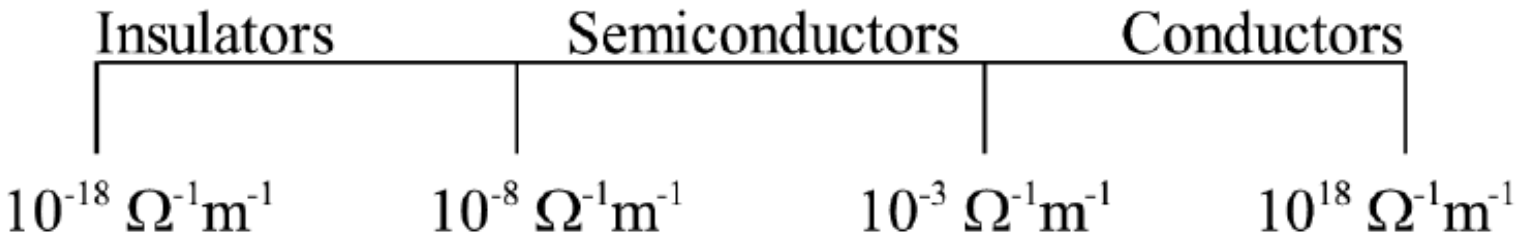
F4250 Aplikace elektroniky

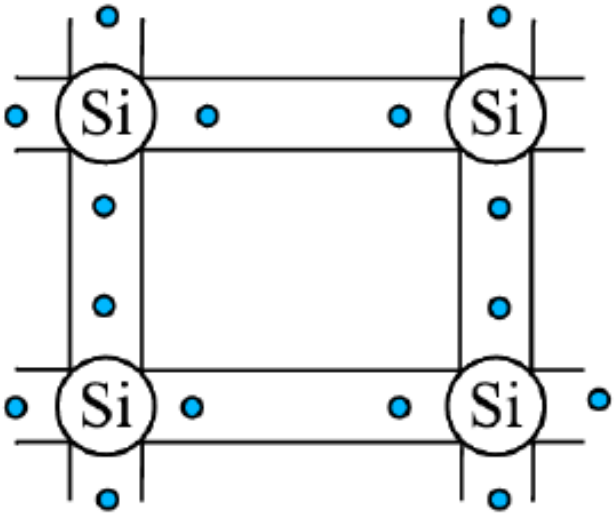
poznámky

úvod diody

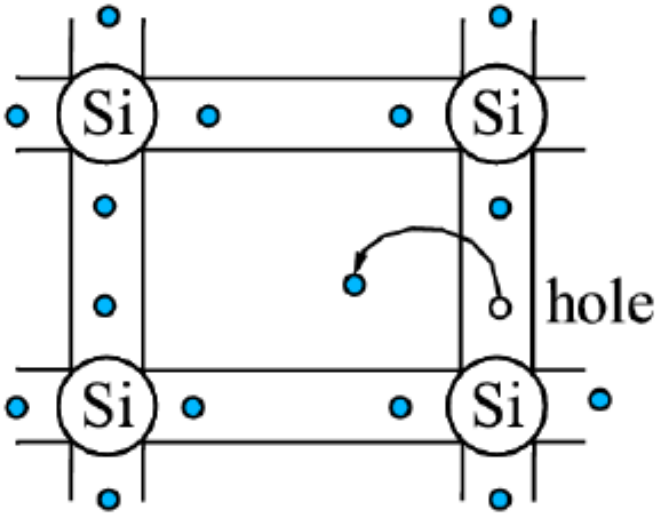
- Dioda a tranzistor, jejich vlastnosti a měření. LED diody
- Nízkofrekvenční zesilovače.
- Operační zesilovač, základní zapojení, využití.
- Zdroje referenčního napětí
- Analogová a digitální informace. AD a DA převodník.
- Analogový a digitální záznam a přenos zvuku a obrazu. Druhy modulace. Rozhlasový vysílač a přijímač.
- Speciální elektronické součástky
- Elektronická zařízení v domácnostech a automobilech. Měřicí přístroje

Brief introduction to semiconductors

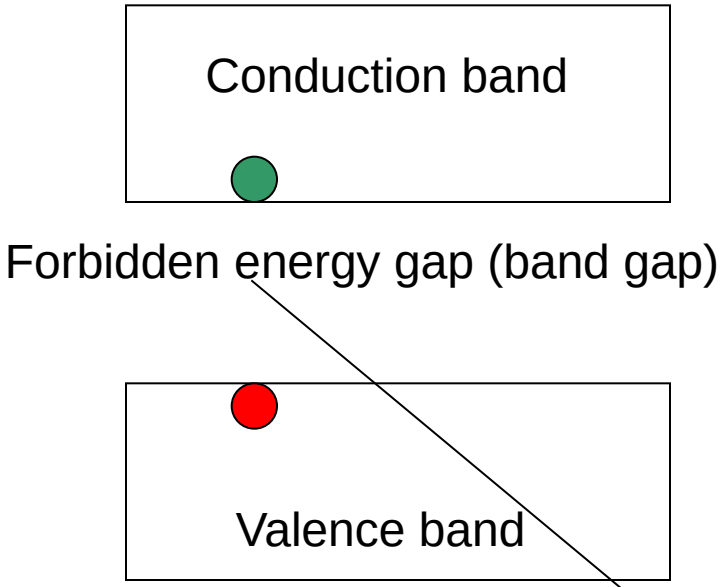




T=0
All electrons are bound in valence bond



T >0
Thermal fluctuations excite electrons from valence bonds. Electron hole pairs are created

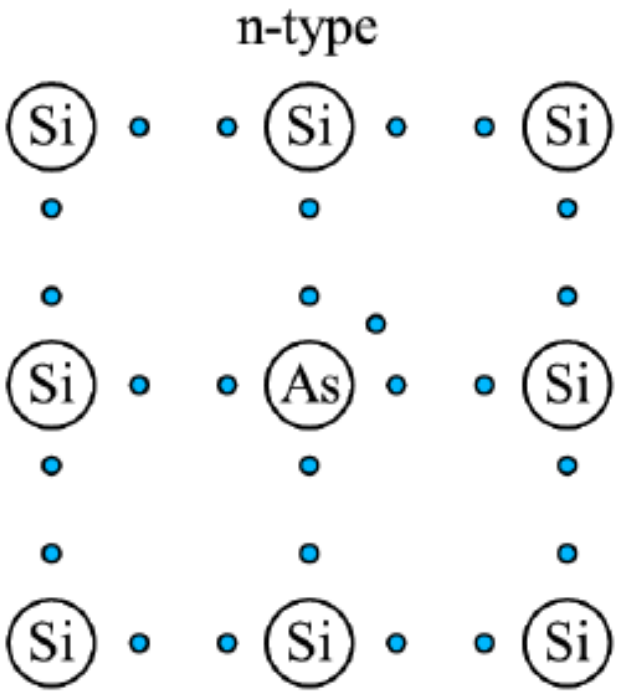


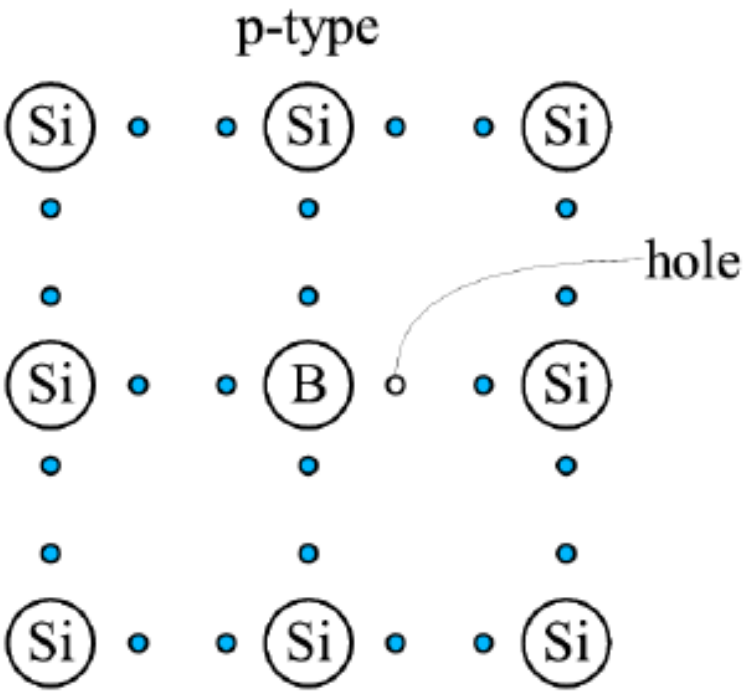
- Insulator: Large band gap. Difficult for electron to jumto conduction band
- Semiconductor: Thermal excitations at room temperature. Moderate applied voltage can bridge gap
- Conductors: conduction and valence bands overlap. Charges flows freely

