

Midterm this Week

- Midterm in lab.
- Duration: 1 hour (2-3pm).
- Material on midterm:
 - Everything from first 4 weeks of class.
 - Thévenin's Theorem & Source Impedance.
 - Impedance of resistors, capacitors, and inductors.
 - Filters (RC,RL,RLC,low-pass,high-pass, bandpass, notch, Chebyshev, Butterworth, etc ...).
 - Basic oscilloscope use, resistor code, etc...
- Midterm will cover design exercises and lab exercises.
- The purpose of the midterm is to consolidate passive analog linear circuitry before we move onto non-linear devices.

Diodes

a non-linear circuit element



- 2-terminal **quantum** device
- ***A diode only conducts in one direction !!!***
- **Non-linear** → **Ohm's Law** doesn't apply !
 - There is no simple Z_{diode} formula !
 - **Thevenin's theorem** doesn't apply !
- **Calculus:** you can linearize a function/system in the vicinity of some V_0 or I_0 .
 - **Ohm's law**, Z_{diode} , and **Thevenin's theorem** can only be used locally around some value of V_0 and I_0 .
 - i.e. you can still write down a differential equation for your circuit (i.e. Kirchhoff's loop and junction laws are still valid).

Intro to Semiconductors

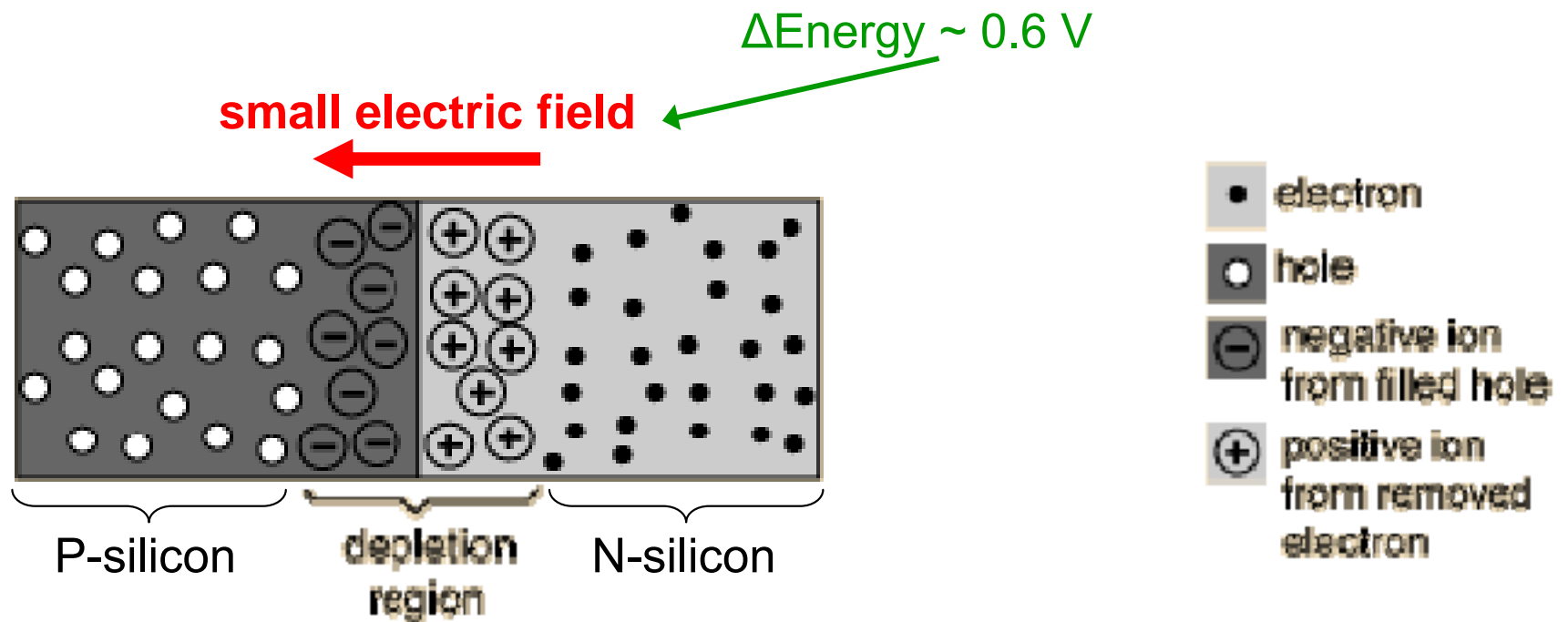
- Semiconductors have a modest resistivity:
- Normally we think of electrons moving in a circuit
- In a semiconductor things are a little different
 - We think of either holes or electrons.
 - Holes (+ charge)
 - Electrons (- charge)

