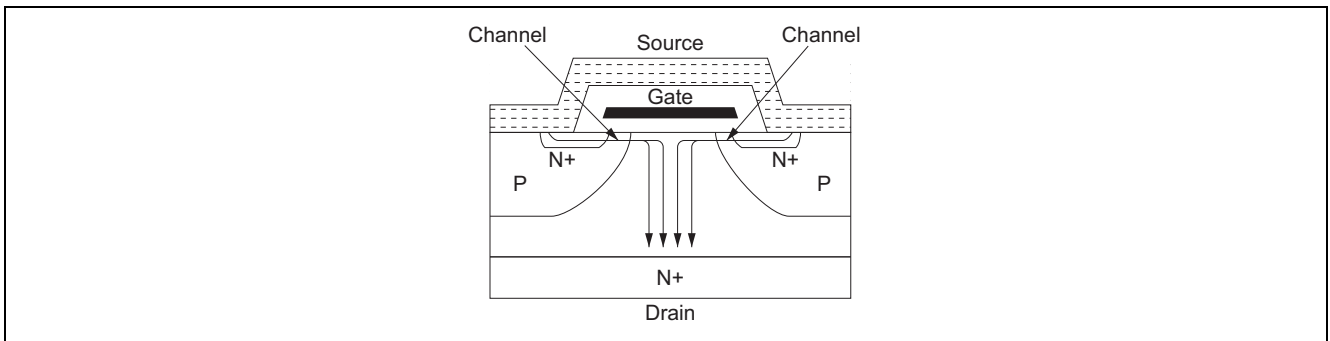


Figure 1 Structure of D Series (Vertical type) (N channel)

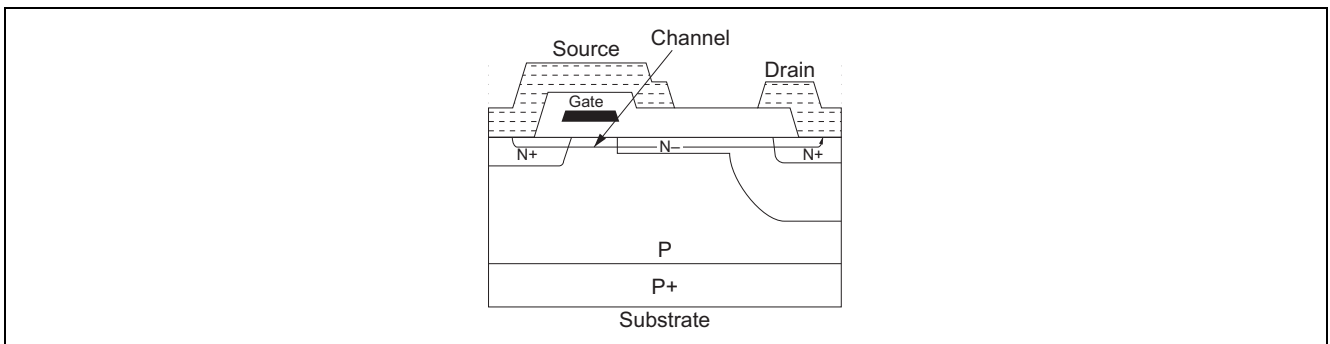


Figure 2 Structure of Series (Lateral type) (N channel)

When a voltage is applied between the drain and source, the electrons in the channel move in the direction of the drain, so a drain current flows.

There are two type of FETs, depletion type (normally ON type) and enhancement type (normally OFF type). In the case of depletion type FETs, drain current flows even if the gate voltage is 0 V, in contrast to enhancement type FETs. Renesas Power MOS FETs are all enhancement type (normally OFF type).

The gate voltage at which the drain current begins to flow is gate cut-off voltage $V_{GS(off)}$. (Figure 4).

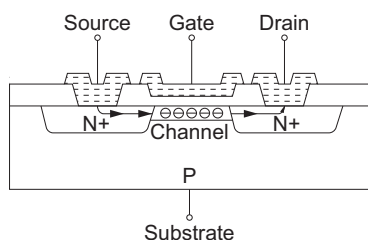


Figure 3 Basic structure of MOS FET (Lateral type)

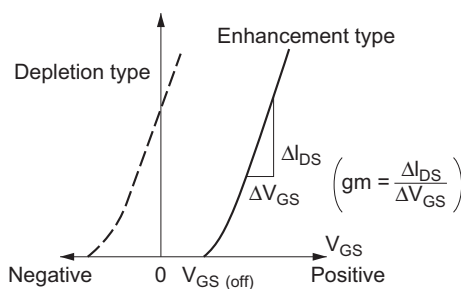


Figure 4 Transfer Characteristics

Normally, there is a quadratic correlation between I_{DS} and V_{GS} . The slope of its curve gives the mutual conductance $g_m \left(= \frac{\Delta I_{DS}}{\Delta V_{GS}} \right)$, that shows amplification factor.