Thermal activated electron hole pair

Intrinsic semiconductors: No impurities

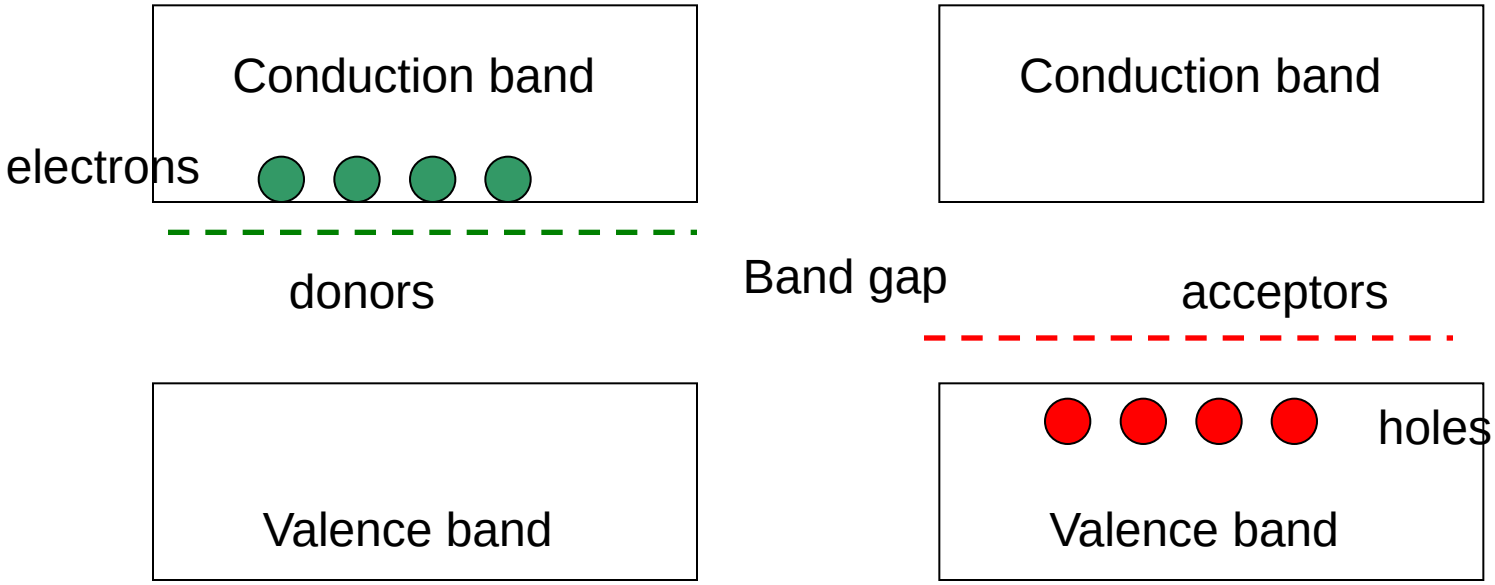
Dopped semiconductors



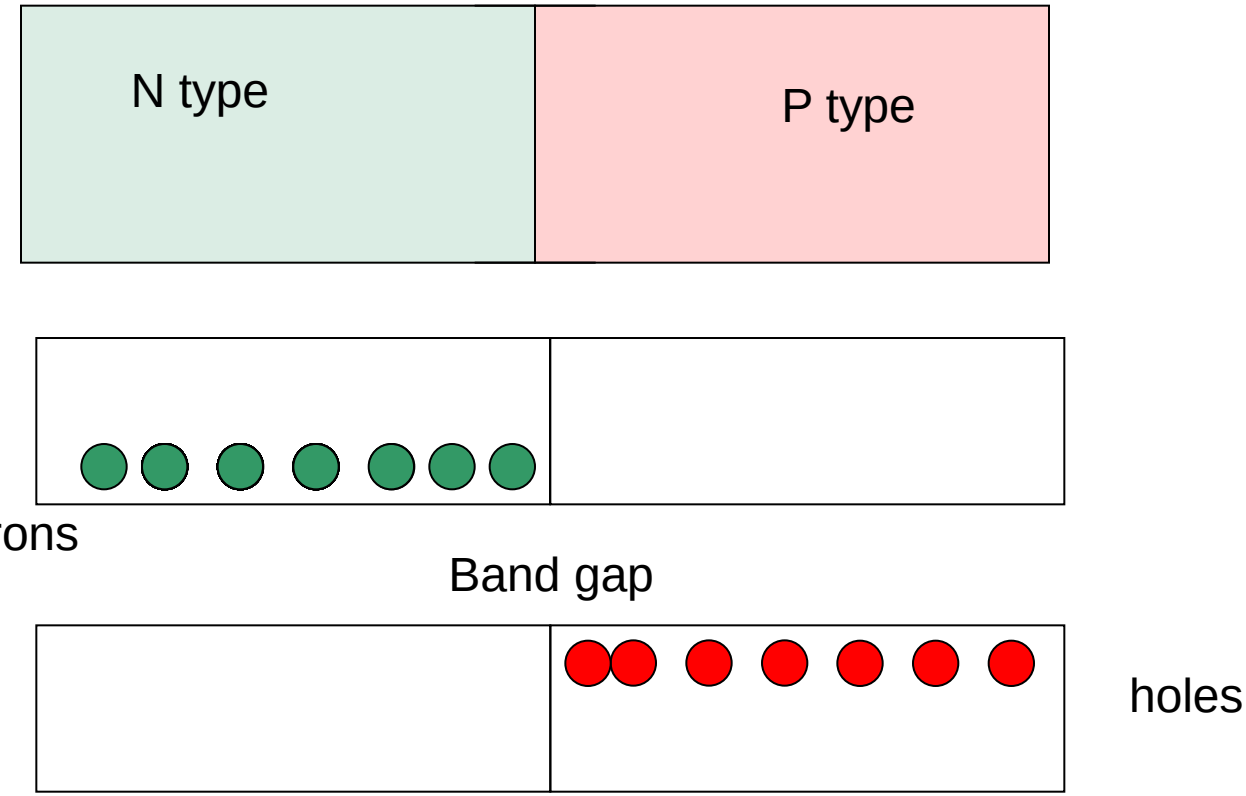


As electron donor
5 valence electrons

B electron acceptor
3 valence electron


Conduction band
electrons
donors
Band gap
Conduction band
acceptors
holes
Valence band
Valence band

