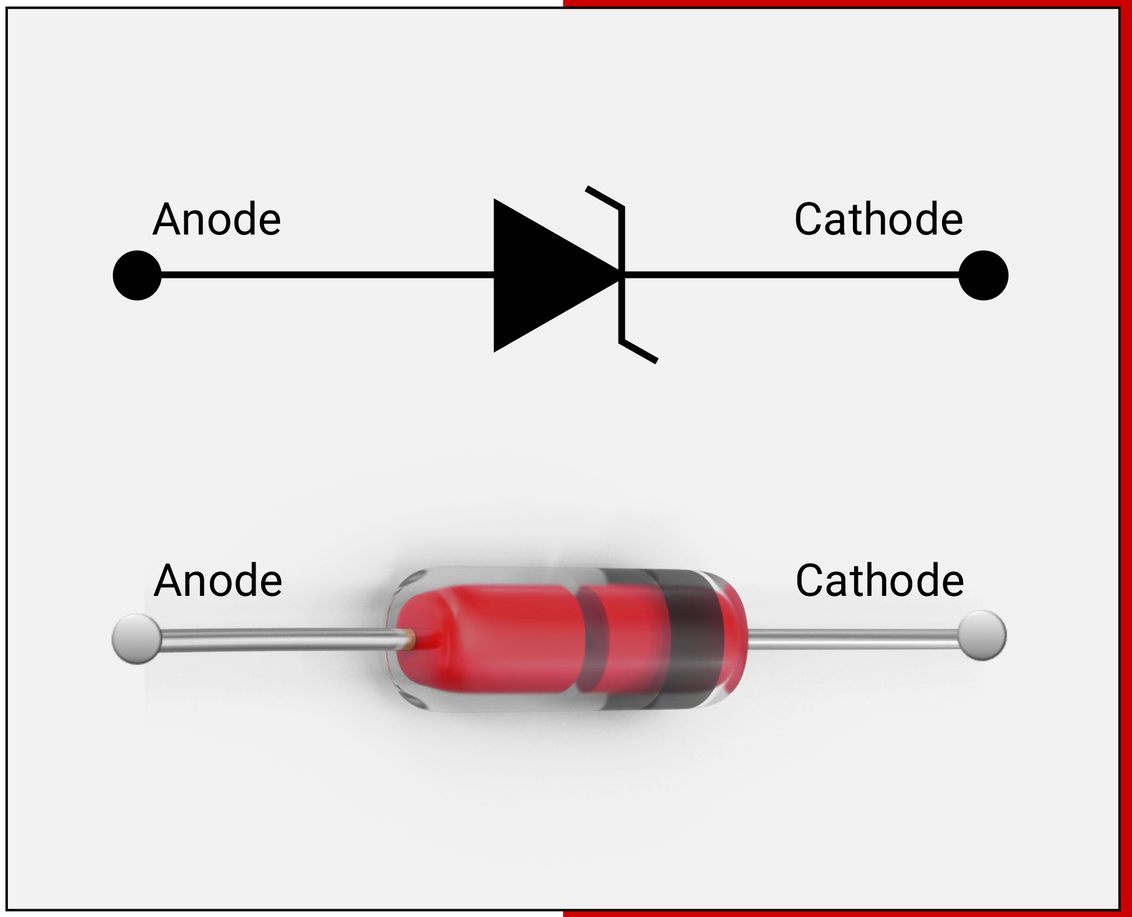
Understanding Zener Diodes

A Technical Guide for Engineers



Micro Commercial Components

What are Diodes?

Diodes act as **electrical check valves**, allowing current to flow in only one direction

Regular Diodes

Zener Diodes

Through **doping and structural design**, the basic p-n junction evolves into specialized diode types

Rectifier Diodes	Schottky Diodes	LEDs	TVS Diodes	Zener Diodes
Power Conversion (AC to DC)	High-Speed Switching	Light Emission	Voltage Spike Protection	Voltage regulation

What is a Zener Diode?

Function

Allows reverse current flow once a set breakdown voltage is reached.