Material	Resistivity
Copper	$1.70 \times 10^{-8} \Omega \cdot m$
Silicon	$6400 \Omega \cdot m$
Rubber	$\sim 10^{13} \Omega \cdot m$

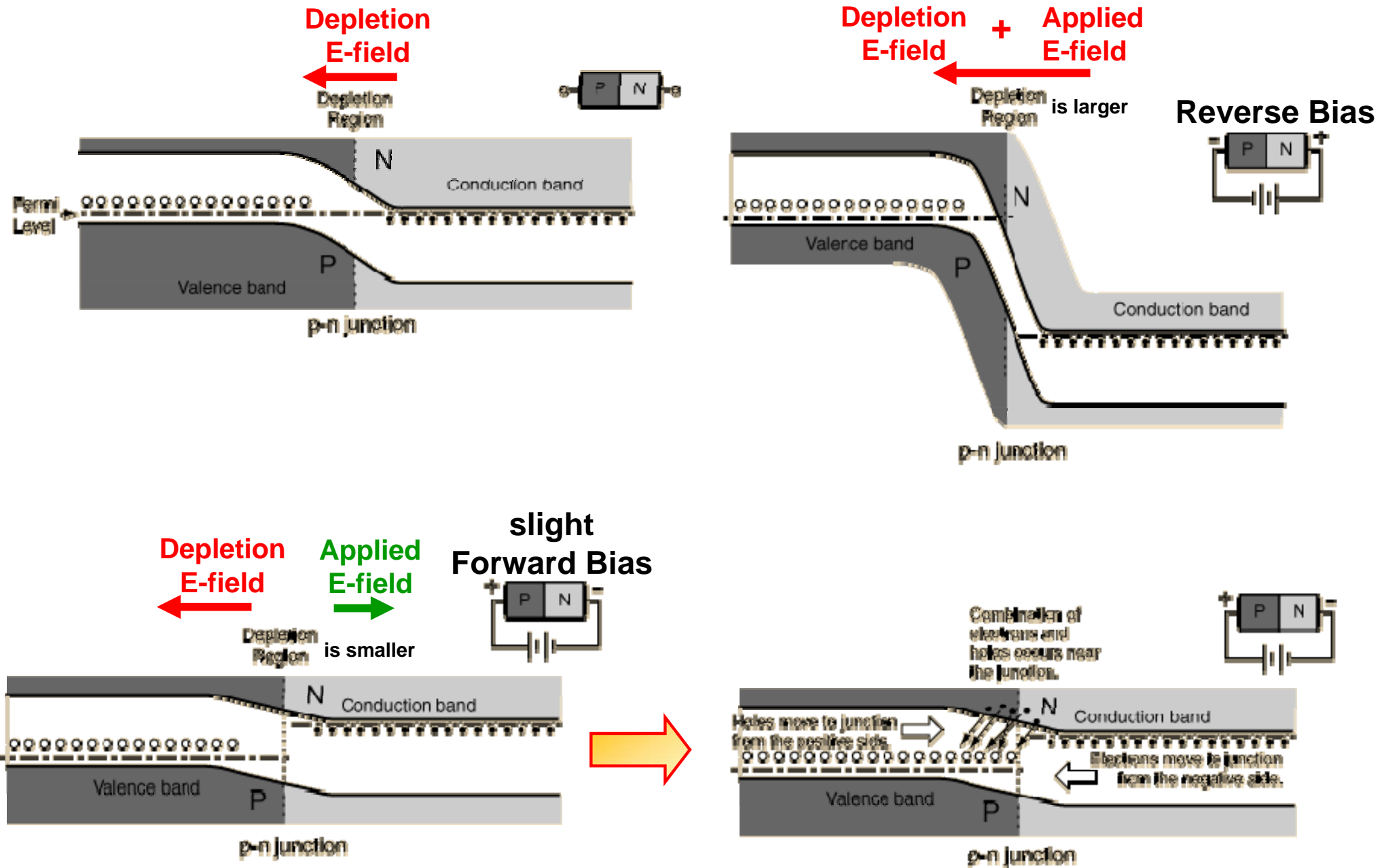


The PN junction

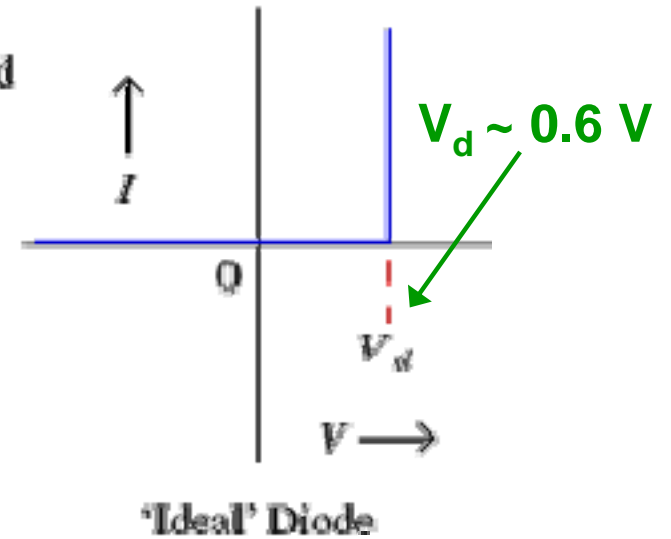
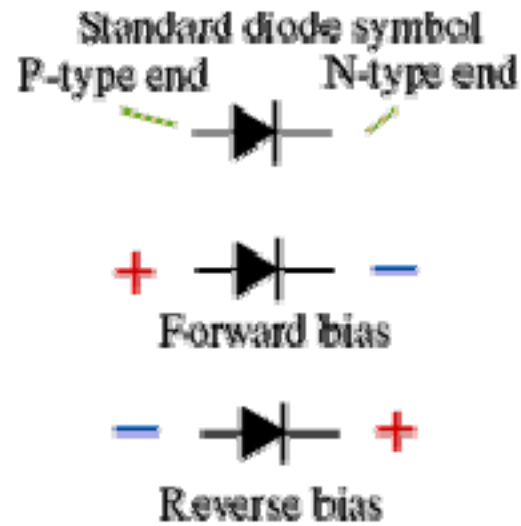
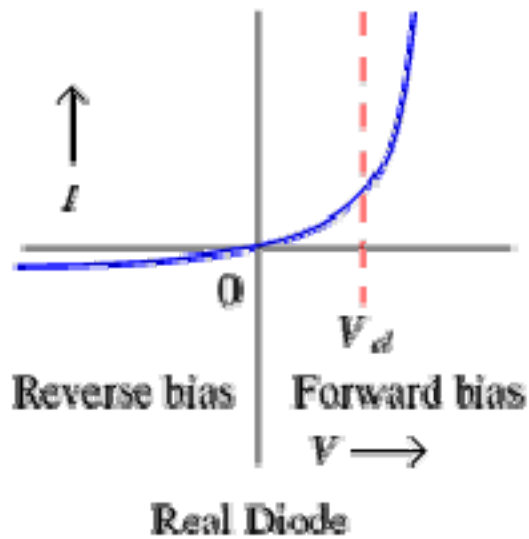
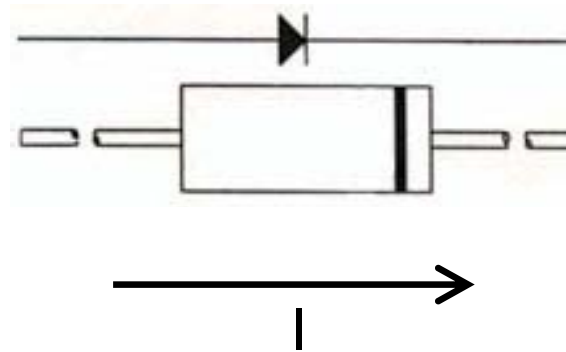
- Made from differently doped silicon
 - N region has more electrons
 - P region had more holes
- At the **PN junction** the holes & electrons recombine to form a small insulating **depletion region**.



How a diode works



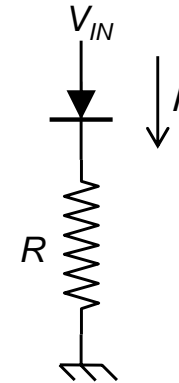
Diode: I-V characteristic curve I



Diode: I-V characteristic curve II

➤ *Simple model*

- Current can only flow in one direction.
- A 0.6V “diode drop” when conducting.
- $IR = V_{IN} - 0.6\text{ V}$
- Useful for designing circuits.