P-N junction

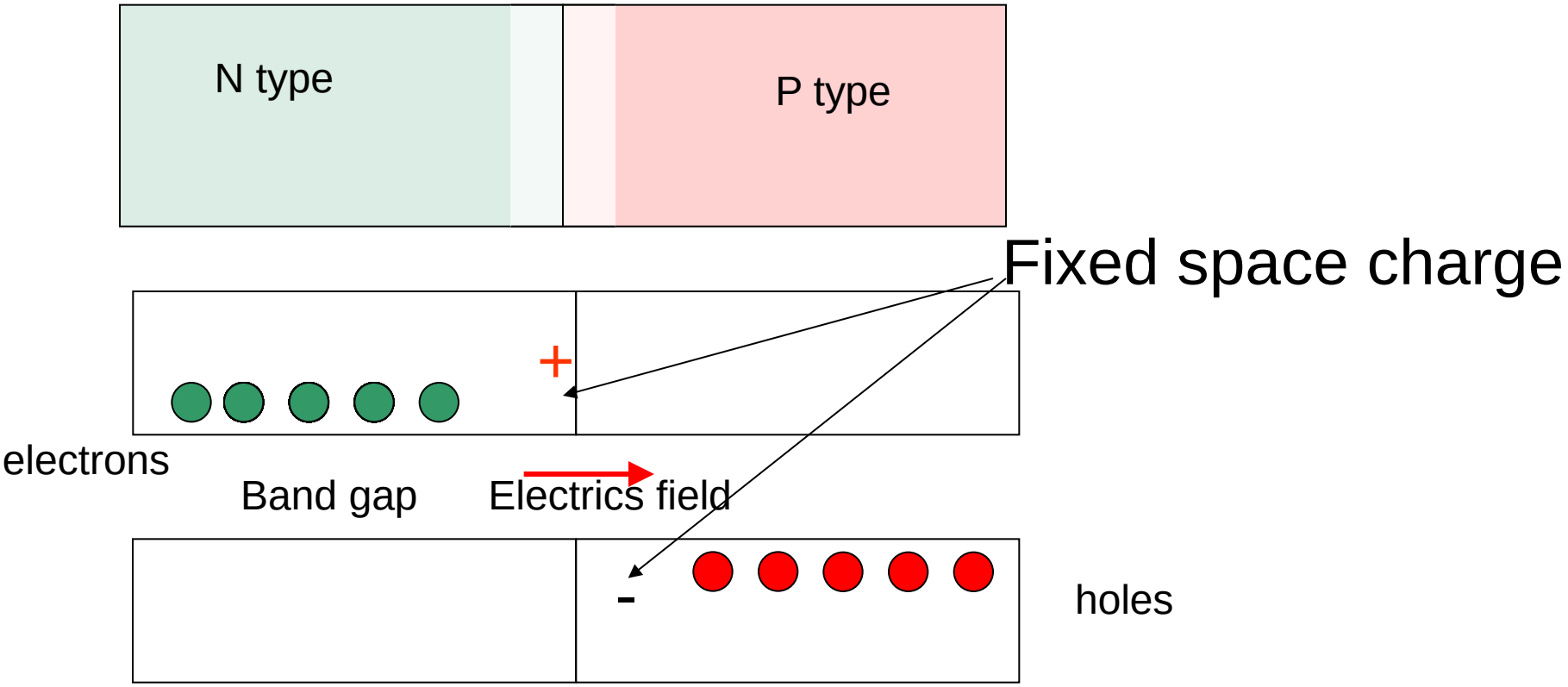


Charges diffuse due to thermal effect

Holes diffuse from right side to left side

Electron diffuse from left side to right side

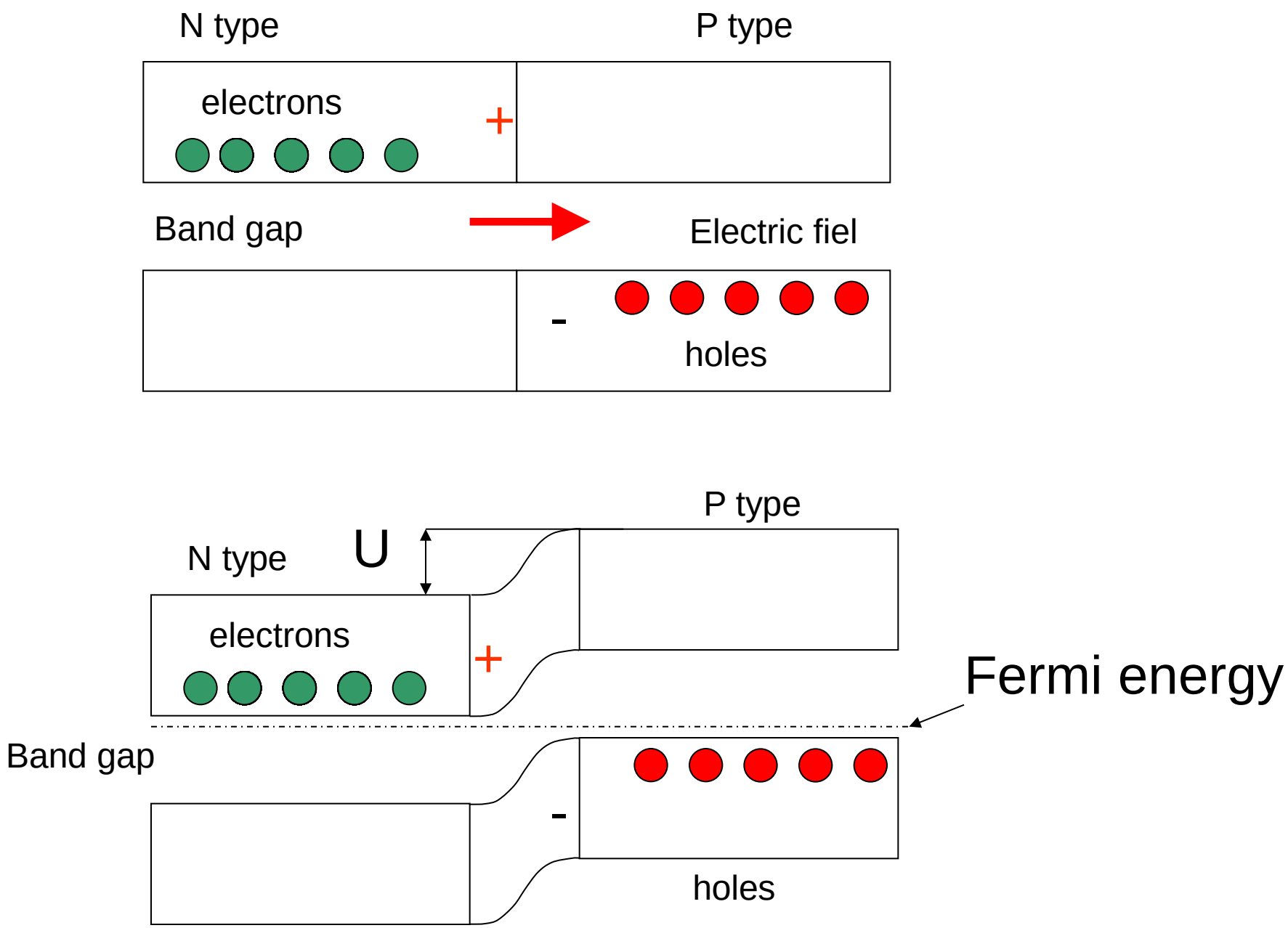
P-N junction

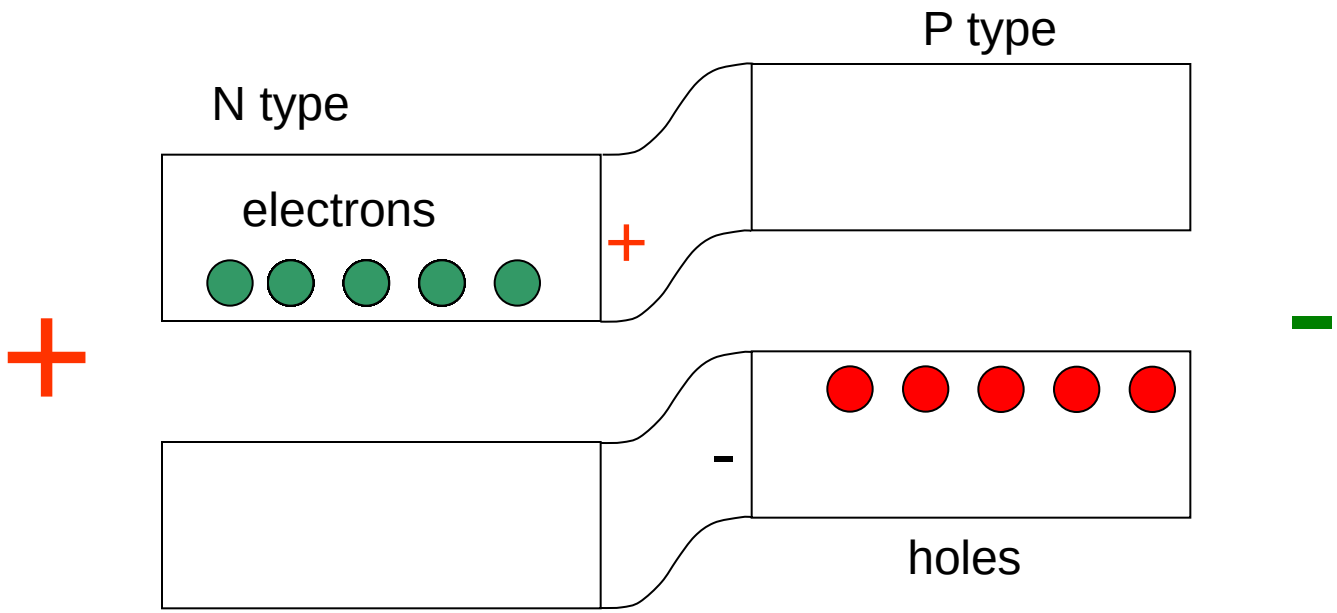


Charges diffuse due to thermal effect

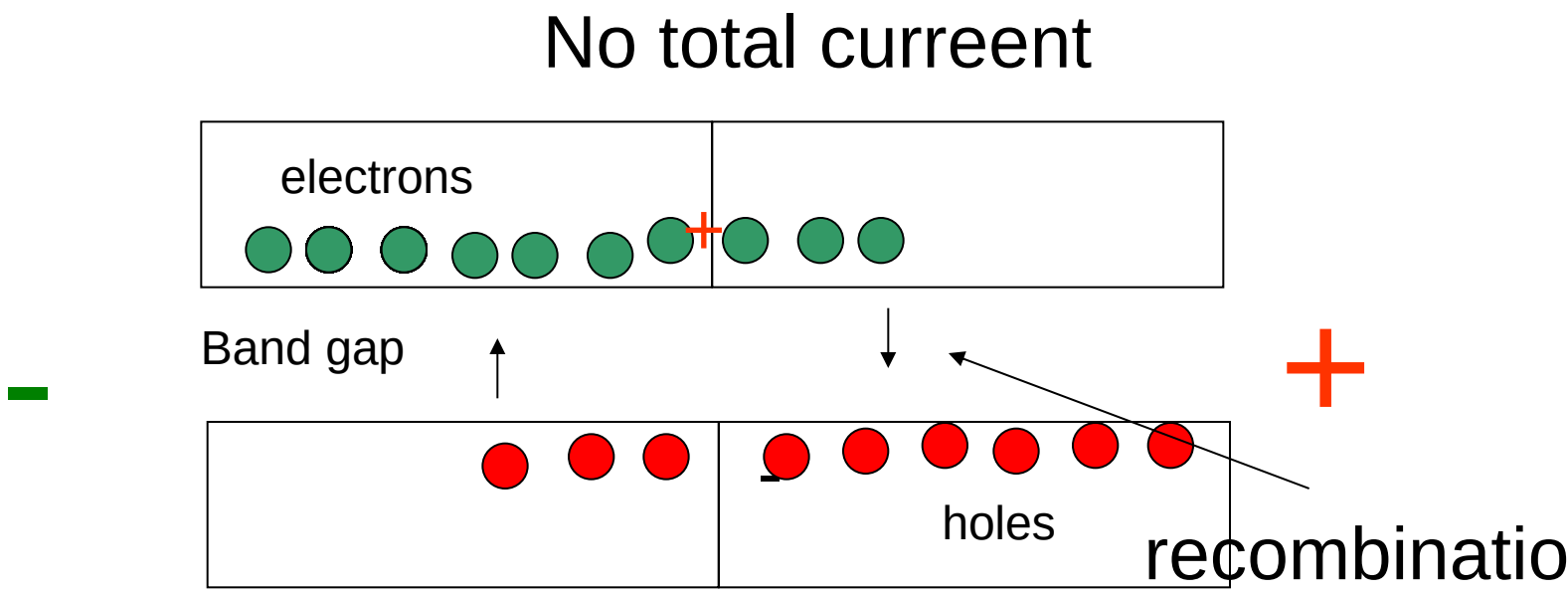
Holes diffuse from right side to left side

Electron diffuse from left side to right side


N type
P type
electrons
+
Band gap
Electric fiel
-
holes
P type
N type
U
electrons
+
Fermi energy
Band gap
-
holes