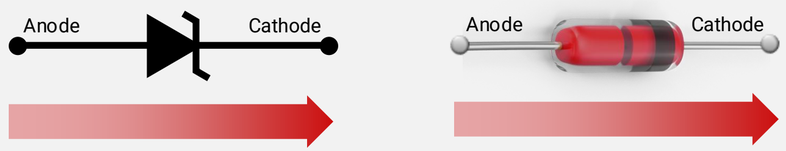
Purpose

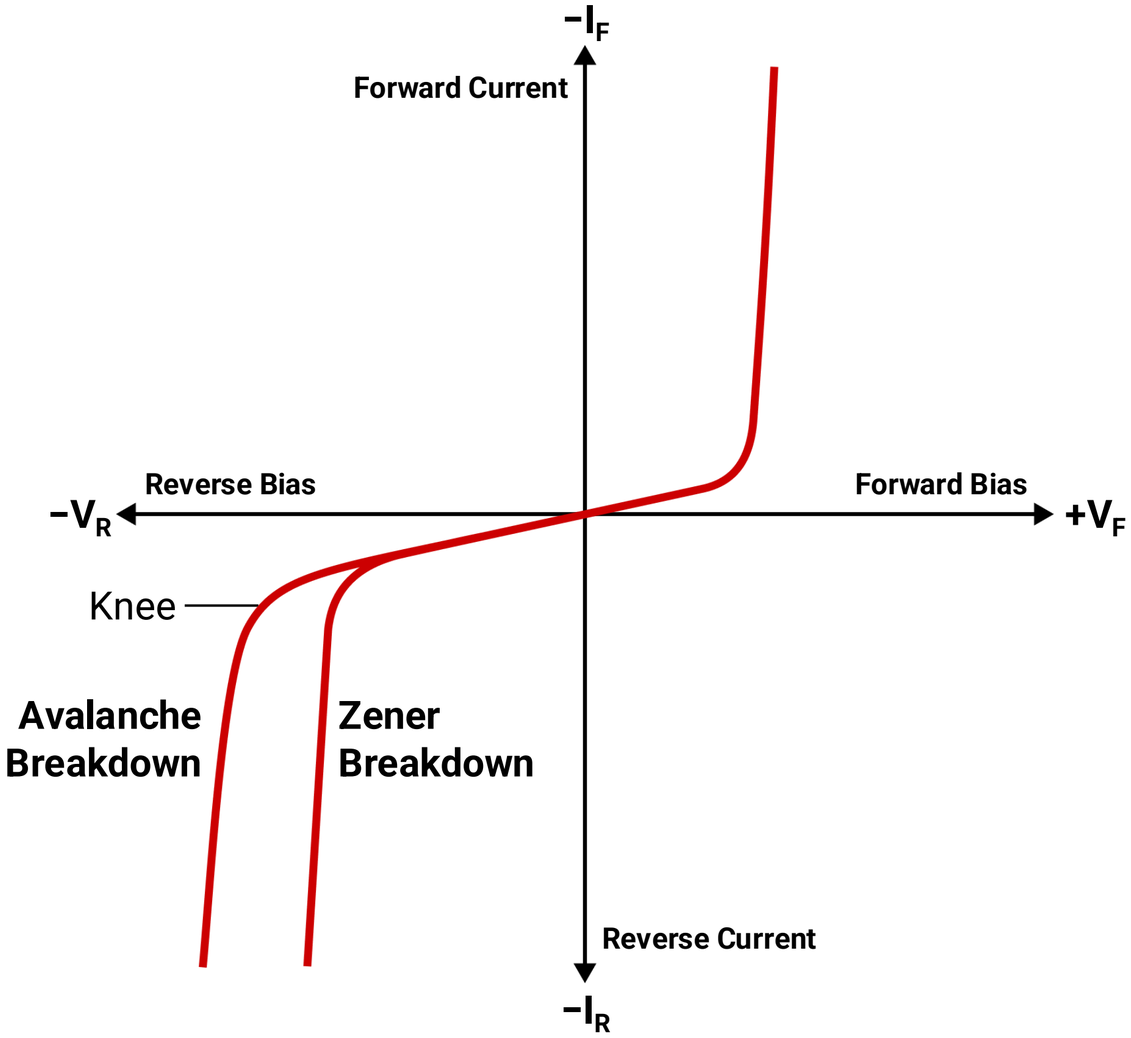
Maintains a stable voltage and protects circuits from overvoltage

