# Introduction to Schottky Diode Networks

Technical advances in the electronics industry, particularly in today's hand-held and portable communication products, has resulted in faster and much more complex semiconductor devices and systems. In this rapidly changing environment, engineers are increasingly confronted with issues that were of minor significance when using slower circuits. The most prominent of these issues is the effects described in the line theory, i.e. line reflections, the signal distortions that they cause, and ultimately the malfunctions that can result by overshoots or undershoots on the signal edges. Schottky diode networks, which are available in various configurations, can in most cases be used to eliminate/prevent these effects from leading to problems in a system.

## Line Reflections

If transmission lines (such as the various data busses in a printed circuit board) are not properly terminated at their ends, the energy transported on a line is not consumed but instead reflected back into the line. These reflections lead to substantial signal distortions. Lack of proper termination at the high frequencies will cause reflections/ringing at the signal edges, which in turn will lead to false triggering of the digital logic and malfunction.

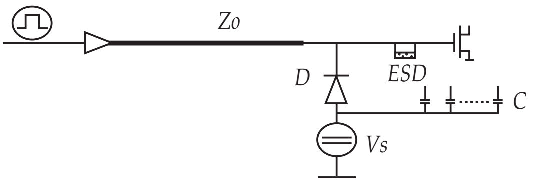


Fig. 1: Simplified circuit (typical) for a Memory module application.

The above-simplified circuit shows similar conditions found in a typical memory module. The ESD circuit (or device) while protecting the input stage transistor also introduces very high impedance to the circuit. The diode conducts when there is a negative overvoltage.

Fig. 2 shows a typical signal form that is produced by a negative edge at the output of a typical CMOS circuit and at the end of the line in the configuration described above. While the signal at the start of the line shows the required response (due to the low resistance), considerable distortion occurs at the end of the line. If this line happens to be an address line, then the distortion could result in the wrong memory cell to be addressed or if the line were to be a data line, then data corruption is likely to occur.

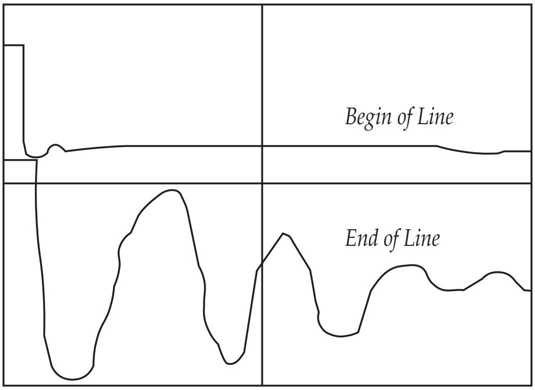


Fig. 2: Typical signal form for high impedance line termination (open-circuit line) for a typical CMOS-type circuit.



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There are several approaches used to eliminate/ reduce the effects of the reflections in the transmissions. There are several commonly used methods for line termination:

### Line Terminated with Resistor

In this case, the energy transported on the line is consumed by the terminating resistor whose value, in an ideal case, is equal to the line impedance.

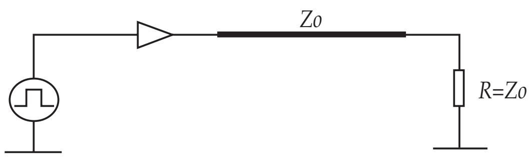



Fig. 3: Line termination using a resistor.

The use of resistors for line termination is ideally suited for ECL type circuits, but is not well suited for TTL and CMOS circuits due to the much higher power consumption caused by the current in the terminating resistor. One additional drawback of using a pure resistive termination is the inability to estimate the exact value of resistors that might be required to match the line impedance.

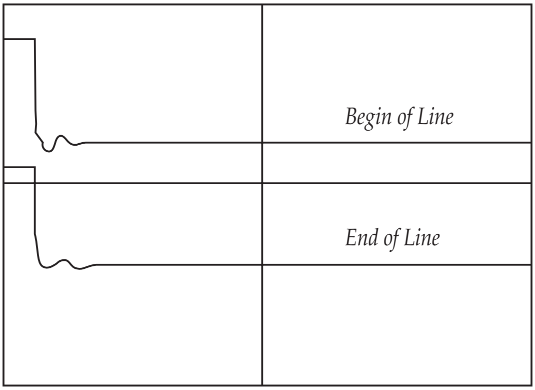



Fig. 4: Typical signal at the beginning and end of an ideally terminated line.

### Line Terminated with Clamping Diodes

Another approach for reducing the distortion caused due to line reflections is to connect clamping diodes at the end of the line to limit the overshoot and undershoots (see Fig.5). This approach ensures that the voltages which are permissible on the circuit inputs of the circuit are maintained and that the inputs of the connected IC's are not overloaded. The diode helps to direct the currents from the over or undershoots to regions that do not affect the circuit (such as Vcc or Vss). Although, with diodes there is a possibility for multiple reflections. These reflections are minimized and signal integrity is fairly well maintained as shown in Fig. 6


Fig. 5: Line termination using clamping diodes.

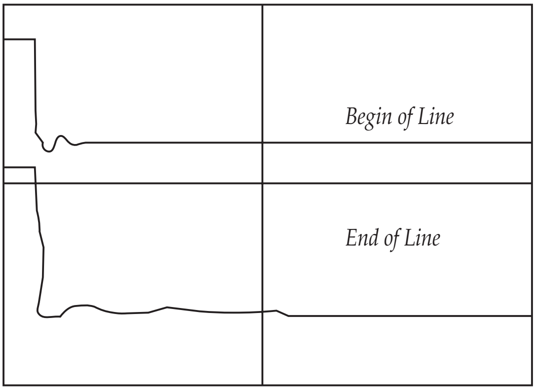



Fig. 6: Typical signal at the beginning and end of line terminated with clamping diodes.