P type
N type
electrons
+
+
-
-
holes

P-N junction

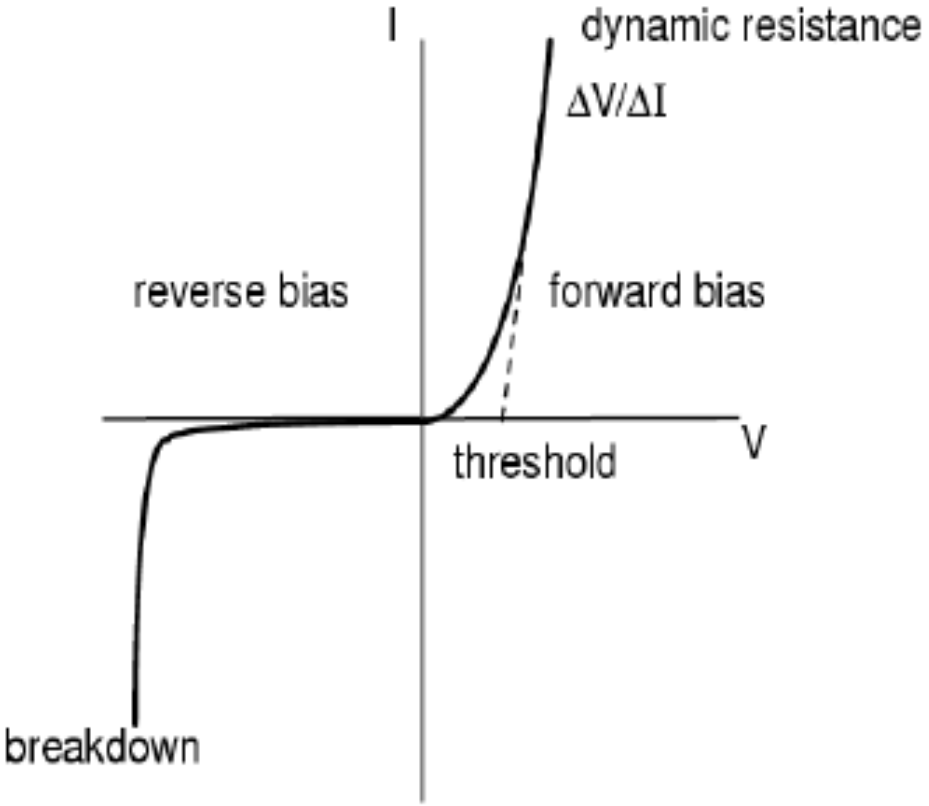


- Voltampérová charakteristika diody
- Křemík E_g=1,2 eV
- Germánium E_g=0,7 eV

$$J = J_s\left(e^{\frac{eU}{kT}} - 1\right)$$

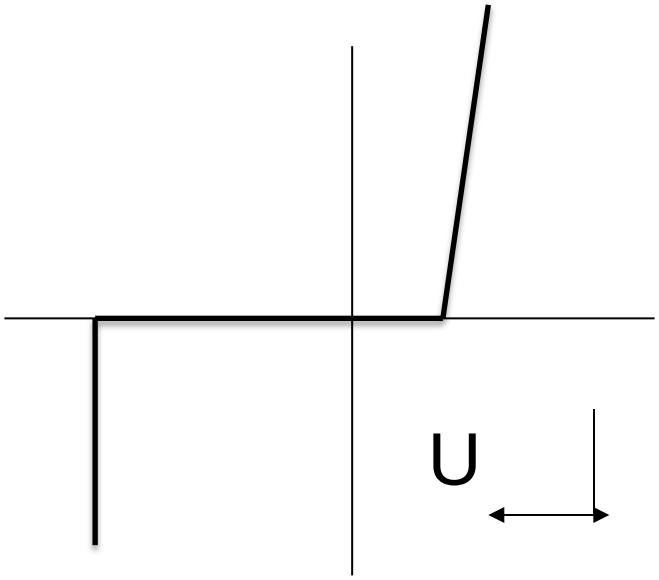
$$J_s = eBT^3 e^{-\frac{E_g}{kT}}$$

Diode Circuits



$$I = I_0(e^{\frac{eU}{kT}} - 1)$$

simple diode model

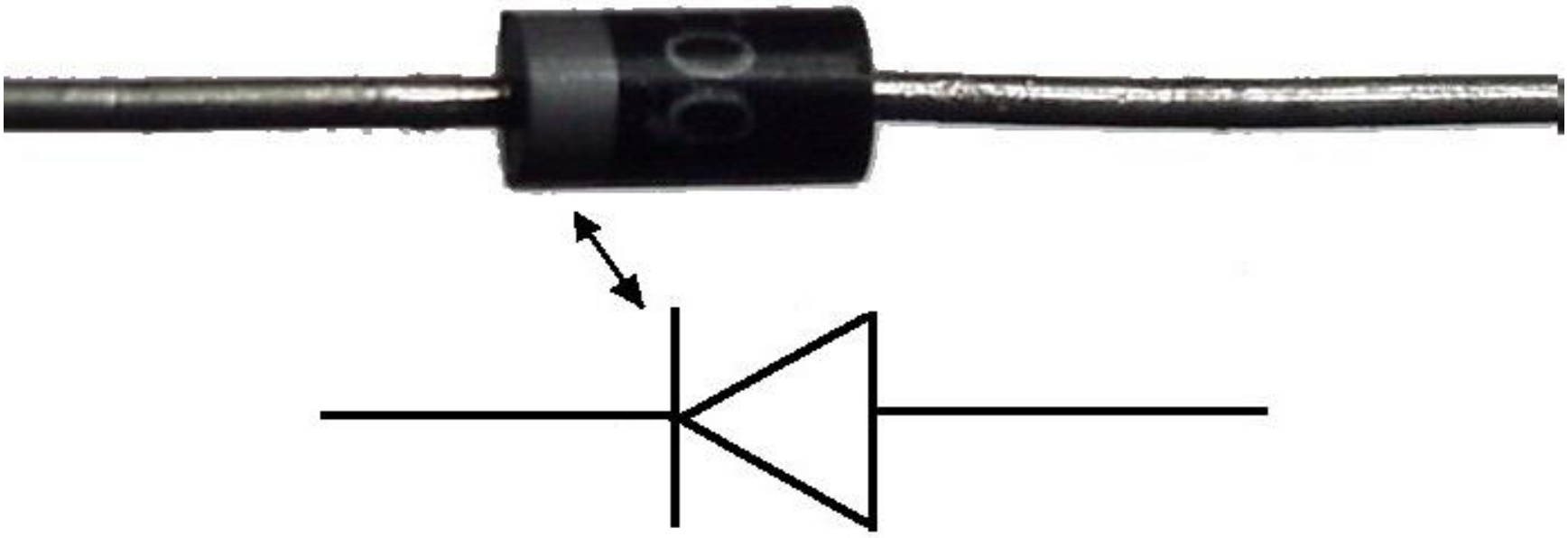


This model is most often used to expain the operation of rectifiers

Rectifiers are AC to DC conversion circuit

U threshold is 0.6 V for silicon diodes

diode



Diode maintenance

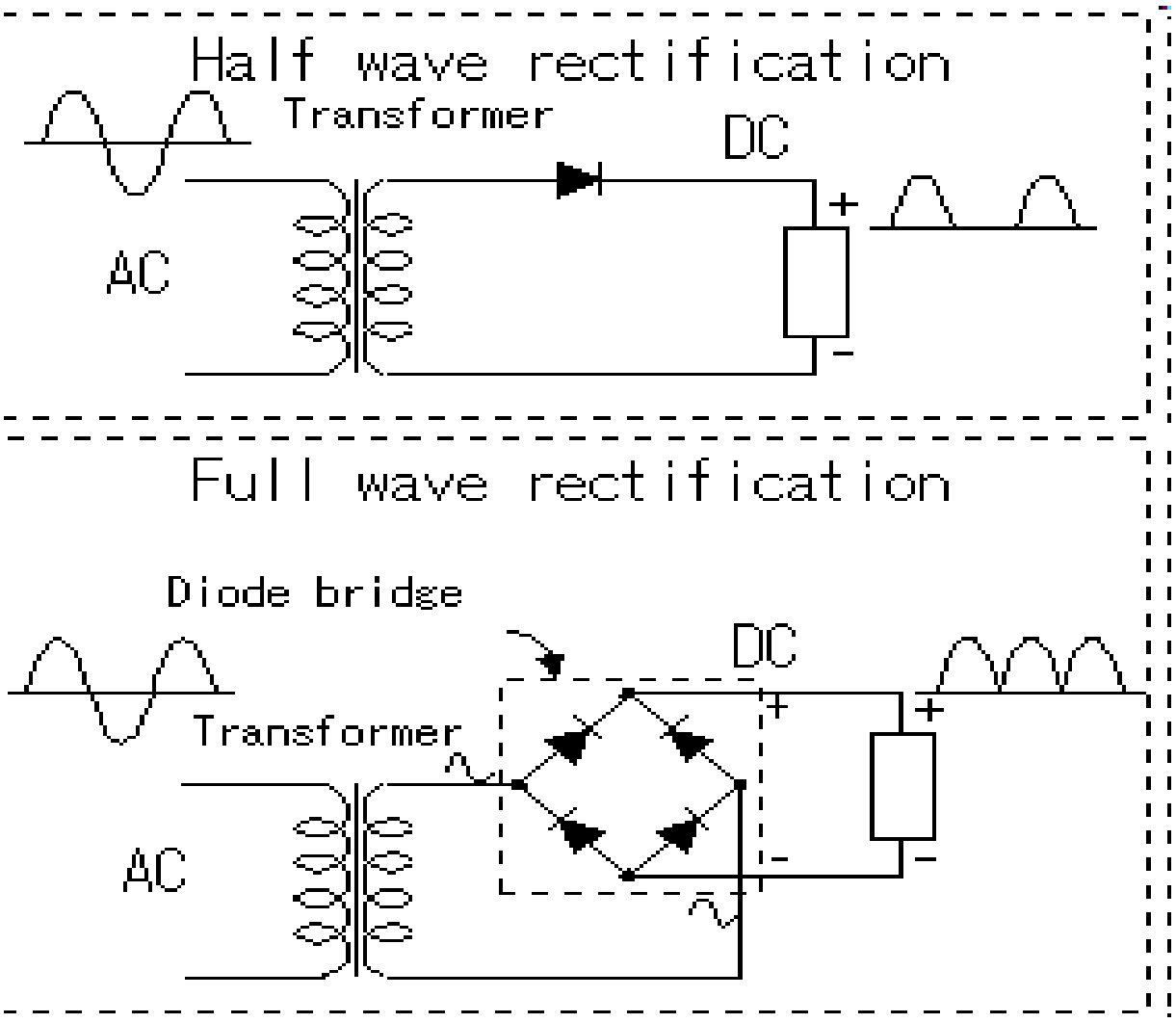
- Standard diode safety precautions
- Avoid
- current overloads
- excessively high operating voltages
- high temperature