Use Case

Common in power supplies, voltage regulators, and protection circuits

Direction of “Normal” Diode Current Flow





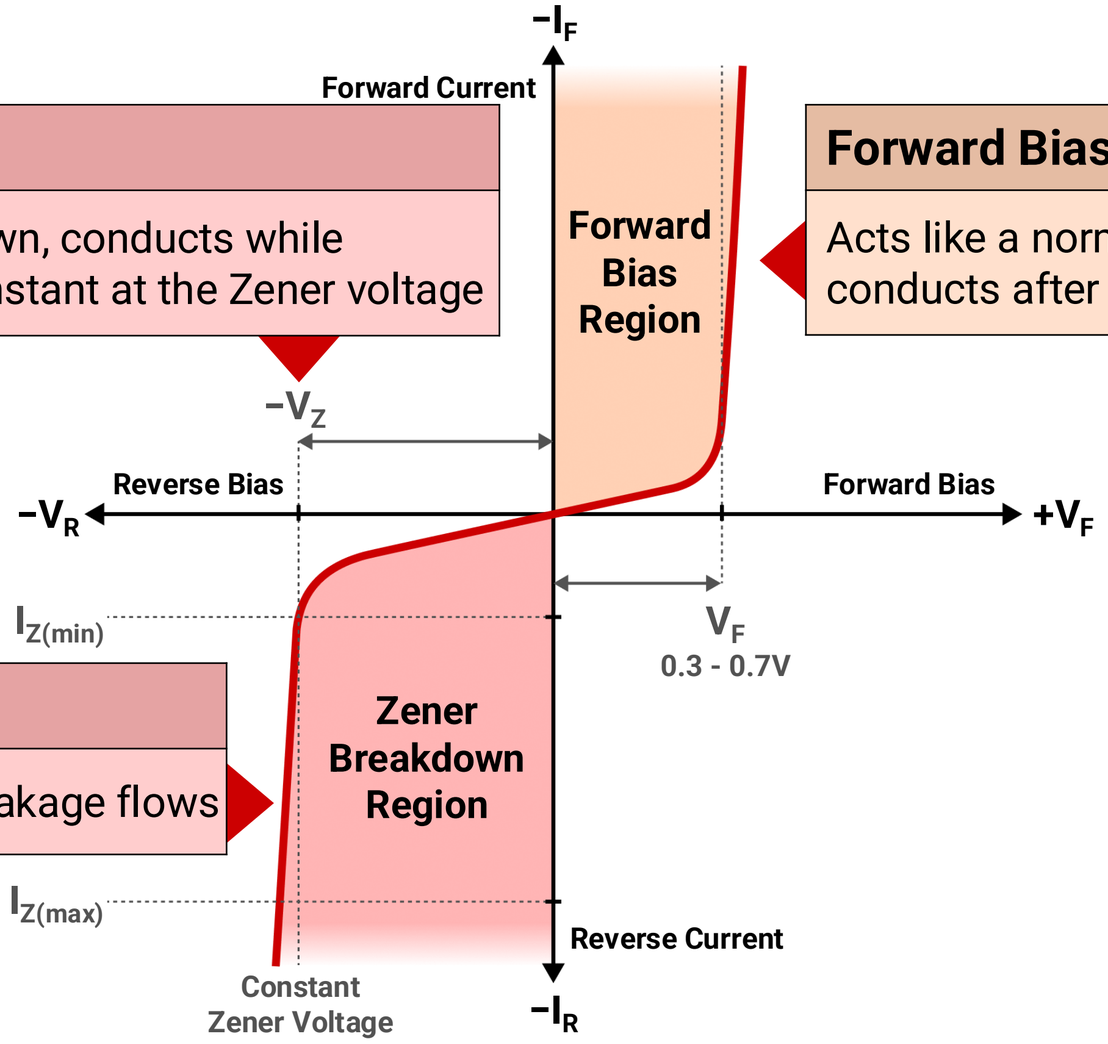
How Does a Zener Diode Work?

Reverse Bias at V_Z

Enters controlled breakdown, conducts while keeping voltage nearly constant at the Zener voltage

Forward Bias

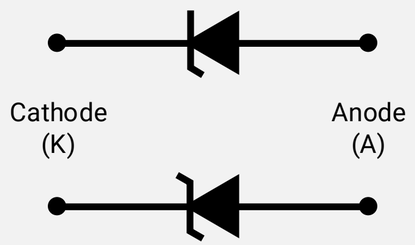
Acts like a normal diode, conducts after ~0.7V



Reverse Bias below V_Z

Blocks current, only tiny leakage flows

Symbol Variants



Why Zener Diodes are Useful

Stable Voltage Regulation

Maintains a constant voltage under varying load conditions

Fast Transient Response

Reacts quickly to sudden voltage spikes

Compact and Cost-Effective

Smaller and Cheaper than integrated voltage regulators

Precision Options

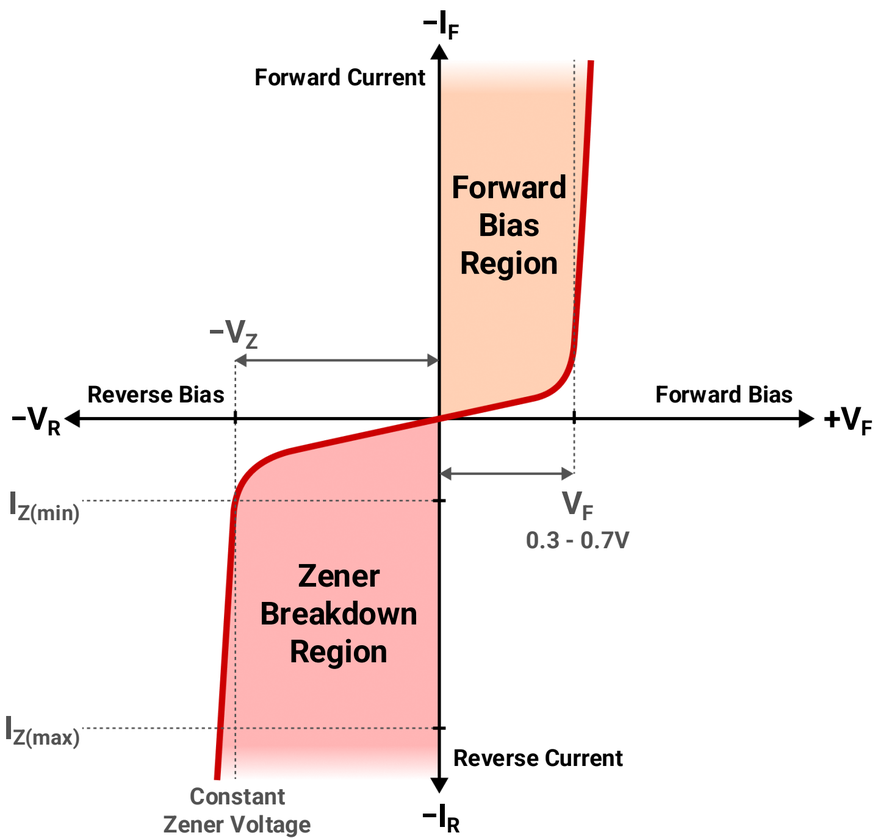
Temperature-compensated versions available for accuracy

