Basics of Analog Multiplexers 4

TIPL 2604

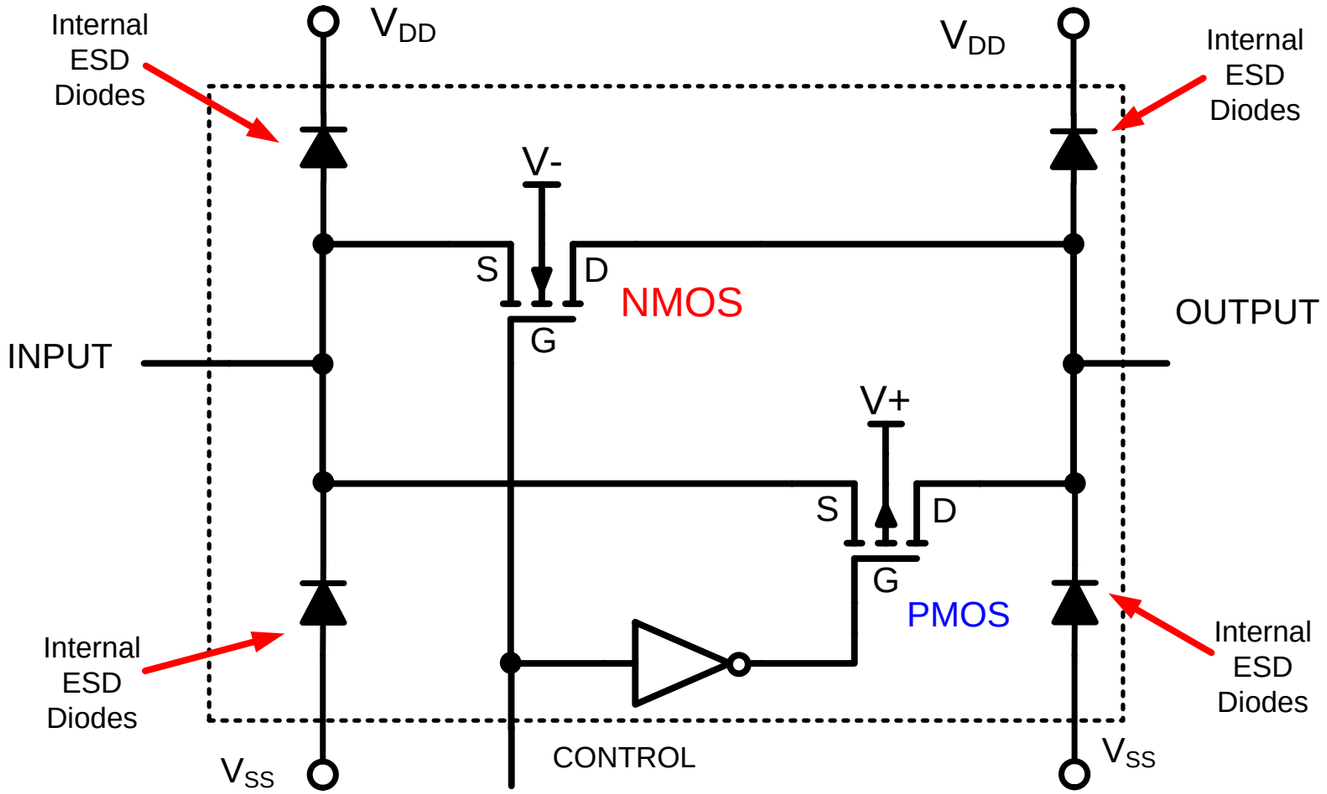
TI Precision Labs – Op Amps

Prepared by Abhijeet Godbole and Art Kay

Presented by Peggy Liska

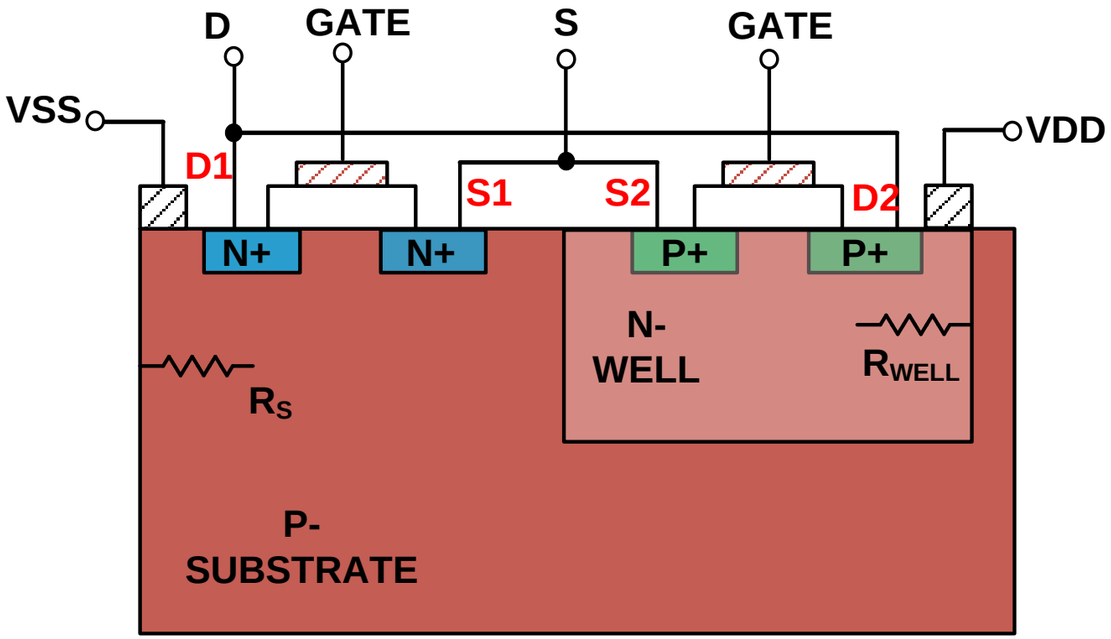
Prerequisites: ESD & EOS (TIPL1401 – 1414)