Testing s diode

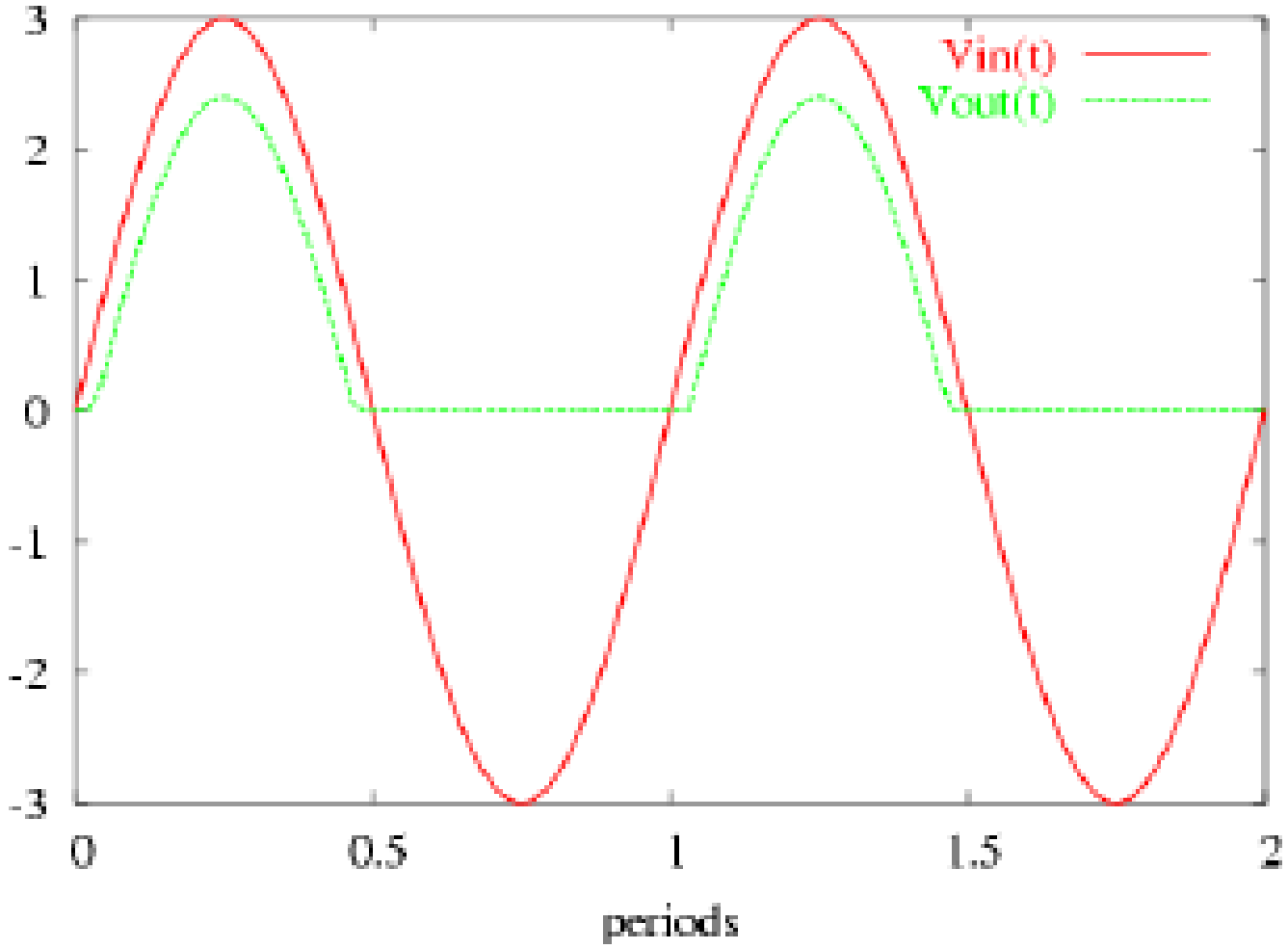
- using an ohmmeter
- a dynamic diode tester.

Type Number		1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	UNITS
Maximum Repetitive Peak Reverse Voltage	V_{RRM}	50	100	200	400	600	800	1000	V
Maximum RMS Voltage	V_{RMS}	35	70	140	280	420	560	700	V
Maximum DC Blocking Voltage	V_{DC}	50	100	200	400	600	800	1000	V
Maximum Average Forward Rectified Current .375"(9.5mm) Lead Length @T_A = 75°C	$I_{F(AV)}$	1.0							A
Peak Forward Surge Current, 8.3 ms Single Half Sine-wave Superimposed on Rated Load (JEDEC method)	I_{FSM}	30							A
Maximum Instantaneous Forward Voltage @1.0A	V_F	1.0							V
Maximun DC Reverse Current @ T_A = 25°C at Rated DC Blocking Voltage @ T_A = 125°C	I_R	5.0 50							uA uA
Maximun Full Load Reverse Current, Full Cycle Average .375"(9.5mm) Lead Length @T_L=75°C	I_R	30							uA
Typical Junction Capacitance (Note 1)	C_J	15							pF
Typical Thermal Resistance (Note 2)	$R_{\theta JA}$	50							°C/W
Operating and Storage Temperature Range	T_J,T_{STG}	-55 to+125							°C