Low Standby Power

Consumers minimal power when idle

Easy to Integrate

Simple to add into existing analog or embedded designs



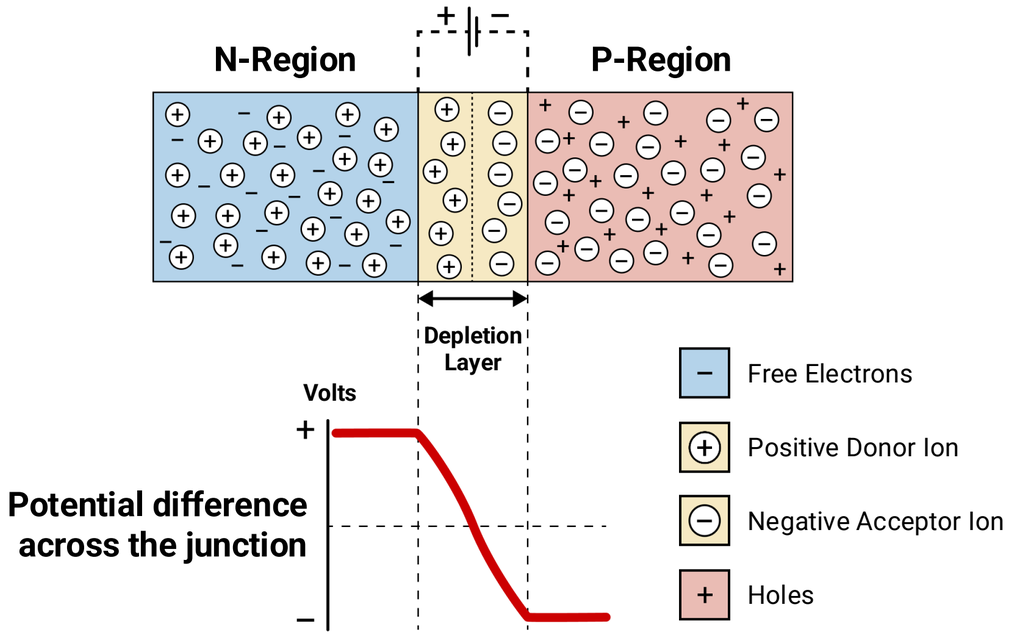
Breakdown Mechanisms Explained

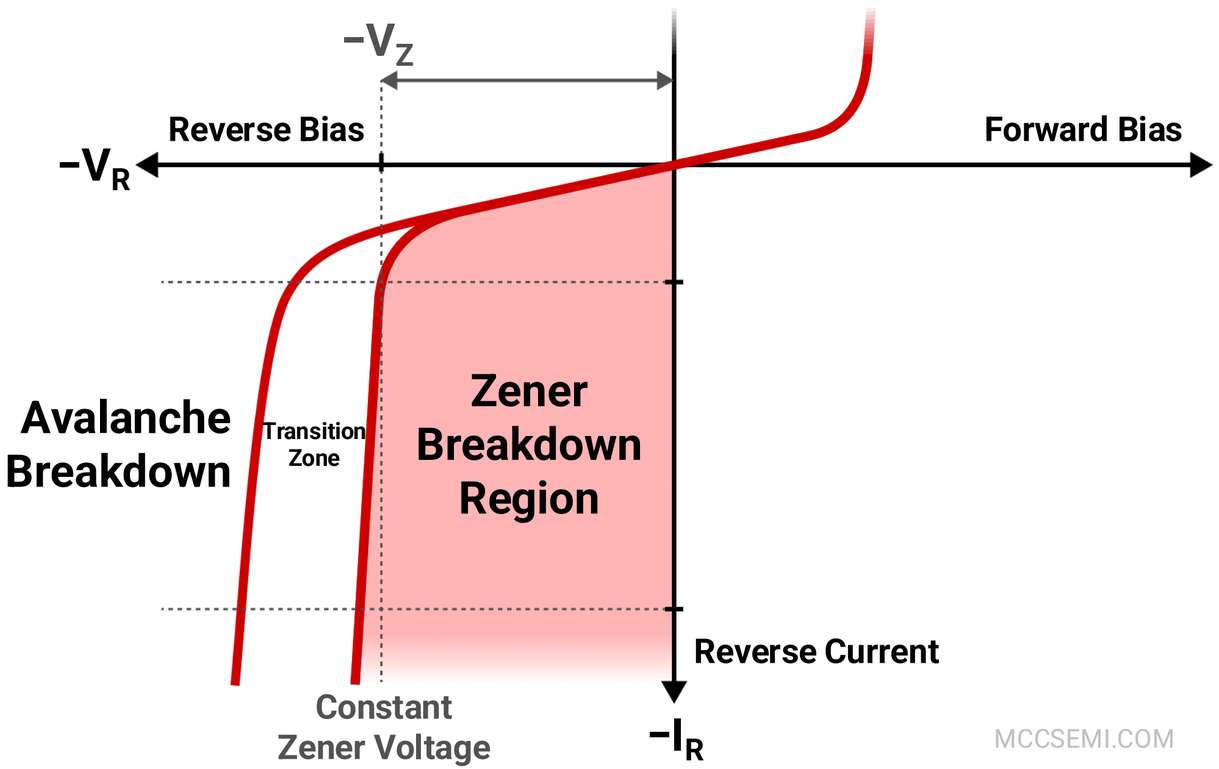
Zener Breakdown (<5V)	
Mechanism	• Quantum tunnelling in heavily doped diodes
Behavior	• Sharp “knee” in I-V curve • Negative temperature coefficient (V_z decreases with temperature)