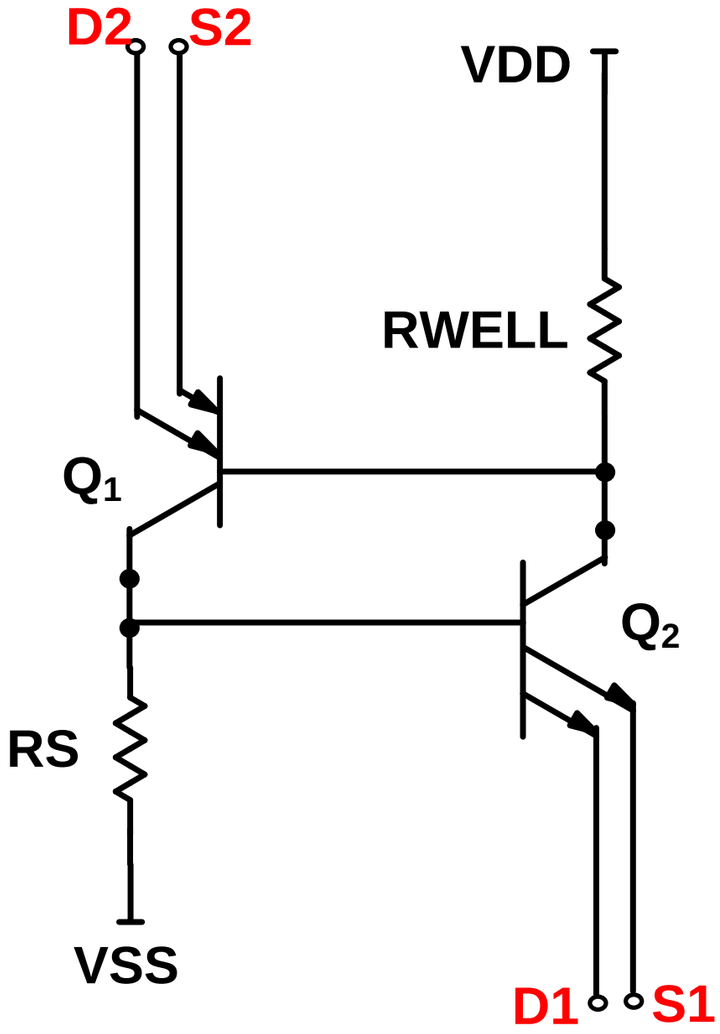
Basic Construction of CMOS Switch



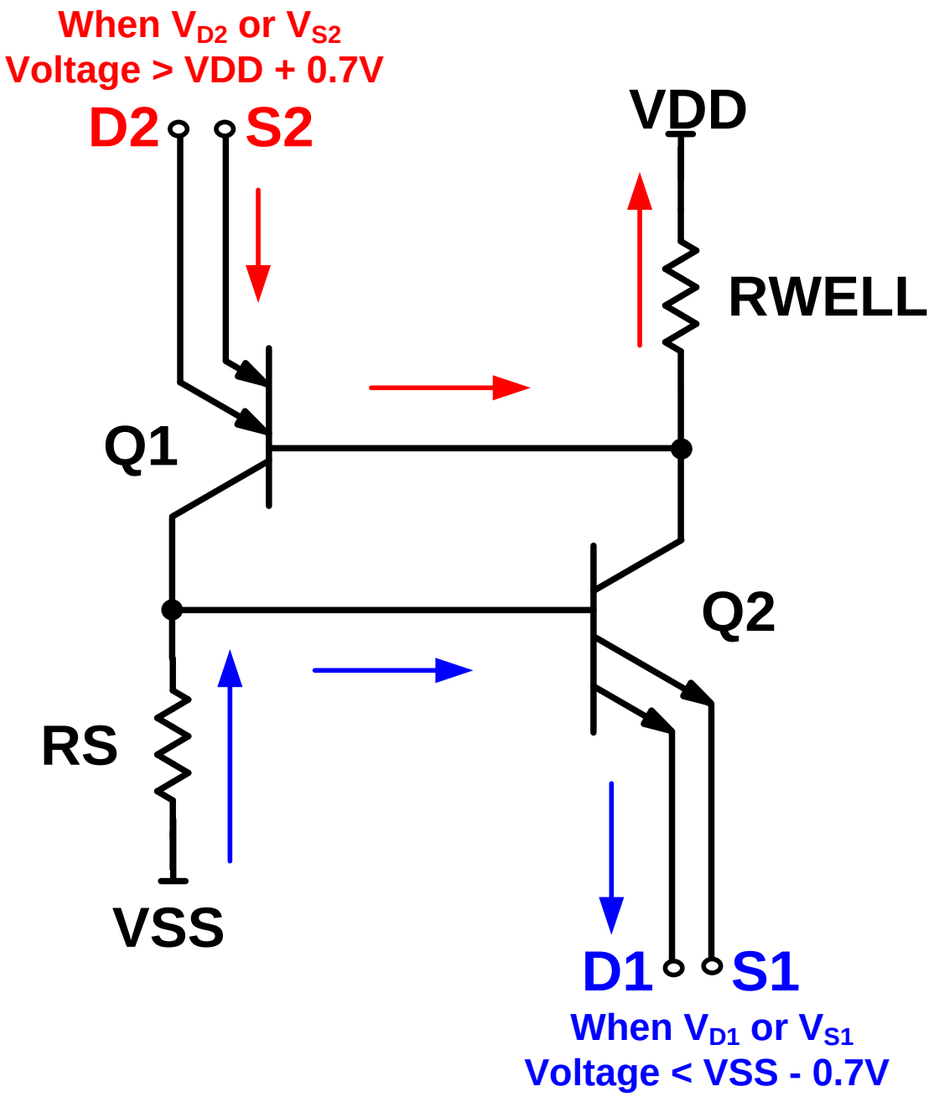
- Parallel combination of N and P channel FET
- Control Signal determines state of the switch
  - Logic High = On
- NMOS impedance = low for negative input
- PMOS impedance = low for positive input
- ESD diodes protect internal circuit from electrostatic discharge

Parasitic Latch-Up in CMOS Switches



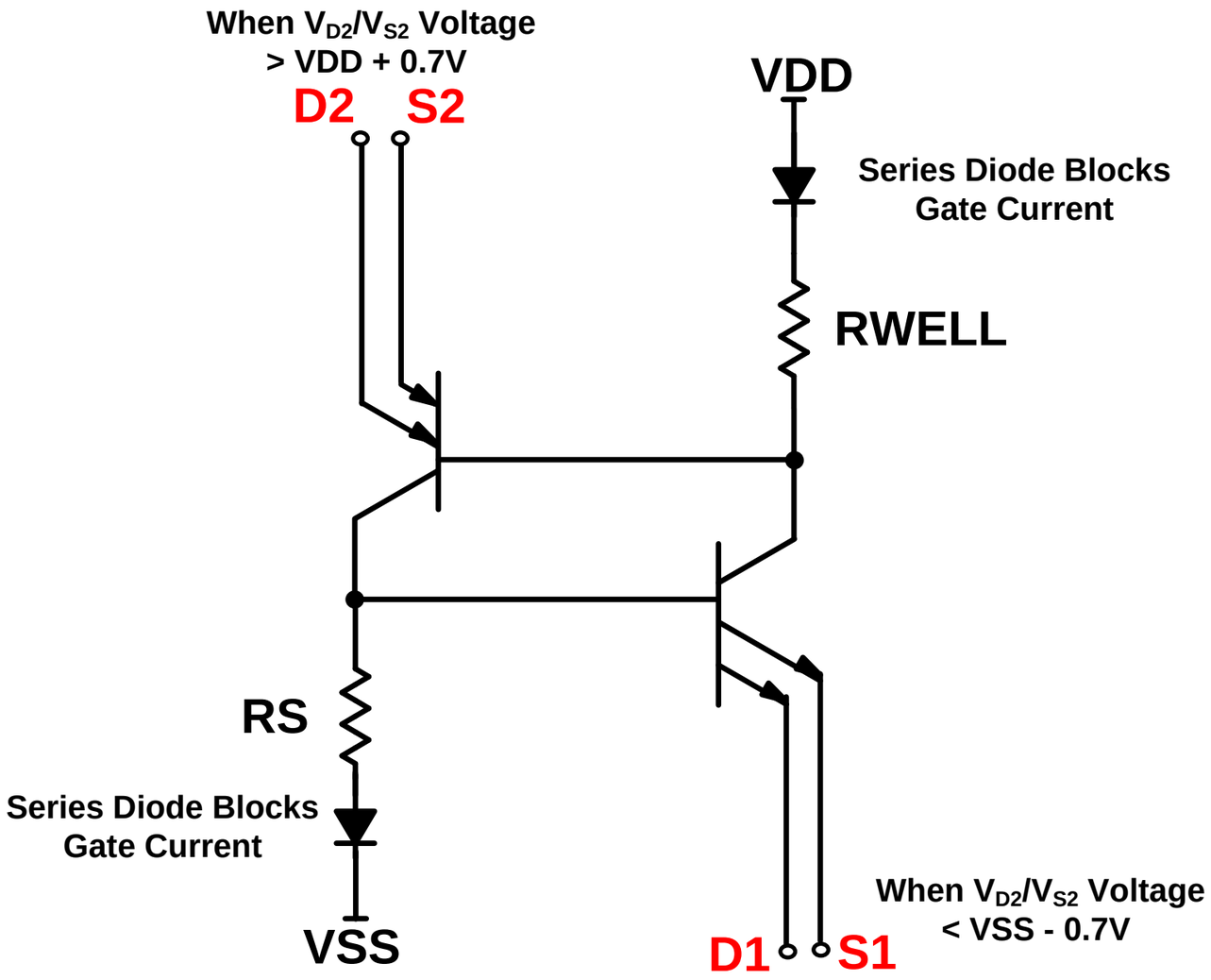


Parasitic Latch-Up in CMOS Switches: SCR Latch



- The parasitic SCR mechanism is shown in here.
- SCR action takes place when either terminal of the switch (source or the drain) is either one diode drop more positive than VDD or one diode drop more negative than VSS.
- Once Triggered, high current will flow between the supplies.