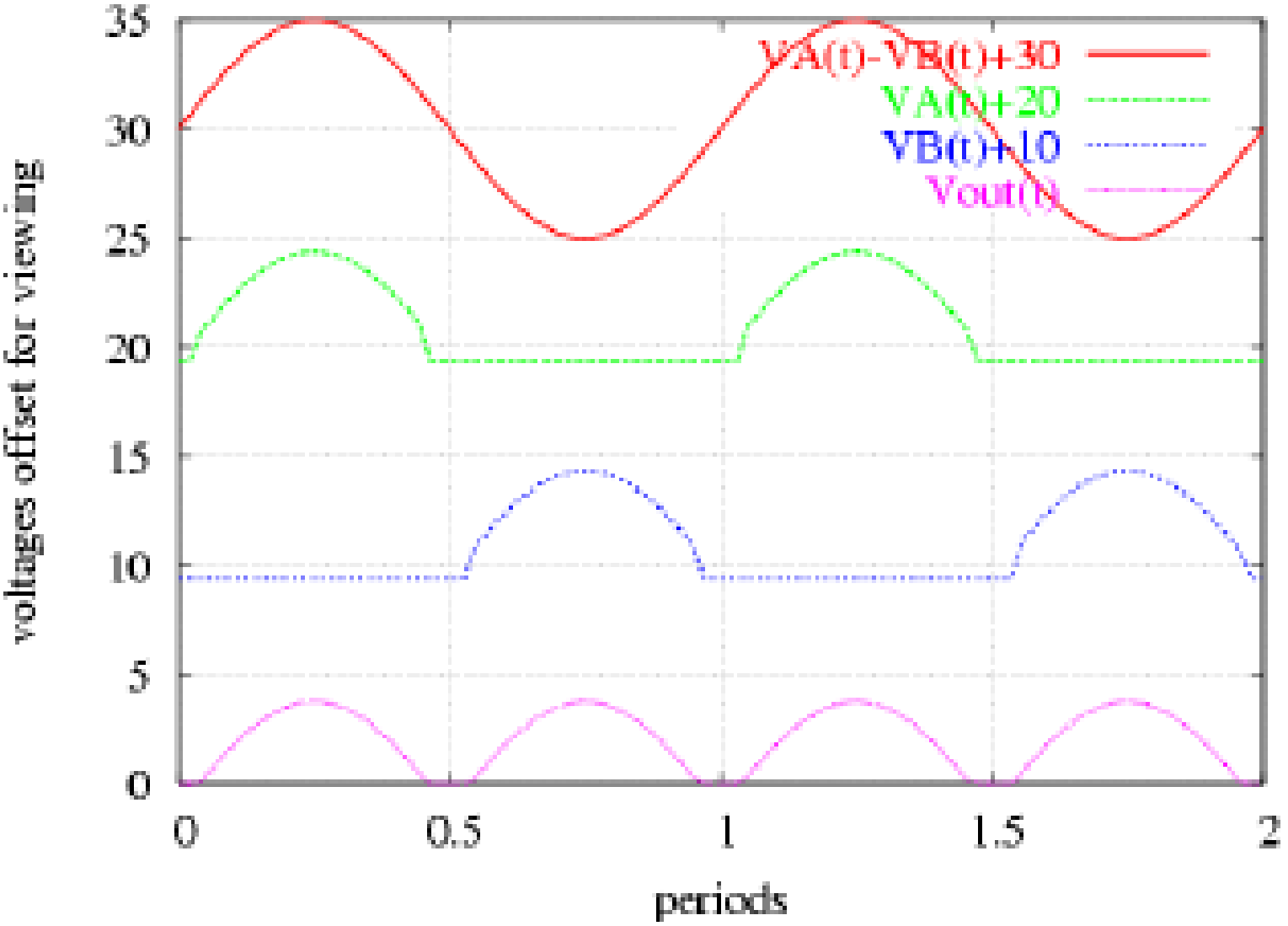
Rectification



Half wave bridge



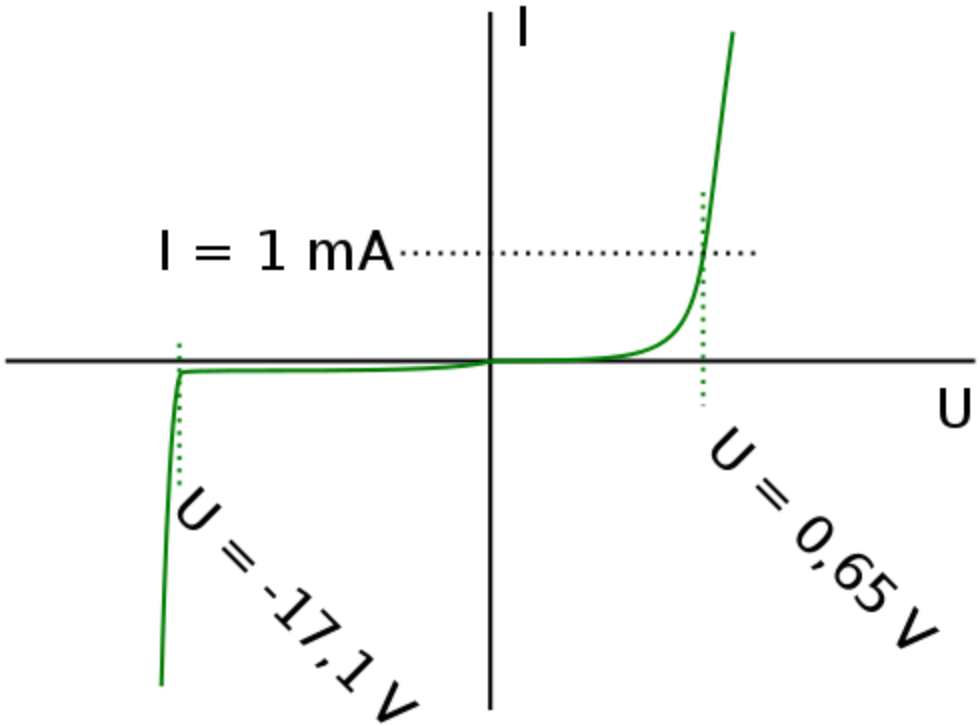
Full wave bridge



Other types of diodes

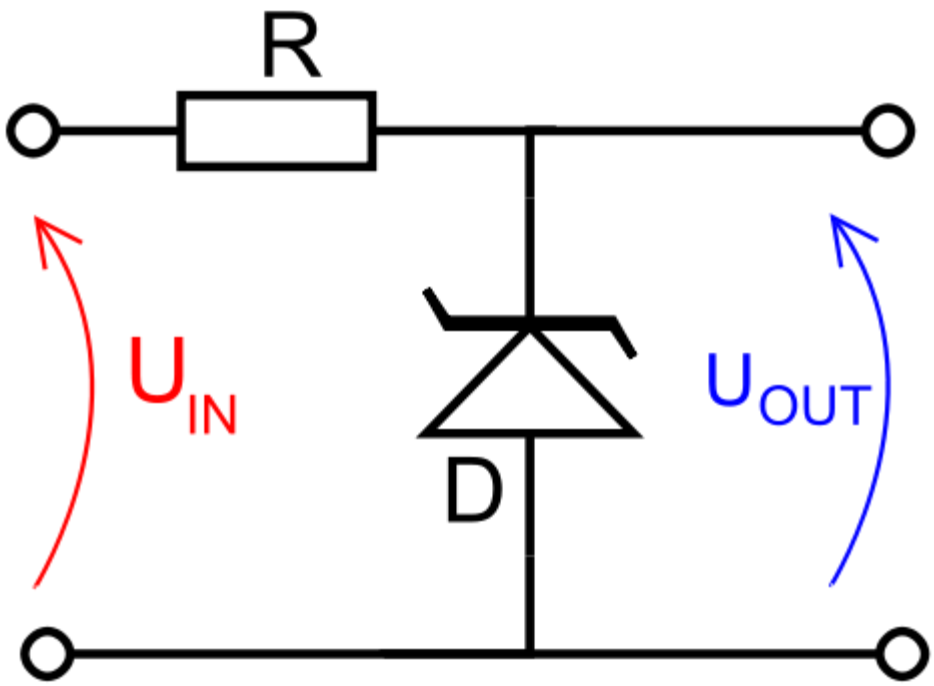
- Voltage regulation diode (Zener diode)
- Light emitting diode
- Variable capacitance diode

Zener diode
(voltage regulation diode)



- Silicon diodes up to about 5.6 volts, the tunelling effect is the predominant
- temperature coefficient is negative.
- Above 5.6 volts, the avalanche effect becomes predominant
- temperature coefficient is positive
- 5.6 V diode, the two effects occur together
- temperature coefficients is almost zero

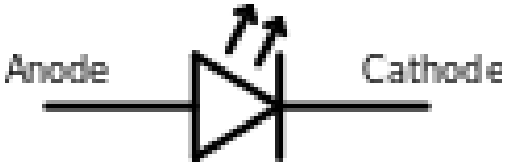
Type	Vznom	Izt	for Vzr and	r	r_{zk} at	I_{zk}	I_R at	V_R	TKvz
BZX55C	V	mA	V	*	*	mA	uA	V	%/k
2V4	2.4	5	2.28~2.56	<85	<600	1	<50	1	-0.09~-0.06
2V7	2.7	5	2.5~2.9	<85	<600	1	<10	1	-0.09~-0.06
3V0	3.0	5	2.8~3.2	<85	<600	1	<4	1	-0.08~-0.05
3V3	3.3	5	3.1~3.5	<85	<600	1	<2	1	-0.08~-0.05
3V6	3.6	5	3.4~3.8	<85	<600	1	<2	1	-0.08~-0.05
3V9	3.9	5	3.7~4.1	<85	<600	1	<2	1	-0.08~-0.05
4V3	4.3	5	4.0~4.6	<75	<600	1	<1	1	-0.06~-0.03
4V7	4.7	5	4.4~5.0	<60	<600	1	<0.5	1	-0.05~+0.02
5V1	5.1	5	4.8~5.4	<35	<550	1	<0.1	1	-0.02~+0.02
5V6	5.6	5	5.2~6.0	<25	<450	1	<0.1	1	-0.05~+0.05
6V2	6.2	5	5.8~6.6	<10	<200	1	<0.1	2	0.03~0.06
6V8	6.8	5	6.4~7.2	<8	<150	1	<0.1	3	0.03~0.07
7V5	7.5	5	7.0~7.9	<7	<50	1	<0.1	5	0.03~0.07
8V2	8.2	5	7.7~8.7	<7	<50	1	<0.1	6.2	0.03~0.08
9V1	9.1	5	8.5~9.6	<10	<50	1	<0.1	6.8	0.03~0.09
10	10	5	9.4~10.6	<15	<70	1	<0.1	7.5	0.03~0.1

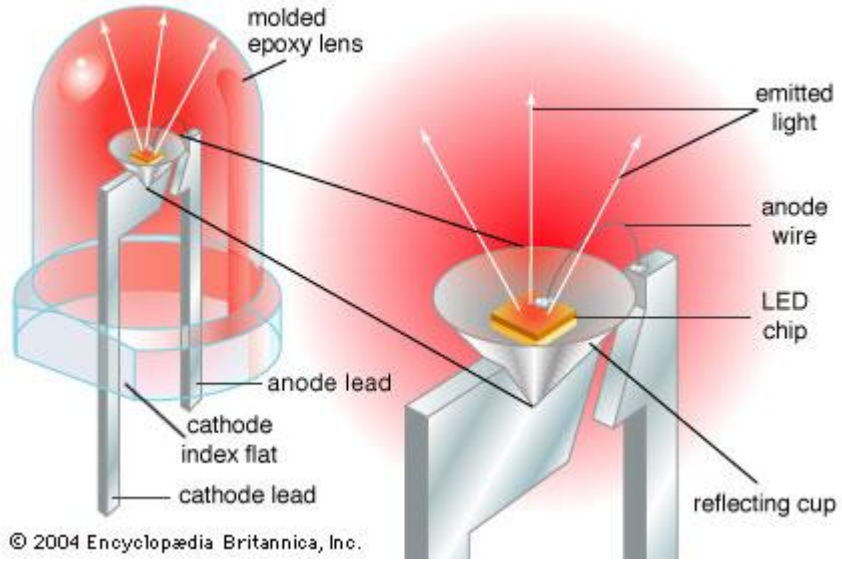

R
U_{IN}
D
U_{OUT}

Precision reference U_{ref}

- Cirrus logic. VRE204
- range 4.5 V accuracy +/- 0.4 mV
- temperature coefficient 0.6 ppm/C,
- -55+125 C
- stability 6 ppm/1000h
- line regulation 6ppm/V
- Supply range13,5-22,0 V
- based on 6.3 zener diode

Light emitting diode LED


Anode
Cathode


molded
epoxy lens
emitted
light
anode
wire
LED
chip
anode lead
cathode
index flat
cathode lead
reflecting cup
© 2004 Encyclopædia Britannica, Inc.