Transition Zone (5V - 7V)	
Mechanism	• Mixed Zener and Avalanche effects
Behavior	• Temperature coefficients nearly cancel • Ideal for precision voltage references (e.g. 6.2V Zener Diodes)

Avalanche Breakdown (>7V)	
Mechanism	• Impact ionization in moderately doped diodes
Behavior	• Gradual I-V curve “knee” • Positive temperature coefficient (V_z increases with temperature)

Zener Breakdown

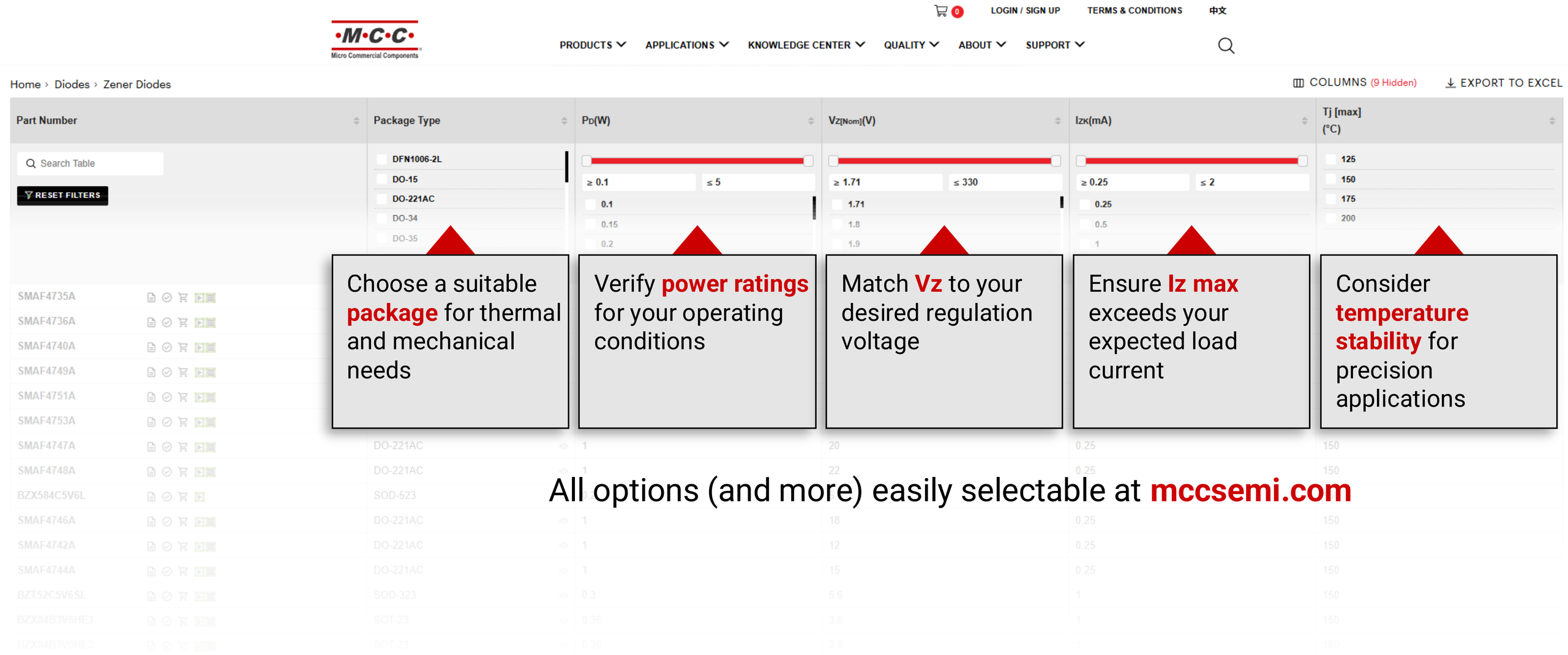




What Are Zener Diodes Used For?