Series Diode Protection Against Latch up



- Series diodes used in VDD and VSS path prevents latch up
- These diodes does not allow reverse gate current to flow in case of over voltage condition
- Input voltage swing limits to

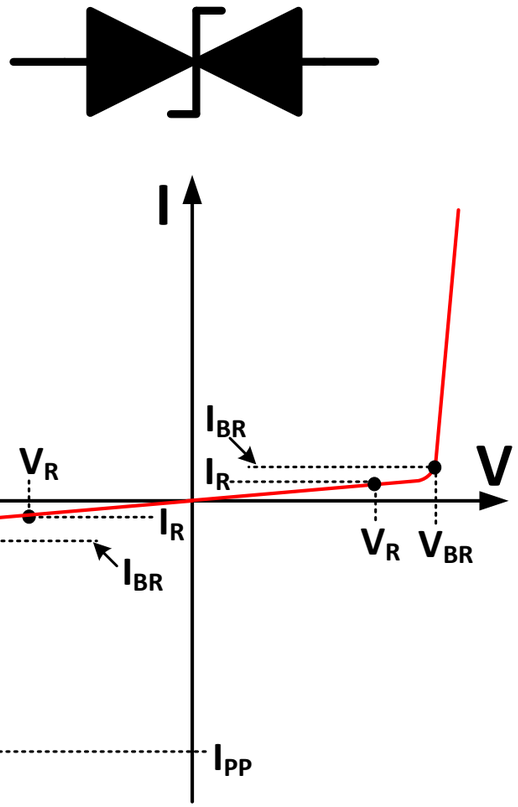
  $V_{IN} <= V_{DD} – 0.7V$ (Typical)
  $V_{IN} >= V_{SS} + 0.7V$ (Typical)

- Reverse voltage of diodes should be greater than maximum over voltage input range

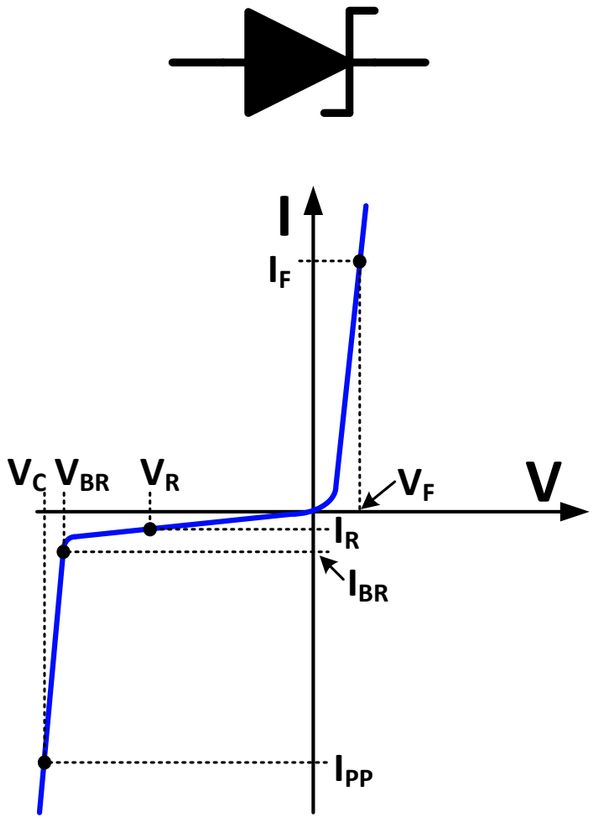
A short background on TVS diodes

Symbol	Parameter
V_{BR}	Breakdown voltage
V_R	Stand-off voltage
V_C	Clamping voltage
V_F	Forward voltage drop
I_{BR}	Breakdown Current @ V_{BR}
I_R	Reverse Leakage @ V_R
I_F	Forward Current @ V_F
I_{PP}	Peak Pulse current @ V_C

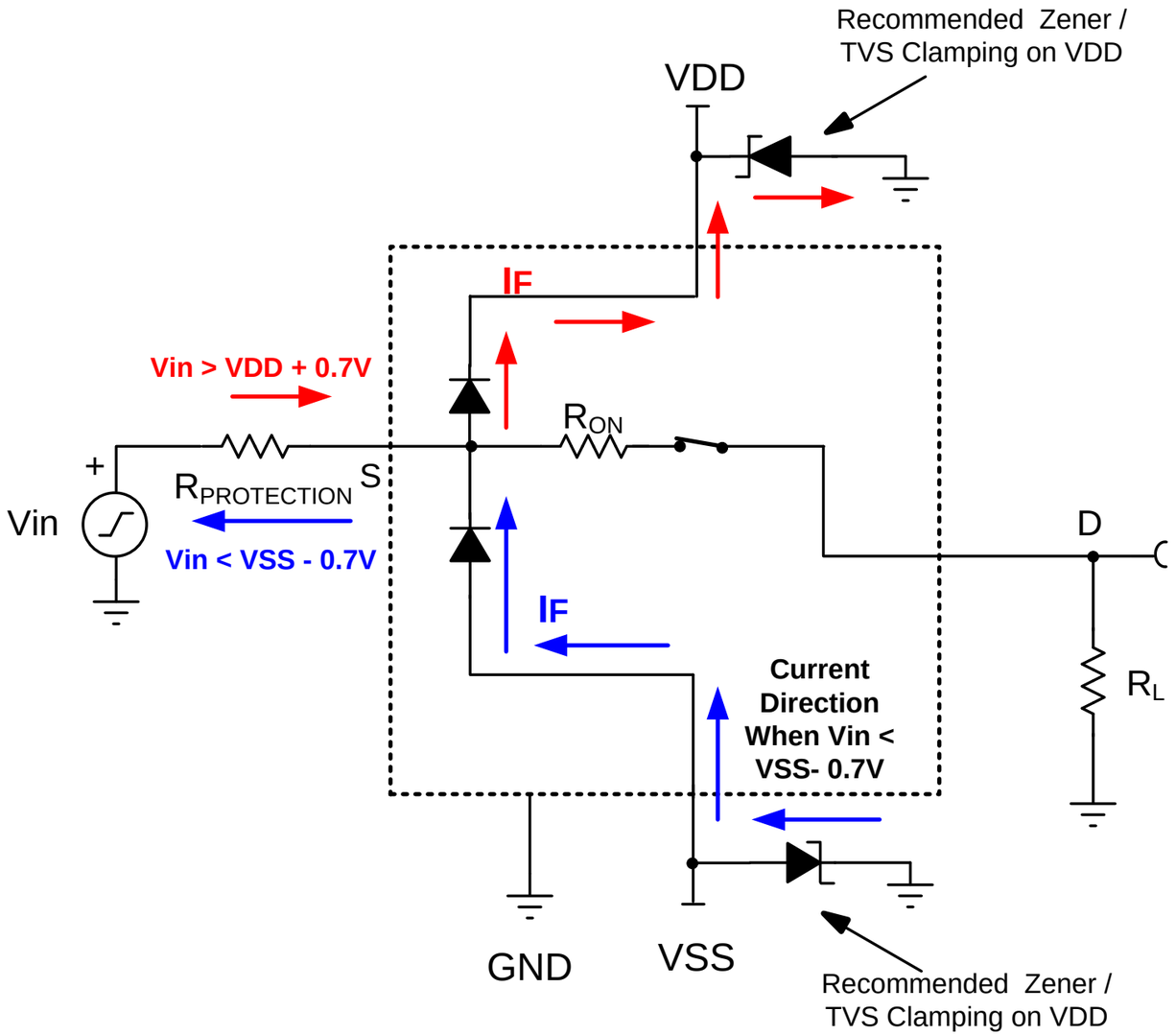
Bidirectional



Unidirectional



Internal ESD Diode & Resistor as EOS Protection



$R_{PROTECTION}$ Example Calculation

$V_{DD} = +15V \quad V_{SS} = -15V$

$V_{OVER\ VOLTAGE}$ at Input Channel $= (+/-)\ 20V$

Let's say internal ESD diode current should not exceed 5mA.