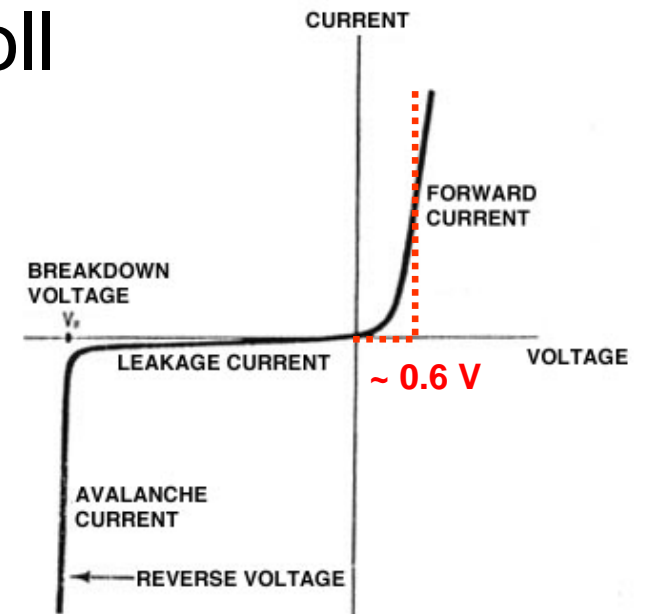
Current only flows in the direction of the arrow.

➤ More complete model: Ebers-Moll equation.

- Not so useful for designing circuits.

➤ A little negative is OK

A lot is “bad” → smoke!!!!



Diode Spec Sheet



January 2007

1N/FDLL 914/A/B / 916/A/B / 4148 / 4448 Small Signal Diode



DO-35

Cathode is denoted with a black band



LL-34

THE PLACEMENT OF THE EXPANSION GAP HAS NO RELATIONSHIP TO THE LOCATION OF THE CATHODE TERMINAL.

DEVICE	1ST BAND	2ND BAND
FDLL914	BLACK	BROWN
FDLL914A	BLACK	GRAY
FDLL914B	BROWN	BLACK
FDLL915	BLACK	RED
FDLL915A	BLACK	WHITE
FDLL915B	BROWN	BROWN
FDLL4148	BLACK	BROWN
FDLL4448	BROWN	BLACK

-1st band denotes cathode terminal and has wider width

Absolute Maximum Ratings* $T_J=25^{\circ}\text{C}$ unless otherwise noted

Symbol	Parameter	Value	Units
V_{RRM}	Maximum Repetitive Reverse Voltage	100	V
I_O	Average Rectified Forward Current	200	mA
I_F	DC Forward Current	300	mA
I_{FRM}	Recurrent Peak Forward Current	400	mA
I_{FSM}	Non-repetitive Peak Forward Surge Current		
	Pulse Width = 1.0 second	1.0	A
	Pulse Width = 1.0 microsecond	4.0	A
T_{STG}	Storage Temperature Range	-65 to +200	$^{\circ}\text{C}$
T_J	Operating Junction Temperature	175	$^{\circ}\text{C}$

* These ratings are limiting values above which the serviceability of the diode may be impaired.

NOTES:

- 1) These ratings are based on a maximum junction temperature of 200 degrees C.
- 2) These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

Thermal Characteristics

Symbol	Parameter	Max.	Units
		1N/FDLL 914/A/B / 4148 / 4448	
P_D	Power Dissipation	500	mW
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	300	$^{\circ}\text{C}/\text{W}$

1N/FDLL 914/A/B / 916/A/B / 4148 / 4448 Small Signal Diode

Diode Spec Sheet

1NFDLL 914/A/B / 916/A/B / 4148 / 4448 Small Signal Diode

Electrical Characteristics* T_A=25°C unless otherwise noted

Symbol	Parameter	Test Conditions	Min.	Max.	Units
V _R	Breakdown Voltage	I _R = 100µA	100		V
		I _R = 5.0µA	75		V
V _F	Forward Voltage	1N914B/4448 I _F = 5.0mA	620	720	mV
		1N916B I _F = 5.0mA	630	730	mV
		1N914/916/4148 I _F = 10mA		1.0	V
		1N914A/916A I _F = 20mA		1.0	V
		1N916B I _F = 20mA		1.0	V
		1N914B/4448 I _F = 100mA		1.0	V
I _R	Reverse Leakage	V _R = 20V		25	nA
		V _R = 20V, T _A = 150°C		50	µA
		V _R = 75V		5.0	µA
C _T	Total Capacitance	V _R = 0, f = 1.0MHz		2.0	pF
		V _R = 0, f = 1.0MHz		4.0	pF
t _{rr}	Reverse Recovery Time	I _F = 10mA, V _{RR} = 5.0V (500mA) I _{rr} = 1.0mA, R _θ = 100Ω		4.0	ns