Voltage Regulation	Overvoltage Protection (Clamping)	Voltage Shifting / Level Shifting	Waveform Clipping (Signal Conditioning)	Surge Suppression (with Current Limiting)	Switching Applications
When reverse-biased at **Vz**, the Zener clamps the output voltage, even if input voltage or load current varies	Placed in parallel with a sensitive load, the Zener conducts when voltage exceeds **Vz**, diverting excess current to ground	Drops a fixed voltage (**Vz**) in series with a signal or power line	Two Zeners in anti-series clip both positive and negative signal peaks at **±(Vz + 0.7V)**	Paired with a resistor or fuse, the Zener limits voltage during surges (e.g. lightning strikes on comms lines)	Exploits the sharp knee of the I-V curve to trigger circuits at precise voltages
Low-power voltage references (e.g. 3.3V or 5V rails in sensors Regulating supplies in op-amp circuits or analog systems	Protecting microcontroller I/O pins from transients Safeguarding power supply outputs from spikes	Reducing 5V logic to 3.3V for mixed-voltage systems Creating negative bias voltages in Amplifier circuits	Audio signal processing (distortion effects) ADC input protection	Telecom equipment (RS-485, Ethernet) Automotive CAN bus line	Brownout detection in microcontrollers Voltage monitor for power sequencing
Simpler and cheaper than IC regulators for fixed voltages	**Fast response (nanoseconds) compared to MOVs or TVS diodes for low-energy spikes**	**No active components needed**	**Low distortion as sharp knee characteristic preserves waveform integrity outside clipped regions**	**Fast recovery compared to fuses**	**Low power as it draws negligible current until breakdown occurs**

Selecting the Right Zener Diode



Choose a suitable **package** for thermal and mechanical needs

Verify **power ratings** for your operating conditions

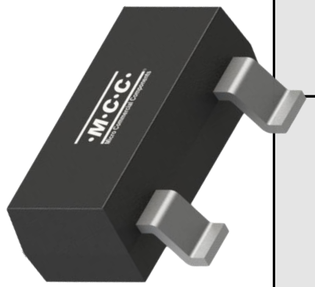
Match **Vz** to your desired regulation voltage

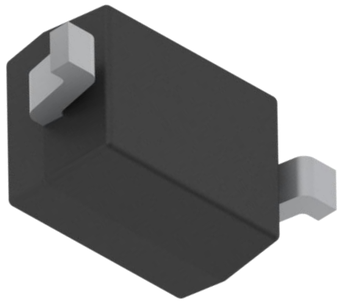
Ensure **Iz max** exceeds your expected load current

Consider **temperature stability** for precision applications

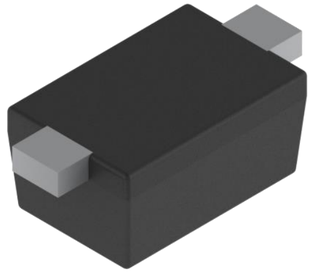
All options (and more) easily selectable at **mccsemi.com**

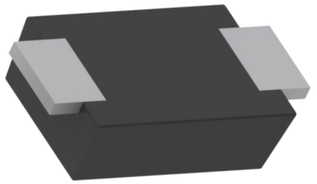
Explore MCC’s Diverse Range of Zener Diodes

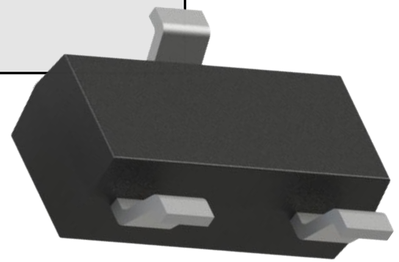




MCC Zener Diode Highlights	
Precision Zeners for analog reference and sensor circuits	**High-current Zeners** for industrial and automotive systems
Low-profile SMD options for space constrained designs	**AEC-Q101 qualified** parts for automotive grade applications







Zener Diodes Application Examples

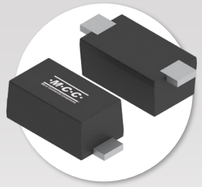
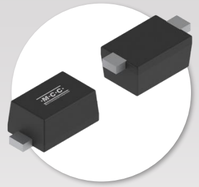
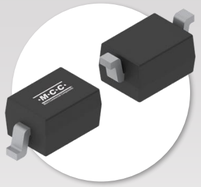
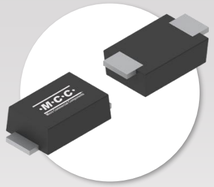
- Voltage Regulation
- Waveform Clipping (Signal Conditioning)
- Overvoltage Protection (Clamping)
- Surge Suppression (with Current Limiting)
- Voltage Shifting / Level Shifting
- Switching Applications