$I_{LIMIT} = 5mA$

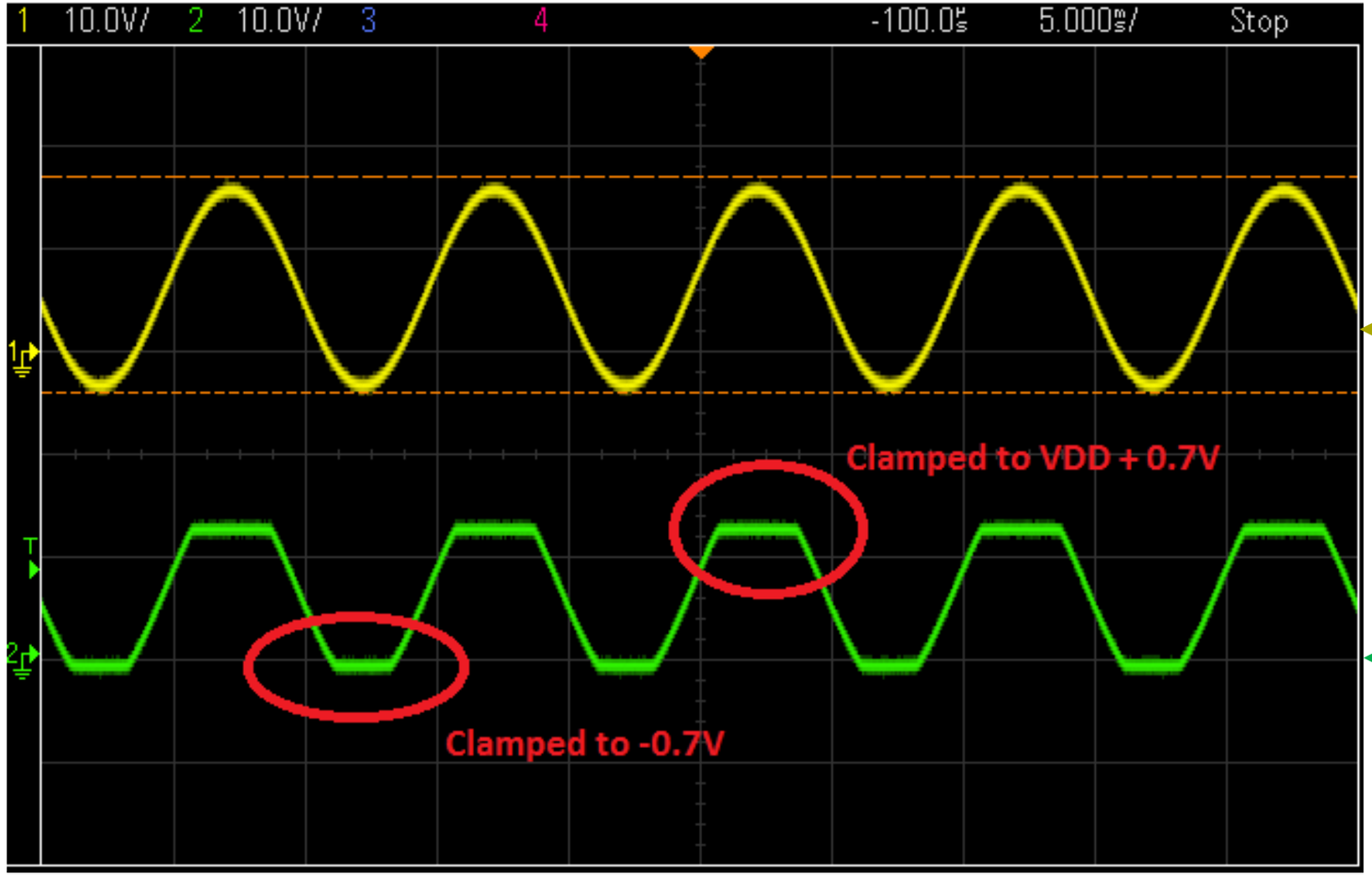
$$R_{PROTECTION} = \frac{V_{IN} - V_{DD} - V_{BE}}{I_{LIMIT}}$$

$$R_{PROTECTION} = \frac{20V - 15V - 0.7V}{5mA}$$

= 860 Ohm.