## Schottky Diode Networks

Bipolar logic circuits already have clamping diodes on their inputs that limit undershoots caused by line reflections to a sufficient degree. However, for many advanced CMOS circuit applications (requiring a high drive capability), additional clamping diodes or diode networks are required.

Precautionary measures against overshoots or undershoots caused by line reflections are essential in the driving of complex (VLSI) circuits. With these devices the protective circuits (clamping diodes) present in the inputs and outputs are seldom capable of damping the voltage spikes or properly discharging the currents. Even if the VLSI circuits contain clamping diodes for limiting undershoots and ensuring that the signals are adequately free of distortion, it must be recognized that part of the negative input current is not conducted to ground, but instead drifts into the substrate of the IC, where it could result in random errors in the functionality of the circuit.

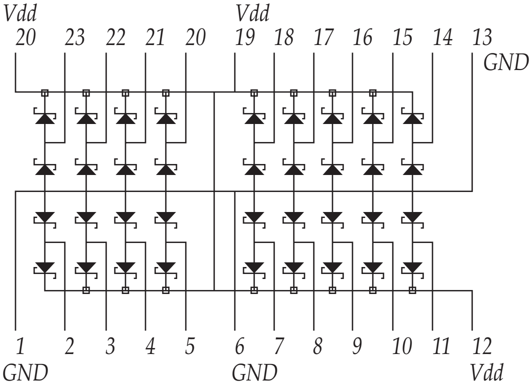
Based on the above facts, typical applications for Schottky Diode Networks are all bus systems on circuit boards that use drivers either with high drive capability and/or a large signal swing (CMOS), where signal distortion is very likely. These diode networks should also be used where VLSI circuits are directly connected to buses that do not have any buffer stages in between.

Critical applications for clamping using Schottky Diode Networks include:

- SRAM and DRAM
- Microprocessors and Microcomputers
- Complex controller circuits

A typical application for these networks is in memory modules, where the lengths of the interconnections are typically long. Resistor networks are better candidates for backplanes of large systems. However, for PC's that use the ISA or the EISA bus architecture, the Schottky Diode Networks are a better alternative compared to resistor terminations.

Schottky Diode Networks for damping line reflections are offered in various configurations. A typical Schottky Diode Network configuration offered by KOA is shown at the top of the next column.




Schottky Diode Networks consist of a number of diodes whose anodes are brought out to one or more terminals for connection to ground and whose cathodes are brought out to one or more terminals for connection to Vcc. In this configuration, the negative undershoots are clamped to ground and the positive overshoots are clamped to Vdd.

Schottky diode benefits:

- Short turn-on time
- Short turn-off time
- Short reverse recovery times
- Low forward voltage (<0.5V)

## Summary

In the absence of any line termination, as shown in Fig.7, there could be a large undershoot of the negative edge of a signal and possibly a corresponding overshoot, which may result in erroneous data or system malfunction.

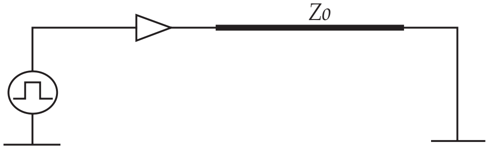



Fig. 7: Line without any termination.

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Signal distortions at the end of the line can be avoided almost entirely by matching the output resistance of the driver to the line impedance (Fig 8.). However, this arrangement increases the propagation delay at the driver output. For this reason such a circuit is mostly unsuitable in bus systems. Also, in some systems (such as Memory modules) it is very difficult to estimate the exact line impedance.

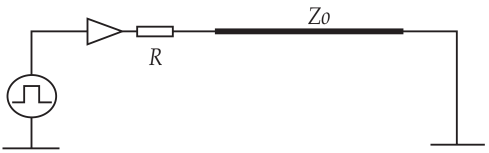


Fig. 8: Line with matching of driver and series resistance.

Schottky diodes at the end of the line (Fig. 9) absorb the energy of the transmission line and thus prevent large positive overshoots or negative undershoots.

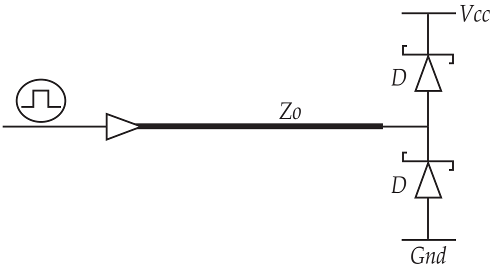


Fig. 9: Line with Schottky Diode Termination.

Diode clamps (as shown in Fig. 9) at the end of transmission lines minimize the effect of reflections by a clamping mechanism as opposed to a termination function. This clamping mechanism is not dependent upon any matching to the impedance of the transmission line. In circuits like the memory modules or memory arrays, it is difficult to estimate the exact line impedance. As memory devices are added or deleted, the characteristic impedance becomes a variable and in most cases an unknown. In such cases, the resistor-termination method becomes less practical and clamping with Schottky Diodes is ideally suited.

Schottky Diode Terminations are effective in a variety of situations. Typical applications for Schottky Diode Terminations include systems that are user expandable (i.e. variable impedance) such as DRAM, SRAM, SDRAM, Cache memory and peripheral buses. They can also be used in systems with fixed impedance environments such as medium to high-speed microprocessor buses.