- lineární zářivky, např. Lumilux 36 W produkují 3350 lm což je 93 lm/W
- vysoce výkonné LED diody CREE dosahují až 90 lm/W
- metalhalogenidová výbojka Narva 70W produkuje 5500 lm tedy 78,6 lm/W
- xenonová výbojka do automobilu cca. 70-90 lm/W (Osram uvádí 3050 lm u 35W výbojky)
- vysokoteplotní žárovka až 35 lm/w
- halogenová žárovka 20 lm/W (Osram uvádí 18 lm/W u automobilových halogenových žárovek)
- osram LED Dragon 2W poskytuje asi 40 lm, což je 20 lm/W [1]
- laboratorně dosažený světelný tok u high power LED CREE byl v roce 2007 v hodnotách 130 lm/W
- bílá výkonná LED využívající vhodný luminofor běžně dosahuje 30 lm/W
- jednotlivá bílá 5mm LED poskytuje 1,8 lm, což je cca. 18-25 lm/W
- trubicová halogenová žárovka 13-14 lm/W
- klasická žárovka 60 W na 230V vykazuje světelný tok 12 lm/W

Více zde: http://www.podzemi.net/news/porovnavani-svetelnych-zdroju/

- Color Wavelength range (nm) Typical efficiency (lm/W)
- Red 620 < λ < 645 72
- Red-orange 610 < λ < 620 98
- Green 520 < λ < 550 93
- Cyan 490 < λ < 520 75
- Blue 460 < λ < 490 37
- Truncated 5800 K blackbody[note 2] 251[7] 37%
- Green light at 555 nm (maximum possible luminous efficacy)683 lm/W
- compact fluorecent 46-75 lm/W

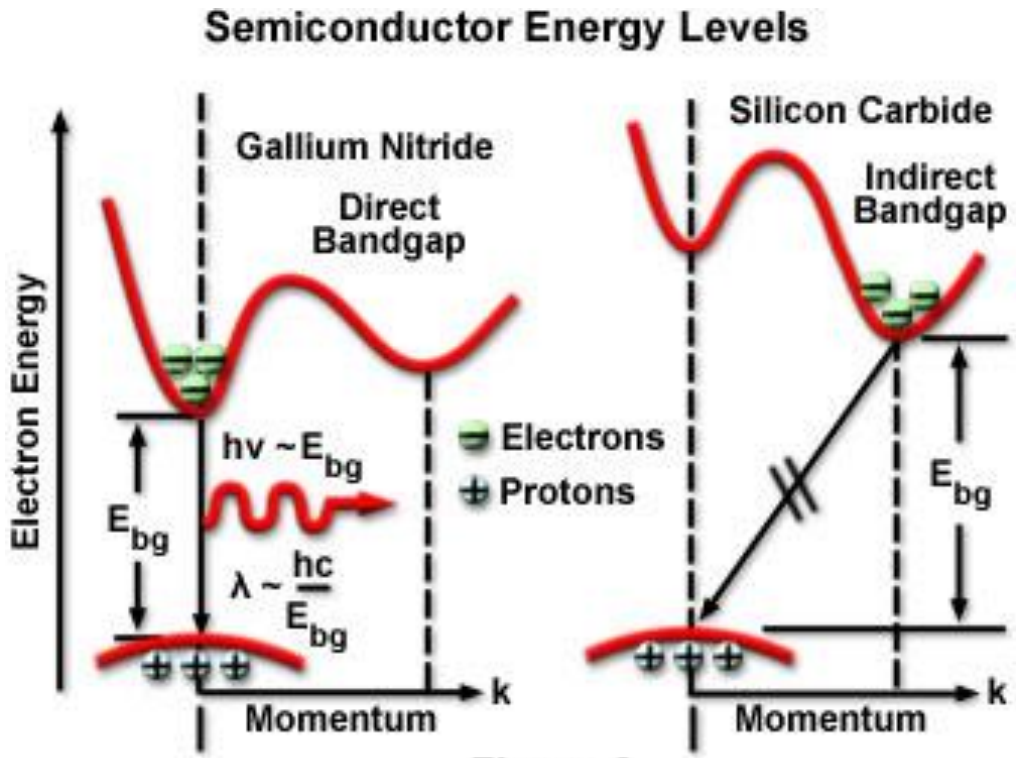
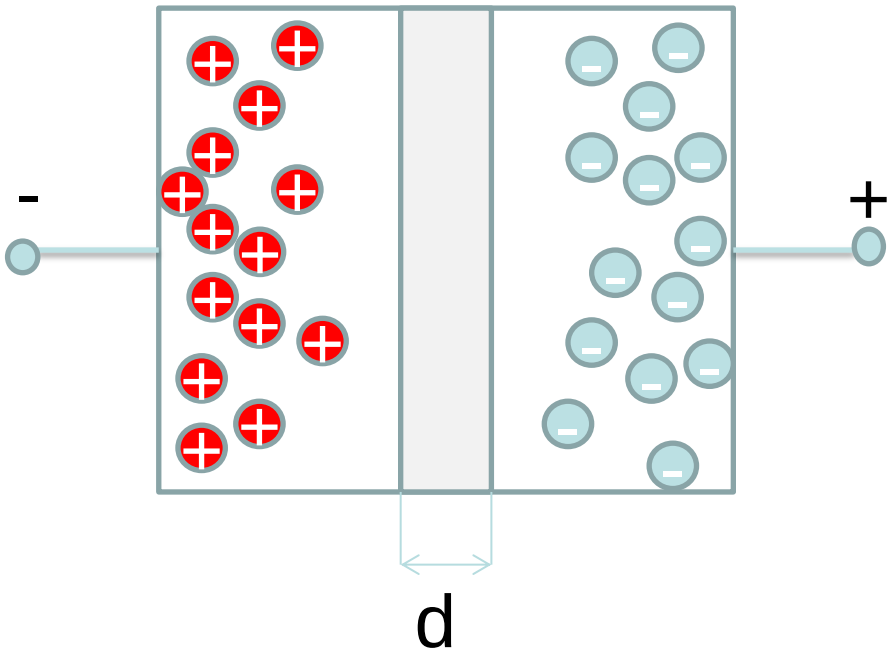
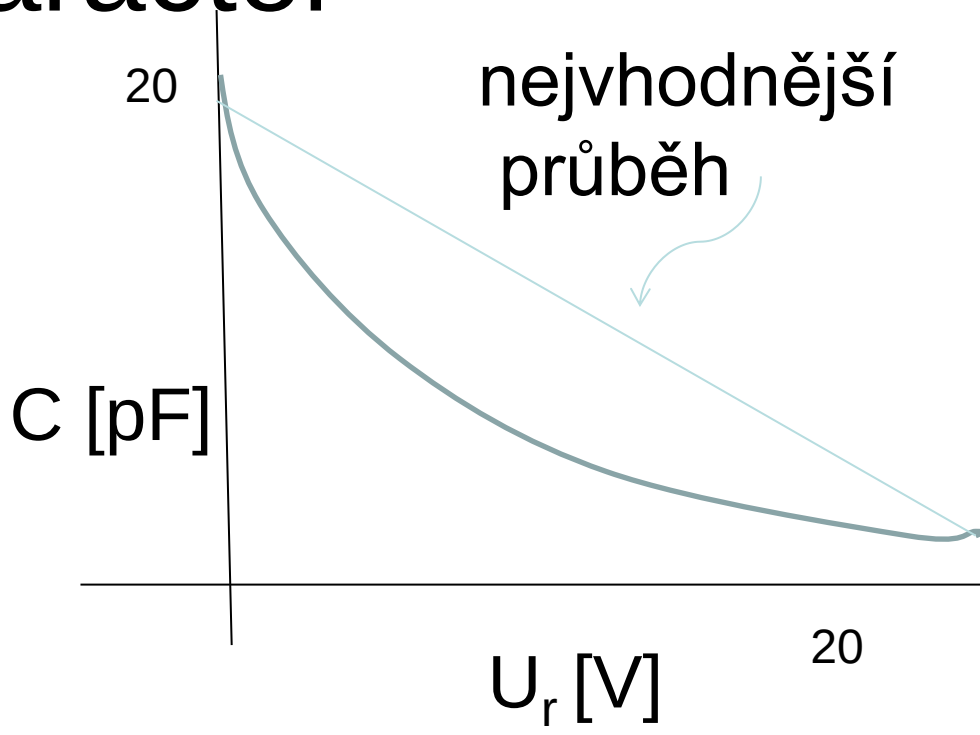

Semiconductor Energy Levels
Gallium Nitride
Direct
Bandgap
Silicon Carbide
Indirect
Bandgap
Electron Energy
hv ~ E bg
E bg
λ ~ hc / E bg
Electrons
Protons
k
Momentum
k
Momentum

Figure 6

- color voltage drop
- infrared 1,6 V
- red 1,8 V až 2,1 V
- orange 2,2 V
- yellow 2,4 V
- green 2,6 V
- blue 3,0 V až 3,5 V
- white 3,0 V až 3,5 V
- Ultraviolet 3,5 V