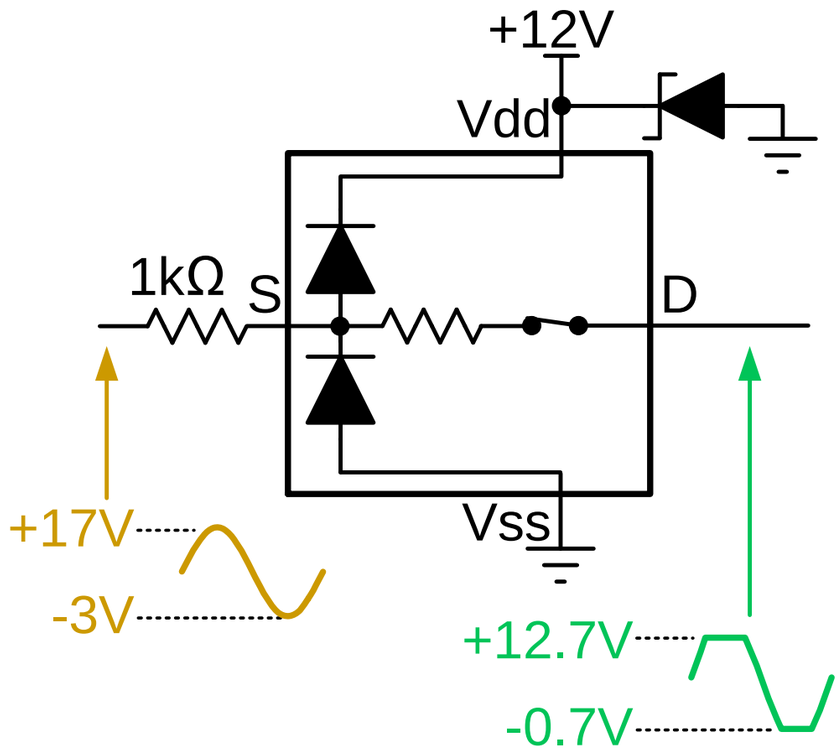
Choose 910 Ohms - Standard Value

MUX36S08 Over voltage Fault Performance



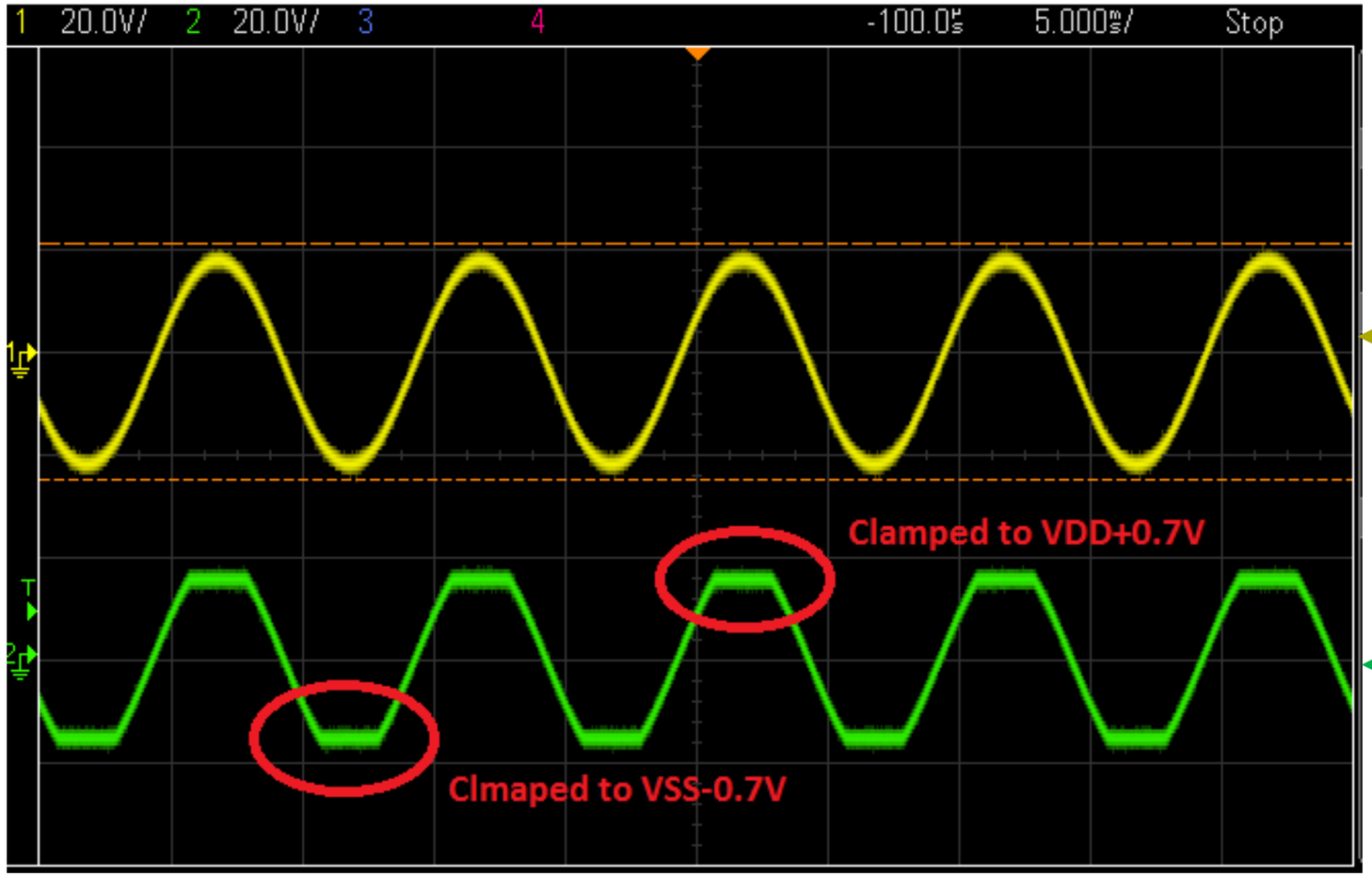
Input
S

Output
D



Vin = 20Vpp, 7V dc offset

MUX36S08 Over voltage Fault Performance



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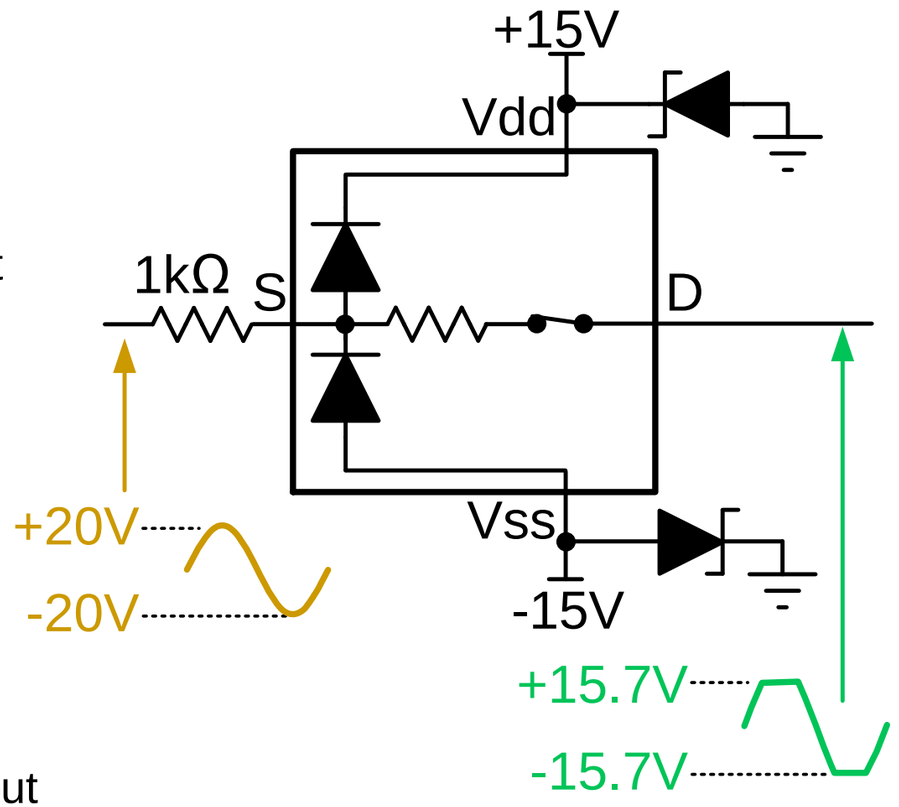
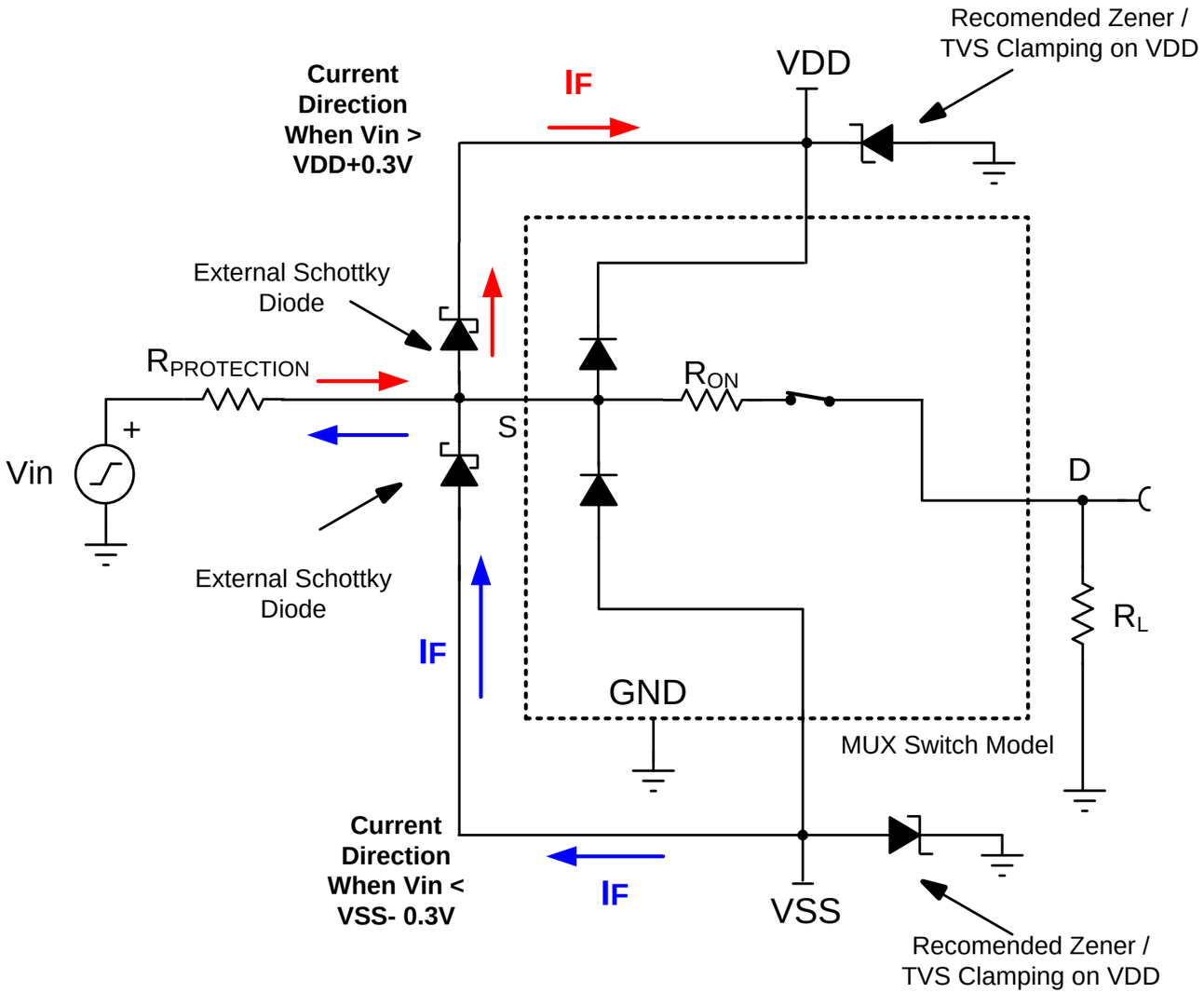