Zener Diodes Package Heat Map

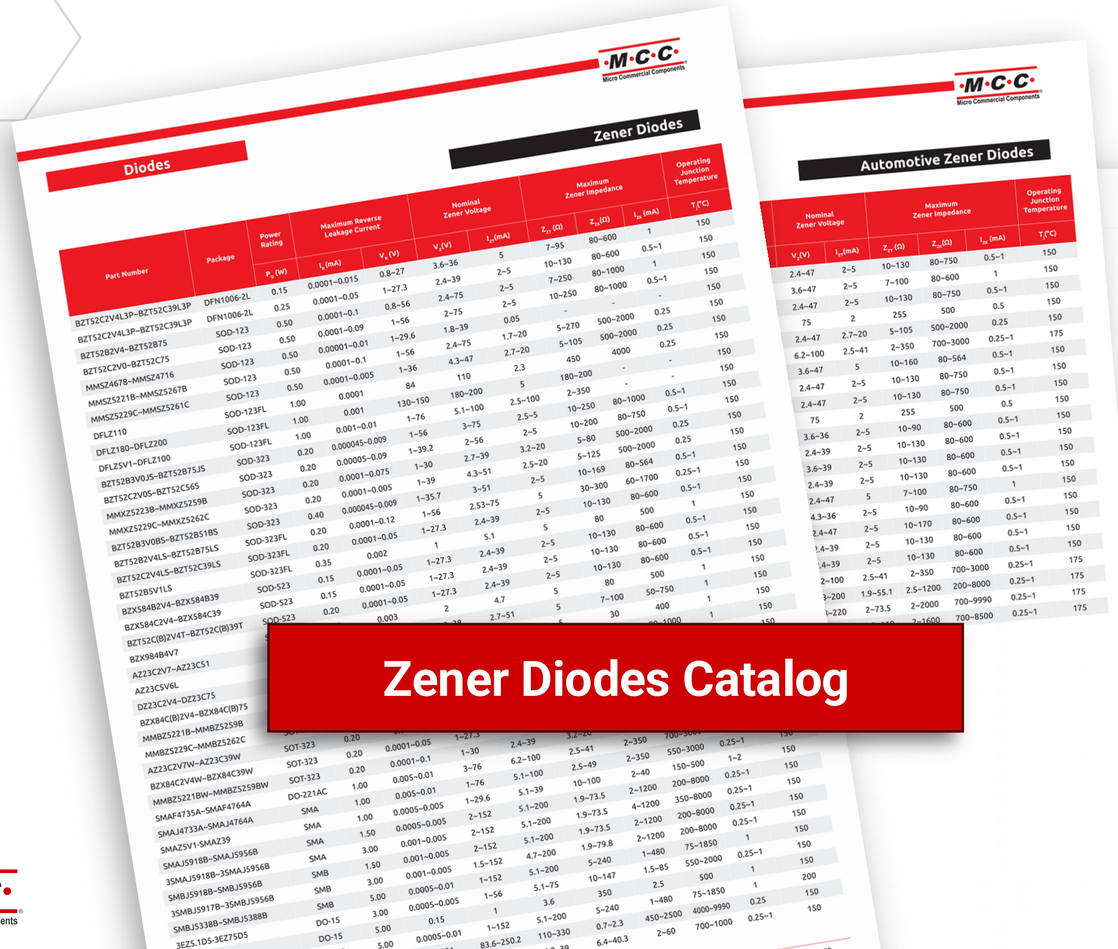
Product Counts
Package Type vs Power Rating

Package Type	Power Rating mW											
	150	200	250	300	350	400	500	1000	1500	2000	3000	5000
DFN1006-2L	57		27									
DO-221AC								30				
SMA								82	75	43	39	
SMB									38		78	51
SOD-123							280					
SOD-123FL								65				
SOD-323		197		2		31						
SOD-323FL		66			1							
SOD-523	115	61										
SOT-23		1		161	200							
SOT-323		152										
DO-15											33	51
DO-41								68	37	32	30	