*Non-recurrent square wave PW = 8.3ms

Typical Characteristics

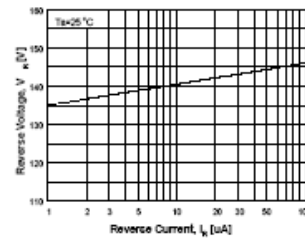


Figure 1. Reverse Voltage vs Reverse Current
BV - 1.0 to 100µA

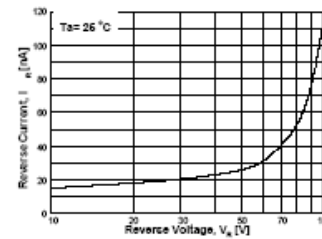


Figure 2. Reverse Current vs Reverse Voltage
IR - 10 to 100V

GENERAL NOTE: The Reverse Current of a diode will approximately double for every 10°C increase in Temperature.

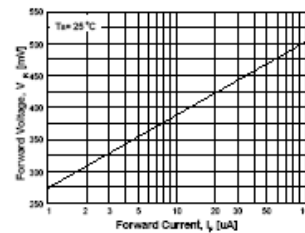


Figure 3. Forward Voltage vs Forward Current
VF - 1 to 100µA

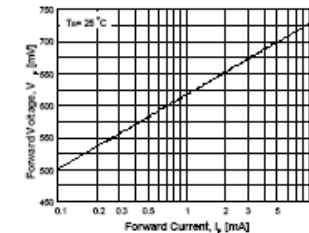


Figure 4. Forward Voltage vs Forward Current
VF - 0.1 to 10mA

Diode Spec Sheet

1NFDLL 914/A/B / 916/A/B / 4148 / 4448 Small Signal Diode

Typical Characteristics (Continued)

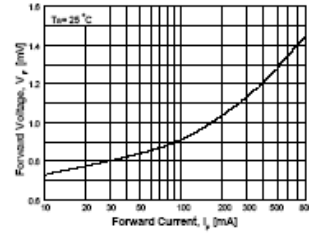


Figure 5. Forward Voltage vs Forward Current
VF - 10 to 800mA

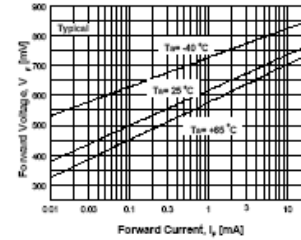


Figure 6. Forward Voltage vs Ambient Temperature
VF - 0.01 - 20 mA (-40 to +65°C)

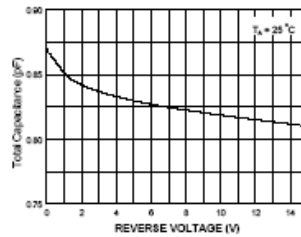


Figure 7. Total Capacitance

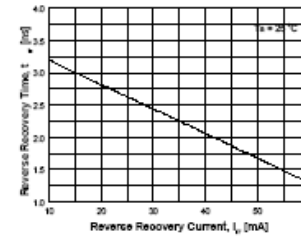


Figure 8. Reverse Recovery Time vs
Reverse Recovery Current
IF = 10mA, IR = 1.0 mA, RREP = 100 Ohms

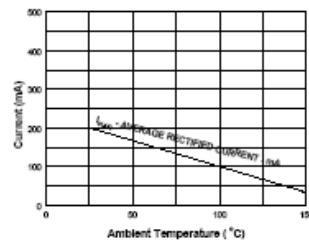


Figure 9. Average Rectified Current ($I_{R(AV)}$)
vs Ambient Temperature (T_A)

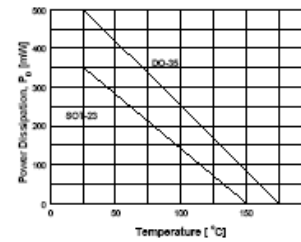


Figure 10. Power Derating Curve

Diode Spec Sheet



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Rev. 122

1NFDLL 914/A/B / 916/A/B / 4148 / 4448 Small Signal Diode

Applications

- Circuit Protection
- Rectification
 - half wave rectifier
 - full wave rectifier
 - Power Supplies
- Frequency manipulation
 - Frequency multiplier
 - Mixers

Fourier Transform (FFT) of Full Wave Rectifier

Fourier space representation of rectified output