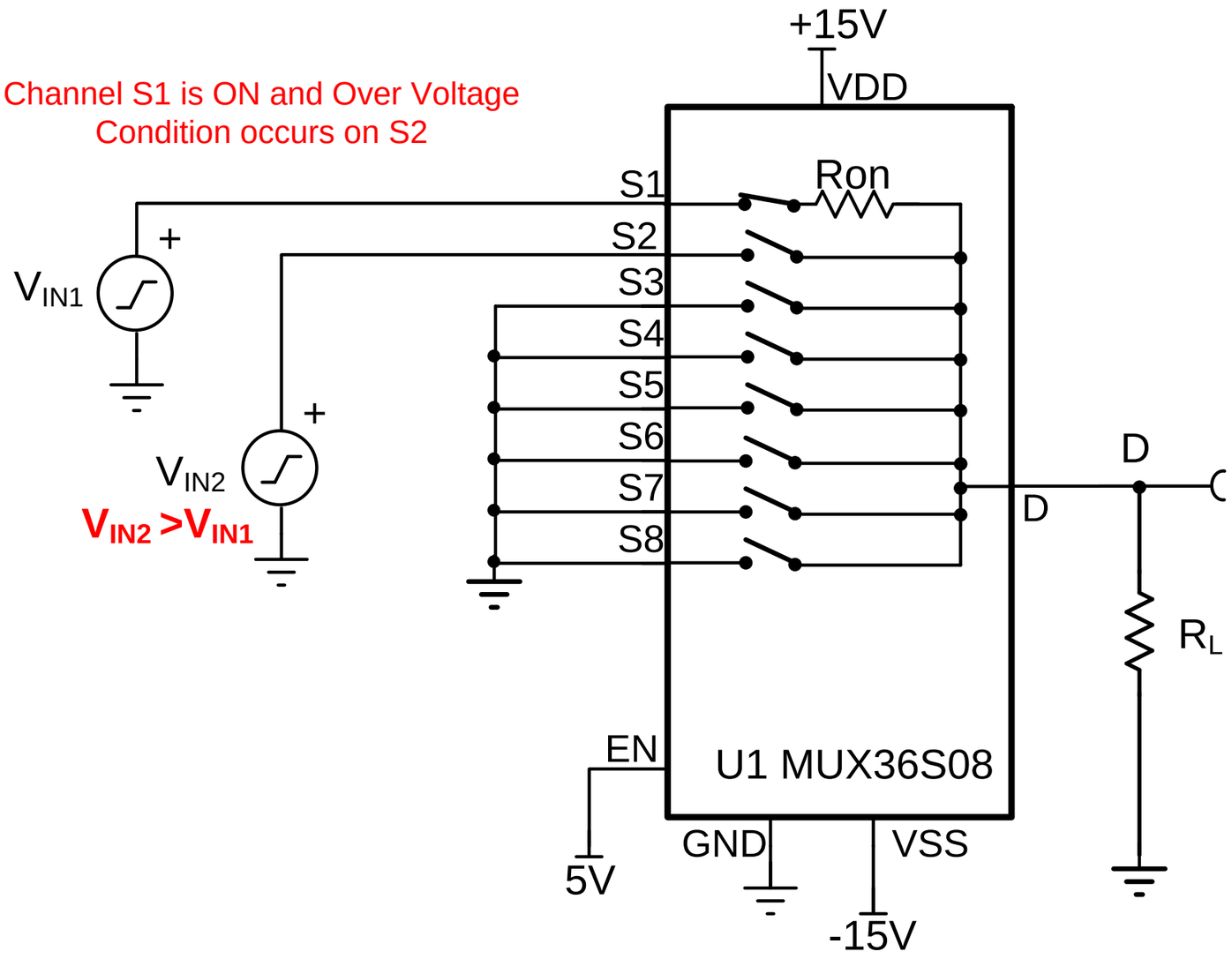
Vin = 40Vpp, 0V dc offset

Using External Clamping Diode as EOS Protection

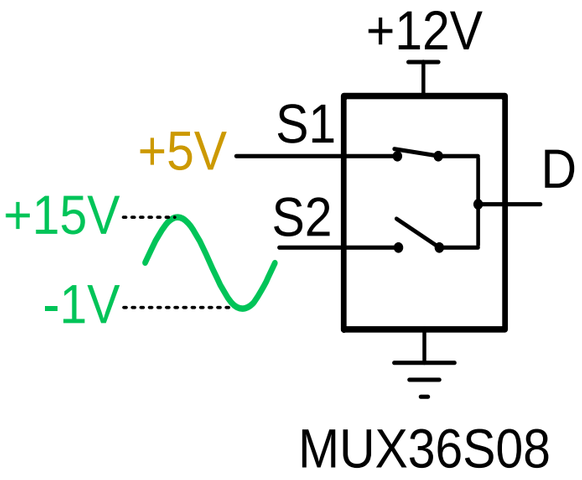


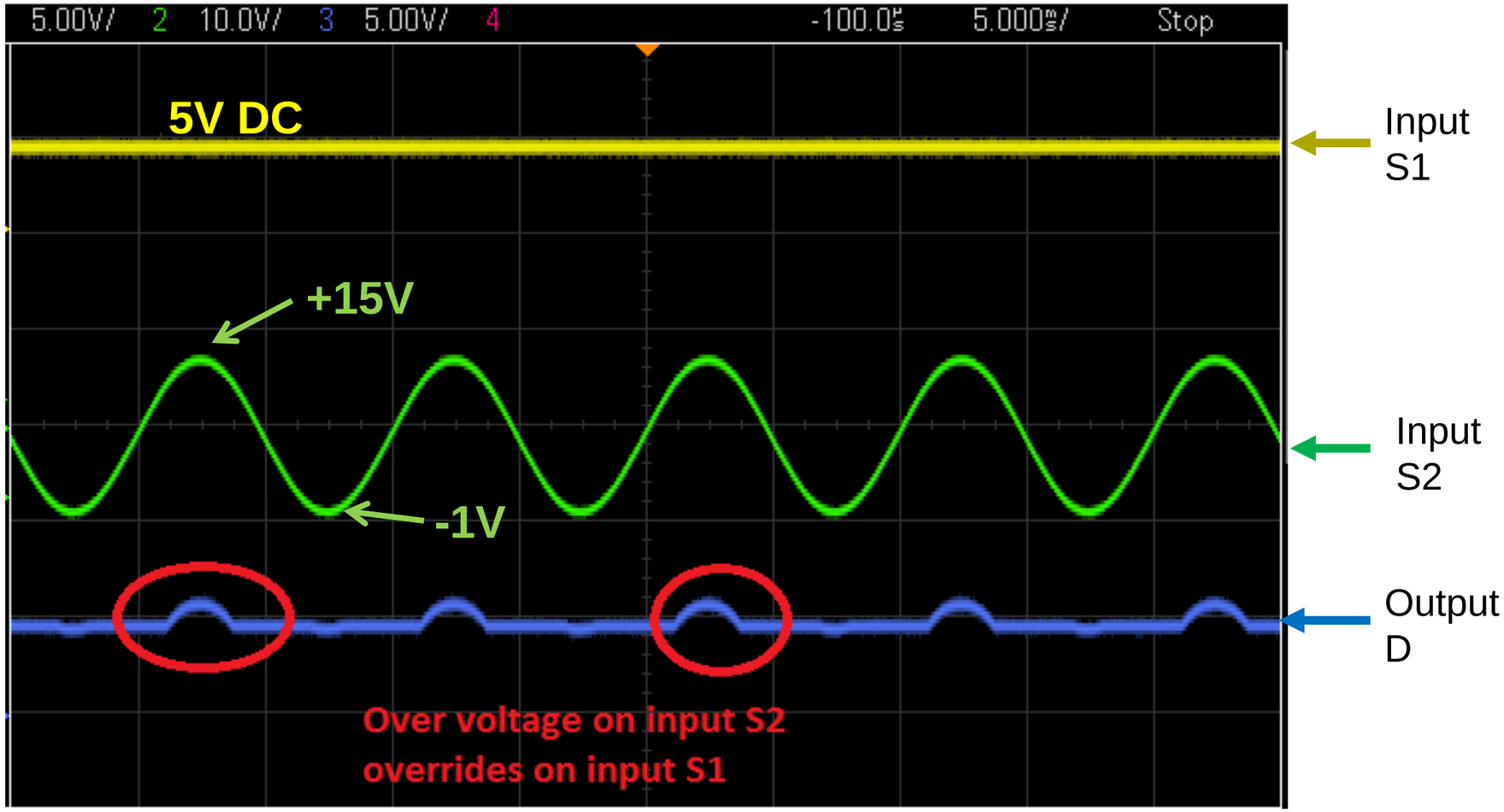
Over Voltage Applied on OFF Channel