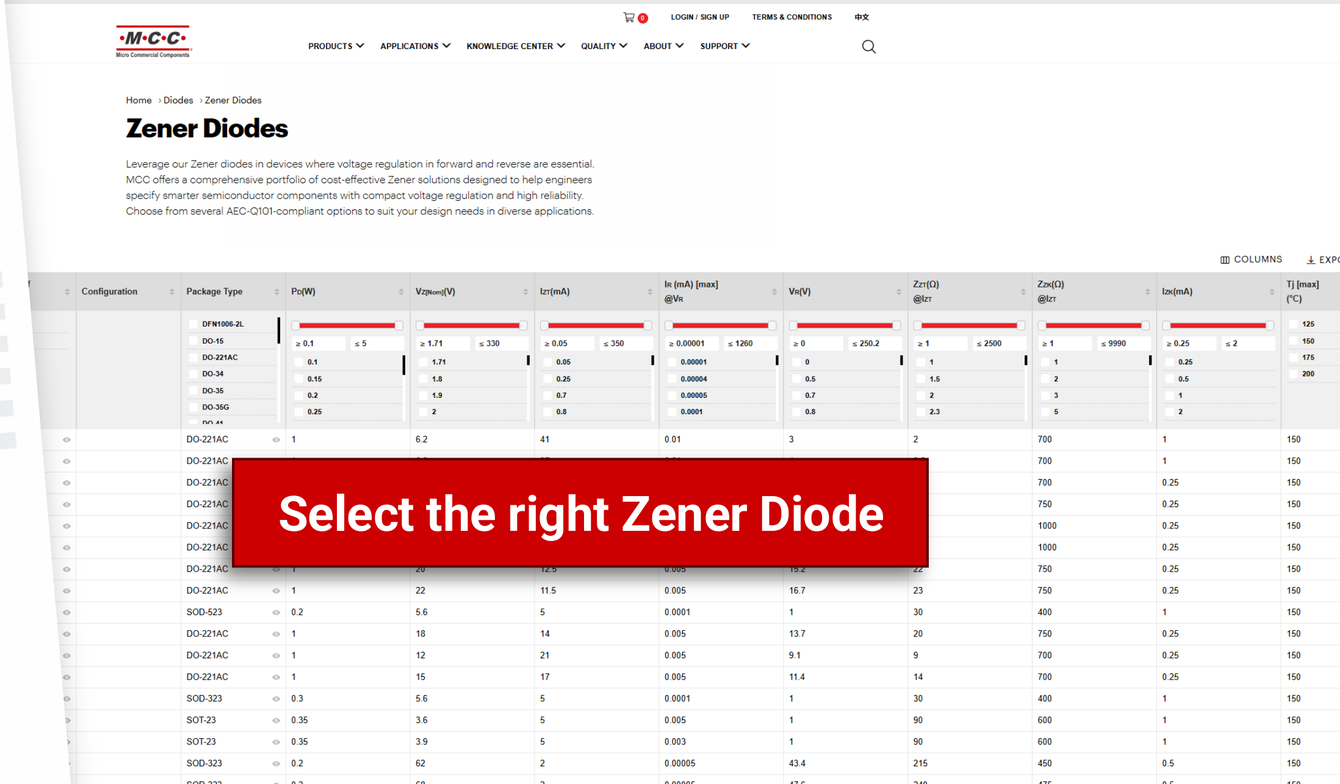
Zener Diodes Overview

Small Area				High Runners			
DFN1006-2L	SOD-123FL	SOD-523	SOD-323	SOT-23	SMA-FL	SMB	SMA
							
1.00 x 0.60 x 0.45 mm	3.58 x 1.65 x 1.13 mm	1.20 x 0.80 x 0.58 mm	1.70 x 1.25 x 0.98 mm	2.92 x 1.30 x 1.00 mm	5.00 x 2.60 x 1.08 mm	5.35 x 3.60 x 2.31 mm	5.20 x 2.60 x 2.17 mm
0.15W Series	1W Series	1W Series	0.2W – 0.4W Series	0.3W – 0.35W Series	1W Series	1.5W – 5W Series	1W – 3W Series
AEC-Q101 Compliant	AEC-Q101 Compliant	AEC-Q101 Compliant	AEC-Q101 Compliant	AEC-Q101 Compliant		AEC-Q101 Compliant	AEC-Q101 Compliant

Explore these additional Zener Diode resources, or contact us at mccsemi.com



Zener Diodes Catalog



Select the right Zener Diode

Micro Commercial Components

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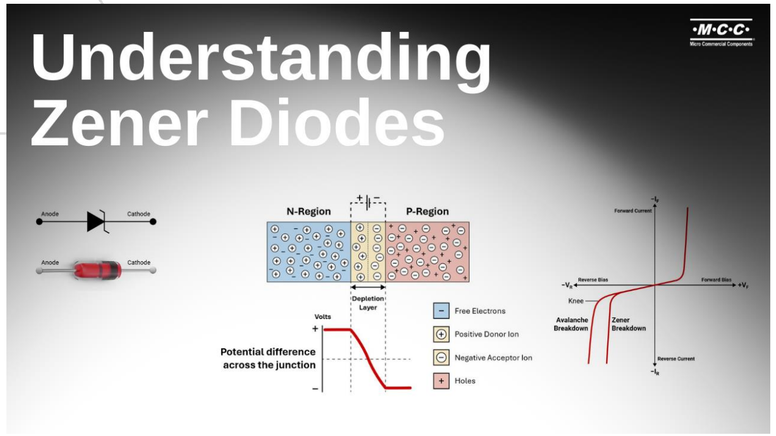
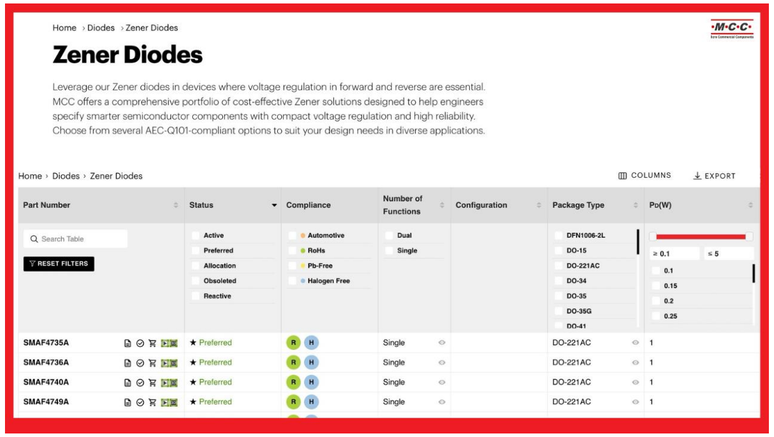


[Zener Diodes Guide]

[Applications]



[Online Catalog]