Breakdown voltage of the drain varies with the structure between the N^+ region of the drain and the gate electrode, as shown in Figure 3. There is only a thin oxide film between the N^+ region and the gate electrode, so the field gradient will be high. This makes it difficult to achieve high drain to gate breakdown voltage, limited to 20 to 30 V in typical MOS FETs.

By widening the space between the N^+ region of the drain and the gate electrode, and easing the electric field concentration, we can make the breakdown voltage larger.

A power MOS FET is formed by multiple cells connected in parallel.

There are two types of power MOS FET structure: the vertical and the lateral structure. We refer to devices with the respective structures as D- and S-series. The structures are illustrated in figures 1 and 2. The features of each type are described below.

- D Series (vertical structure)

In D series the drain (N^+) is placed beneath the silicon substrate. The gate electrode covers over the N region between P channels, to ease the electric field concentration beneath the gate. The electrons flow out of the source and reach to the N region through the P channels horizontally. On the surface of the N region, there is an accumulation layer of N^+ produced by the positive voltage applied to the gate electrode. Therefore, the electrons are attracted to the accumulation layer, to flow to the drain through the N region vertically.

Consequently the D series is referred to as a vertical structure. In this structure, the case is connected to the drain.

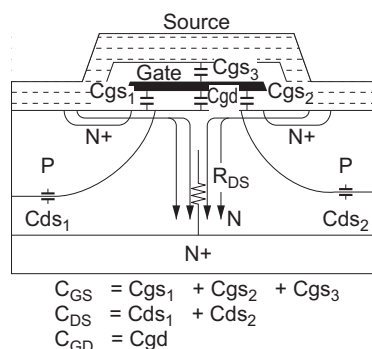


Figure 5 Structure of D Series (Vertical type) (N channel)

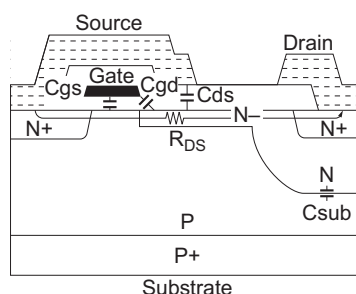


Figure 6 Structure of S Series (Lateral type) (N channel)

In the D series the channel (N region) is placed in the silicon, and the size of one unit can be smaller than that of S series. This enables the switching ON resistance of D series to be smaller than that of S series with the same voltage and the same chip size.

Electrostatic capacitances are the junction capacitances and the MOS capacitances as shown in Figure 5.

Here, the capacitance between the drain and the gate, C_{GD} , is relatively large, so in the source earth circuit, C_{GD} 's effects to the input capacitance (C_{iss}), to the output capacitance (C_{oss}) and to the feedback capacitance (C_{rss}) should be considered.

The gate electrode is made of polysilicon, which has long been used effectively in CMOS LSI. Polysilicon resistance is about 100 times larger than that of metals. When using it for the gate electrode, we lower the gate resistance by using a mesh gate pattern, and by connecting the polysilicon gate and the metal electrode effectively. To find the switching time of the vertical structure, more complicated operation analysis is required, because the feed back capacitance (C_{gd}) is large and the voltage dependence of the drain resistance is large. The input capacitance can't be determined simply by the time constant of the gate resistance. This will be further explained in the "Attention of Handling Semiconductor Devices".

- S Series (lateral structure)

In S series, the drain (N^+ region) is placed on the surface of the silicon. The region between the drain (N^+) and P channel is an N region produced by ion implantation, and it makes the strength of the electrostatic field even. Moreover, the source electrode is extended to cover a part of the N region, working as a field plate to prevent electrostatic field concentration around the gate. The electrons flow out of the source and reach to the drain through the P channel and the N region laterally. This is why the S series is called a lateral structure.

The substrate is connected to the source electrode, and the case to the source.

The feedback capacitance (C_{rss}) is indicated as C_{gd} in Figure 6. The source field plate is extended above the N region, so the C_{gd} is shielded by the field plate and the capacitance of the N region (C_{ds}). This results in a very small value of feedback capacitance (C_{rss}).