Channel S1 is ON and Over Voltage Condition occurs on S2

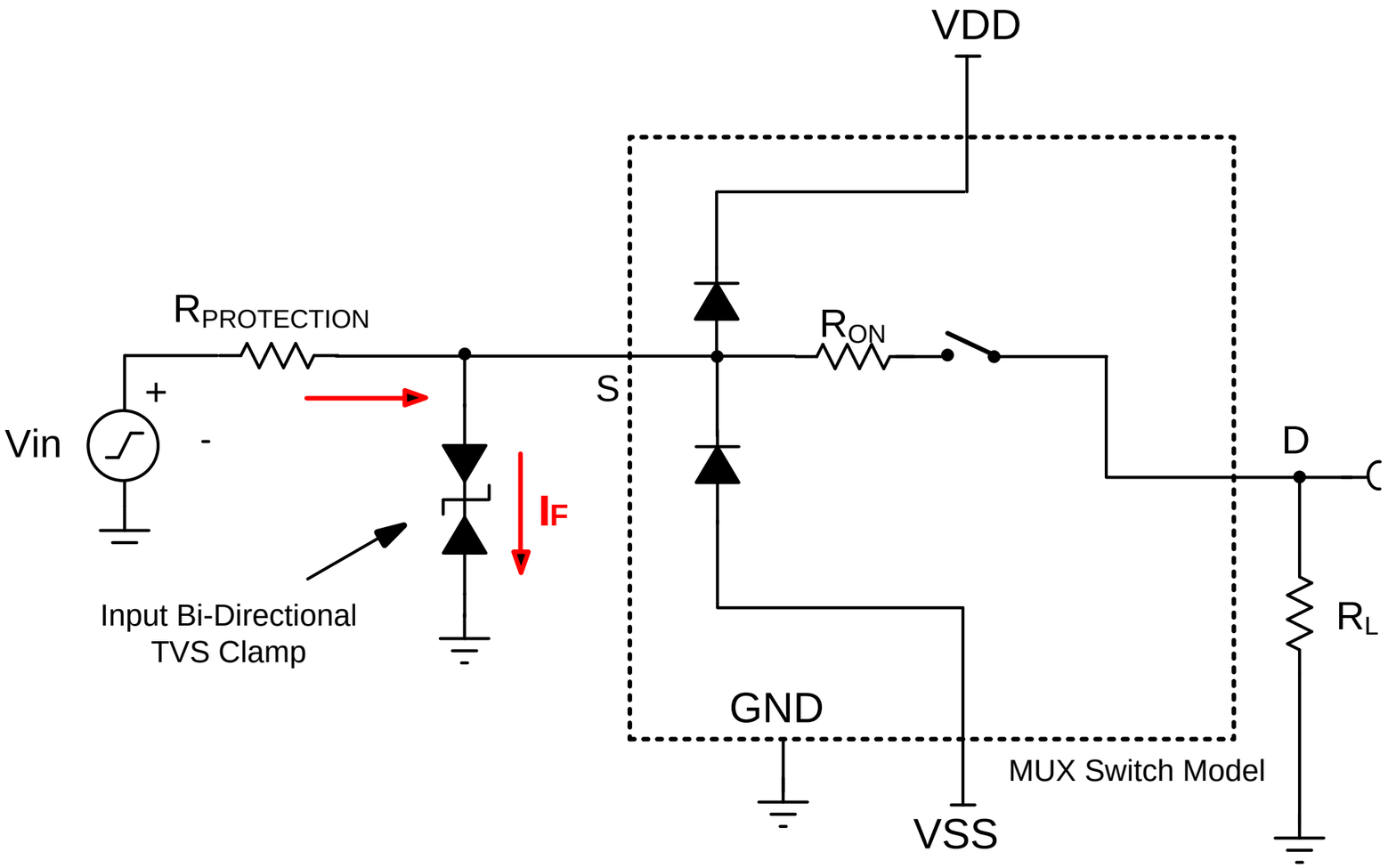


MUX36S08 Over voltage Fault Performance



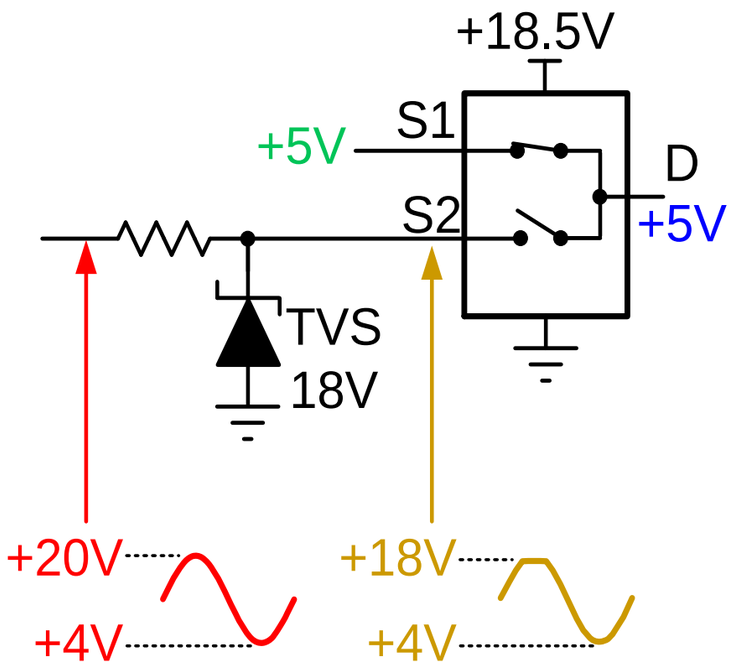


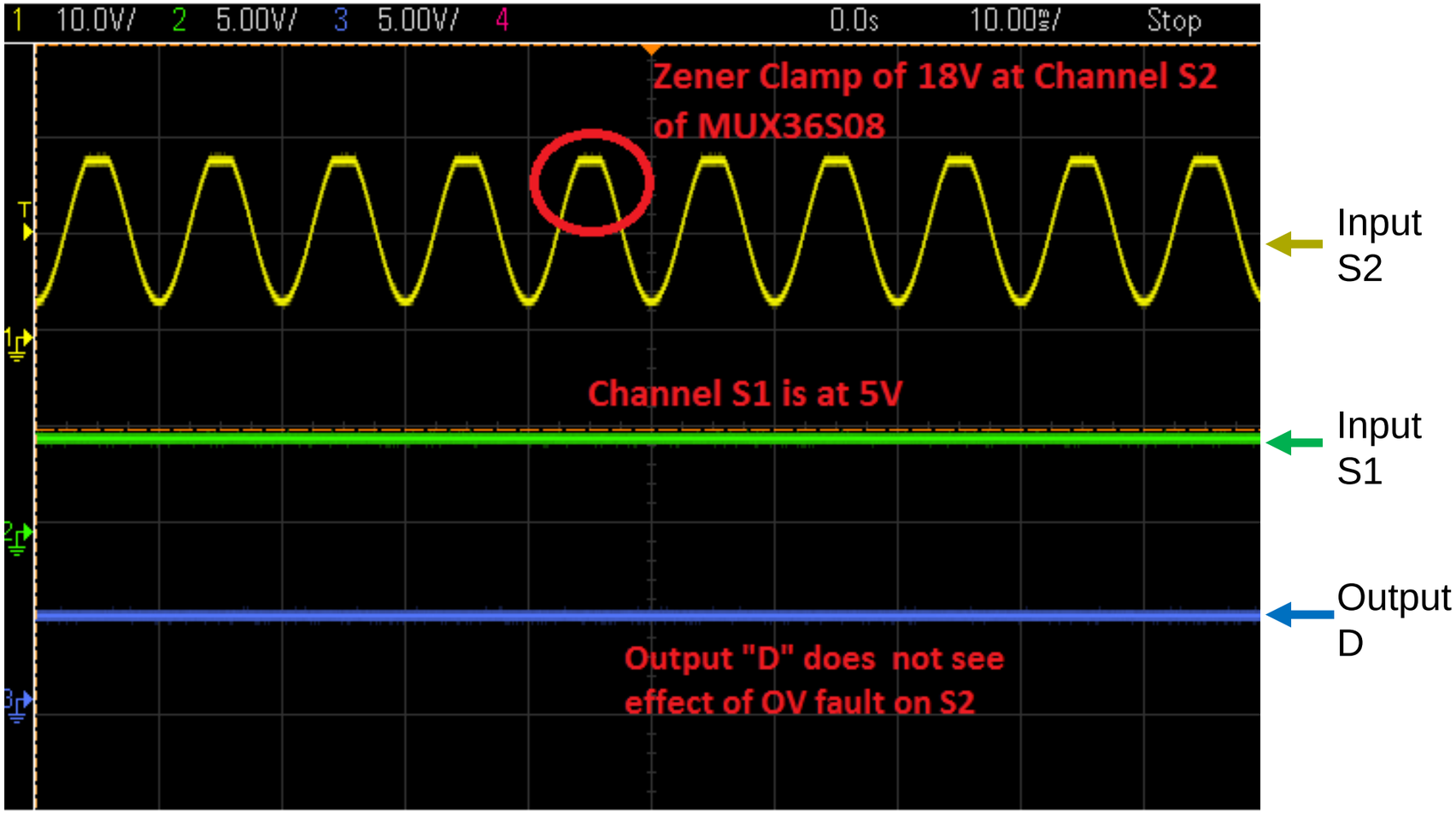
Zener/TVS clamping at Input as EOS Protection



- Input voltage clamped using zener or TVS diode
- Series resistor acts as a current limiting resistor
- For Unipolar operation, Zener diode or unidirectional TVS diode can work
- For Bipolar operation Bi-directional TVS diode has to be selected

MUX36S08 Over voltage Fault Performance





Thanks for your time!
Please try the quiz.

Basics of Analog Multiplexers – 4

Multiple choice quiz

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Quiz: Basics of Analog Multiplexers – 4

1. The primary function of the internal ESD diodes in the multiplexer device is
   a. To give protection against ESD events during assembly and test of the devices.
   b. To clamp the input/output pin to reference point (Supply pins/ GND etc) in the case of an ESD event.
   c. Turn off the device in case of ESD event.
   d. Both a & b

2. A latch up condition in a CMOS switch
   a) Is an undesirable activation of the parasitic SCR structure.
   b) Has no effect of functionality of device.
   c) Can lead to excessive current flow in to the device.
   d) Both a and c

Quiz: Basics of Analog Multiplexers – 4

3. Which one of the following is the protection scheme for a multiplexer in the case of an over-voltage/over-current event at the input?
   a) Adding a series protection resistor between the input source and the multiplexer input channel
   b) Clamping the supply pins using a Zener diode or TVS
   c) Clamping the input voltage within the device recommended conditions using a Zener diode or TVS clamp
   d) All of the above

4. Adding series diodes in the multiplexer supply path can
   a) Help prevent latch up
   b) Limit the signal swing at the multiplexer input
   c) Has no effect on the multiplexer parasitic latch up
   d) Both a & b

Quiz: Basics of Analog Multiplexers – 4

5. Protection schemes that include an external schottky diode clamp
   a) Help with the reduction of device power dissipation in the case of over-voltage.
   b) Should have schottky diodes with a forward drop less than that of the internal ESD diodes of the device.
   c) Should have schottky diodes with a forward drop higher than that of the internal ESD diodes of the device.
   d) Both a & b

Basics of Analog Multiplexers – 4

Multiple choice quiz - solutions

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Quiz: Basics of Analog Multiplexers – 4

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Exercises

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1. A multiplexer MUX36S08 has the following test conditions.

VDD = 18V, VSS connected to GND = 0V, Vin (max) = 25V

Calculate the value of the series protection resistor.

(Internal ESD diode current should be limited to 4mA. Internal ESD diode forward voltage drop is 0.7V.)

2. The multiplexer used in particular application has a use-case where an over-voltage event occurs on ab OFF channel as shown below. Choose an input series protection resistor and Zener diode with the proper clamping voltage so that the break down current of the Zener diode is not more than 5mA.

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Solution

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Calculate the value of the series protection resistor.

(Internal ESD diode current should be limited to 4mA. Internal ESD diode forward voltage drop is 0.7V.)

$R_{PROTECTION}$ Calculation

$V_{DD} = +18V \quad V_{SS} = 0V$

$V_{OVER\ VOLTAGE}$ at Input Channel $= 25V$

Internal ESD diode current should not exceed 4mA.

$I_{LIMIT} = 4mA$

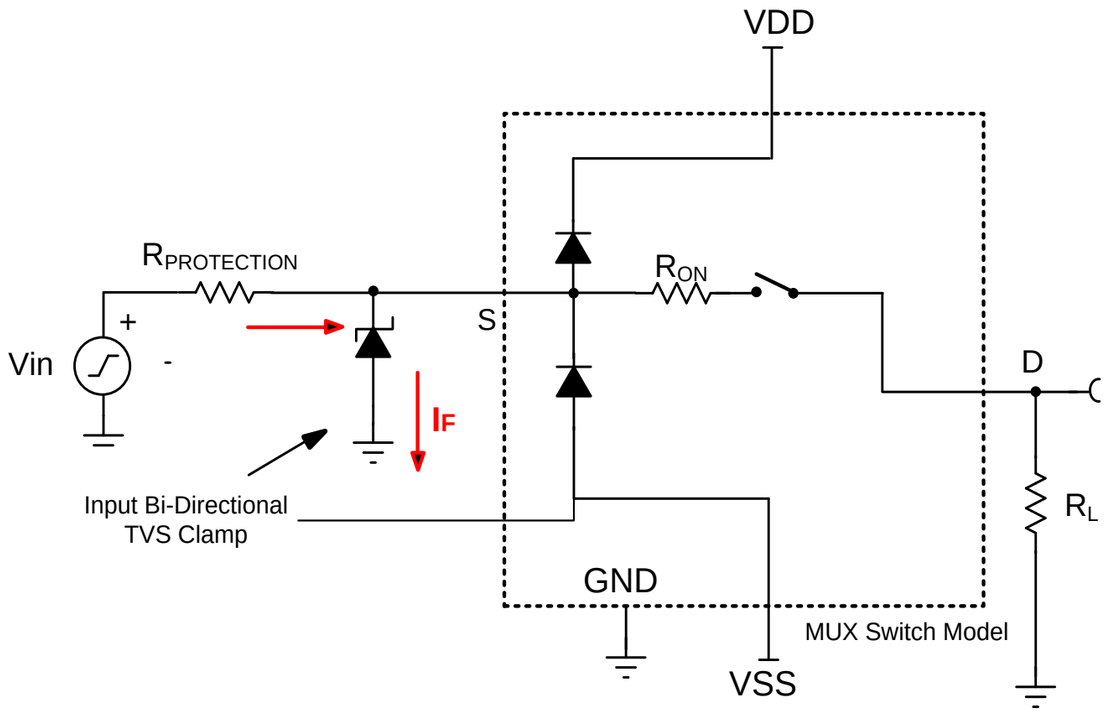
$$R_{PROTECTION} = \frac{V_{IN} - V_{DD} - V_{BE}}{I_{LIMIT}}$$

$$R_{PROTECTION} = \frac{25V - 18V - 0.7V}{4mA}$$

= 1.57 k ohm. Choose 1.6 k ohms - Standard Value

2. The multiplexer used in particular application has a use-case where an over-voltage event occurs on an OFF channel as shown below. Choose an input series protection resistor and Zener diode with the proper clamping voltage so that the break down current of the Zener diode is not more than 5mA.

The input protection on the OFF channel with a series resistor and Zener Diode clamping is shown in the below figure. We will now see how to calculate the value of RPROTECTION and the Zener Breakdown Voltage.



$R_{PROTECTION}$ Example Calculation

$V_{DD} = +13V \quad V_{SS} = 0V$

$V_{OVER\ VOLTAGE}$ at Input Channel $= 15V$

Breakdown current of Zener diode should not exceed 5mA.

$I_{LIMIT} = 5mA$

$$R_{PROTECTION} = \frac{V_{IN} - V_{DD} - V_{BE}}{I_{LIMIT}}$$

$$R_{PROTECTION} = \frac{15V - 13V - 0.2V}{5mA}$$

= 360 Ohm.

Choose 365 Ohms - Standard Value