From the view points of chip and package, the S series is very suitable for high frequency use, because the input and the output leads are separated electrically

Website and Support

Renesas Electronics Website

<http://www.renesas.com/>

Inquiries

<http://www.renesas.com/contact/>

All trademarks and registered trademarks are the property of their respective owners.

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Aug. 18, 2004	-	First edition issued
2.00	Aug. 18, 2014	-	The format was changed into the newest thing. The document number was changed.

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation of these circuits, software, and information in the design of your equipment. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from the use of these circuits, software, or information.
 2. Renesas Electronics has used reasonable care in preparing the information included in this document, but Renesas Electronics does not warrant that such information is error free. Renesas Electronics assumes no liability whatsoever for any damages incurred by you resulting from errors in or omissions from the information included herein.
 3. Renesas Electronics does not assume any liability for infringement of patents, copyrights, or other intellectual property rights of third parties by or arising from the use of Renesas Electronics products or technical information described in this document. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
 4. You should not alter, modify, copy, or otherwise misappropriate any Renesas Electronics product, whether in whole or in part. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from such alteration, modification, copy or otherwise misappropriation of Renesas Electronics product.
 5. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The recommended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.
"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; and industrial robots etc.
"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control systems; anti-disaster systems; anti-crime systems; and safety equipment etc.
Renesas Electronics products are neither intended nor authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems, surgical implantations etc.), or may cause serious property damages (nuclear reactor control systems, military equipment etc.). You must check the quality grade of each Renesas Electronics product before using it in a particular application. You may not use any Renesas Electronics product for any application for which it is not intended. Renesas Electronics shall not be in any way liable for any damages or losses incurred by you or third parties arising from the use of any Renesas Electronics product for which the product is not intended by Renesas Electronics.
 6. You should use the Renesas Electronics products described in this document within the range specified by Renesas Electronics, especially with respect to the maximum rating, operating supply voltage range, movement power voltage range, heat radiation characteristics, installation and other product characteristics. Renesas Electronics shall have no liability for malfunctions or damages arising out of the use of Renesas Electronics products beyond such specified ranges.
 7. Although Renesas Electronics endeavors to improve the quality and reliability of its products, semiconductor products have specific characteristics such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Further, Renesas Electronics products are not subject to radiation resistance design. Please be sure to implement safety measures to guard them against the possibility of physical injury, and injury or damage caused by fire in the event of the failure of a Renesas Electronics product, such as safety design for hardware and software including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult, please evaluate the safety of the final products or systems manufactured by you.
 8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. Please use Renesas Electronics products in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. Renesas Electronics assumes no liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
 9. Renesas Electronics products and technology may not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You should not use Renesas Electronics products or technology described in this document for any purpose relating to military applications or use by the military, including but not limited to the development of weapons of mass destruction. When exporting the Renesas Electronics products or technology described in this document, you should comply with the applicable export control laws and regulations and follow the procedures required by such laws and regulations.
 10. It is the responsibility of the buyer or distributor of Renesas Electronics products, who distributes, disposes of, or otherwise places the product with a third party, to notify such third party in advance of the contents and conditions set forth in this document. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties as a result of unauthorized use of Renesas Electronics products.
 11. This document may not be reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
 12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products, or if you have any other inquiries.
- (Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its majority-owned subsidiaries.
(Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.



SALES OFFICES

Renesas Electronics Corporation

<http://www.renesas.com>

Refer to "<http://www.renesas.com/>" for the latest and detailed information.

Renesas Electronics America Inc.

2801 Scott Boulevard Santa Clara, CA 95050-2549, U.S.A.
Tel: +1-408-588-6000, Fax: +1-408-588-6130

Renesas Electronics Canada Limited

1101 Nicholson Road, Newmarket, Ontario L3Y 9C3, Canada
Tel: +1-905-898-5441, Fax: +1-905-898-3220

Renesas Electronics Europe Limited

Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K.
Tel: +44-1628-585-100, Fax: +44-1628-585-900

Renesas Electronics Europe GmbH

Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.

Room 1709, Quantum Plaza, No.27 ZhiChunLu Haidian District, Beijing 100191, P.R.China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.

Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, P. R. China 200333
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited

Unit 1601-1613, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852 2886-9022/9044

Renesas Electronics Taiwan Co., Ltd.

13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886 2-8175-9670

Renesas Electronics Singapore Pte. Ltd.

80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.

Unit 906, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics Korea Co., Ltd.

12F., 234 Teheran-ro, Gangnam-Ku, Seoul, 135-920, Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5141