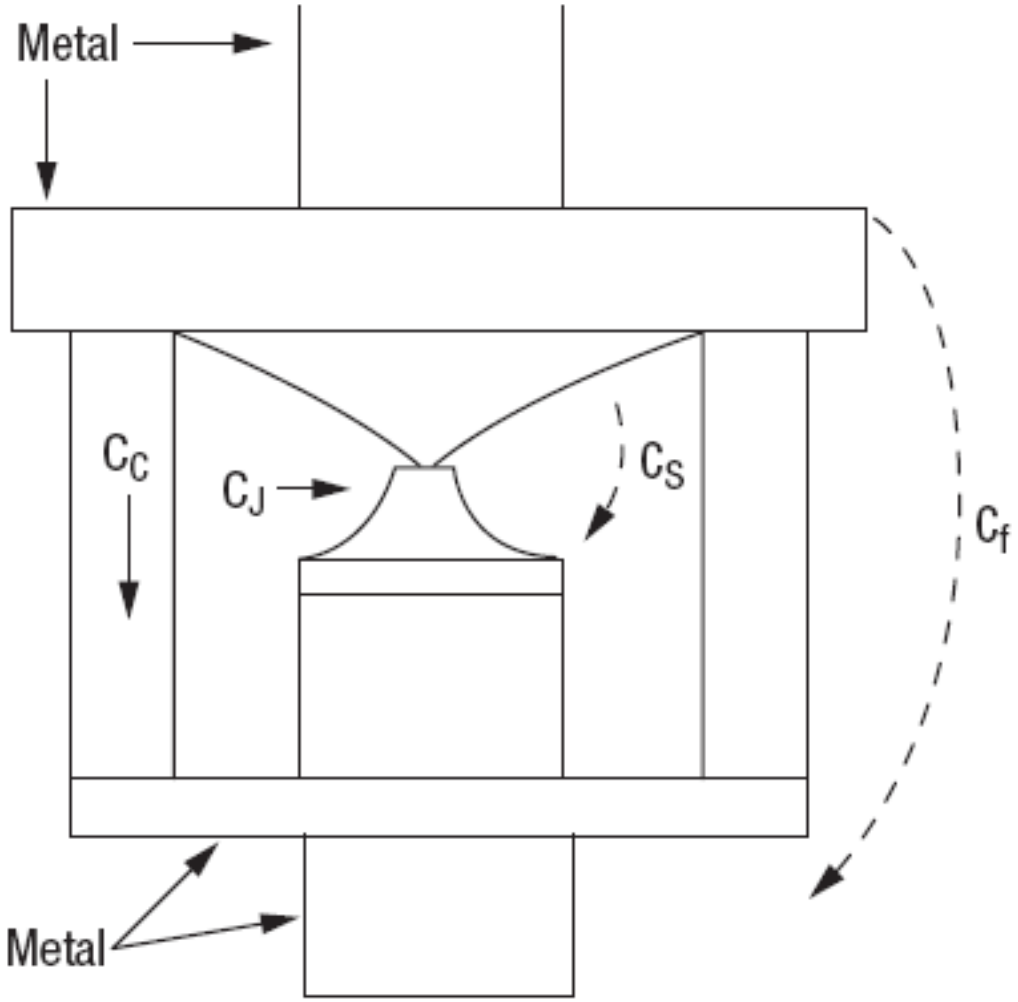
varicap varactor





Kapacity 10-1000 pF

$$C \approx \frac{1}{\sqrt{U}}$$


Metal
C_C
C_J
C_S
C_f
Metal

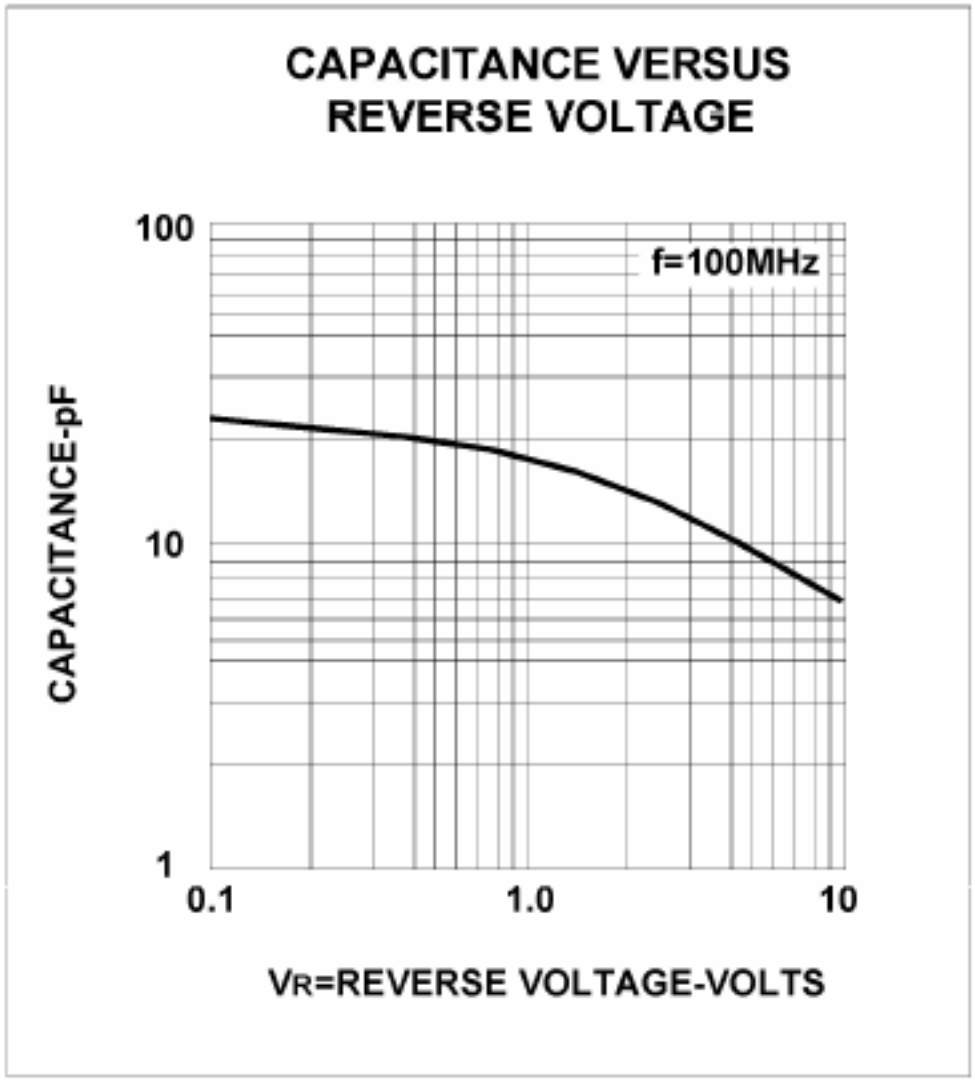
Tuner AFC diode 1S2638

Absolute Maximum Ratings (T_a = 25 °C)

Parameter	Symbol	Value	Unit
Breakdown Voltage	BV	10	V
Forward Current	I_F	250	mA
Power Dissipation	P_D	350	mW
Operating Temperature Range	T_{opr}	- 65 to + 175	°C
Storage Temperature Range	T_{stg}	- 65 to + 200	°C

Characteristics at T_a = 25 °C

Parameter	Symbol	Min.	Max.	Unit
Reverse Current at V_R = 10 V	I_R	-	5	µA
Nominal Capacitance at V_R = 4 V, f = 1 MHz	C	5	20	pF
at V_R = 4 V, f = 100 MHz	Q	50	-	-

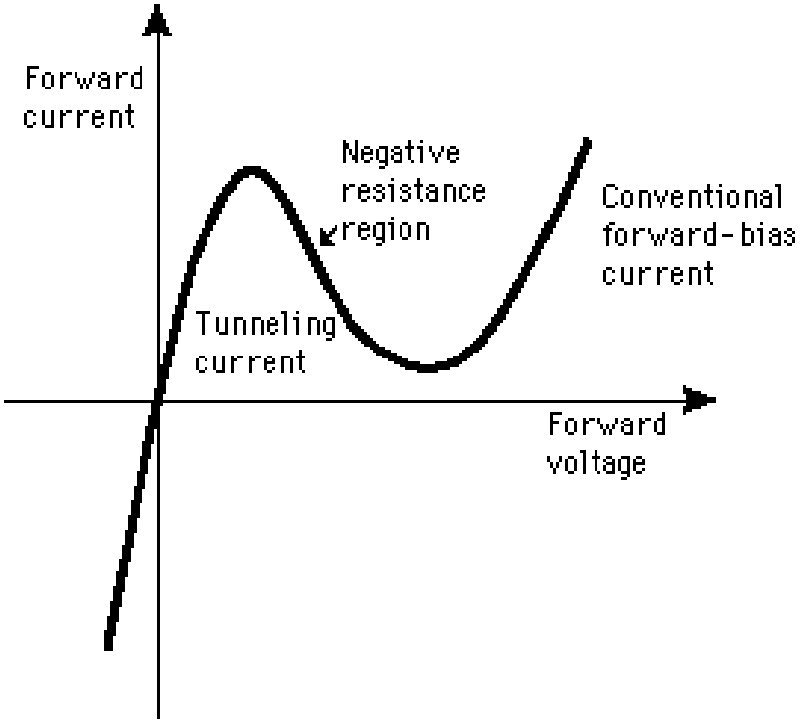

CAPACITANCE VERSUS
REVERSE VOLTAGE
100
10
1
f=100MHz
CAPACITANCE-pF
0.1
1.0
10
VR=REVERSE VOLTAGE-VOLTS

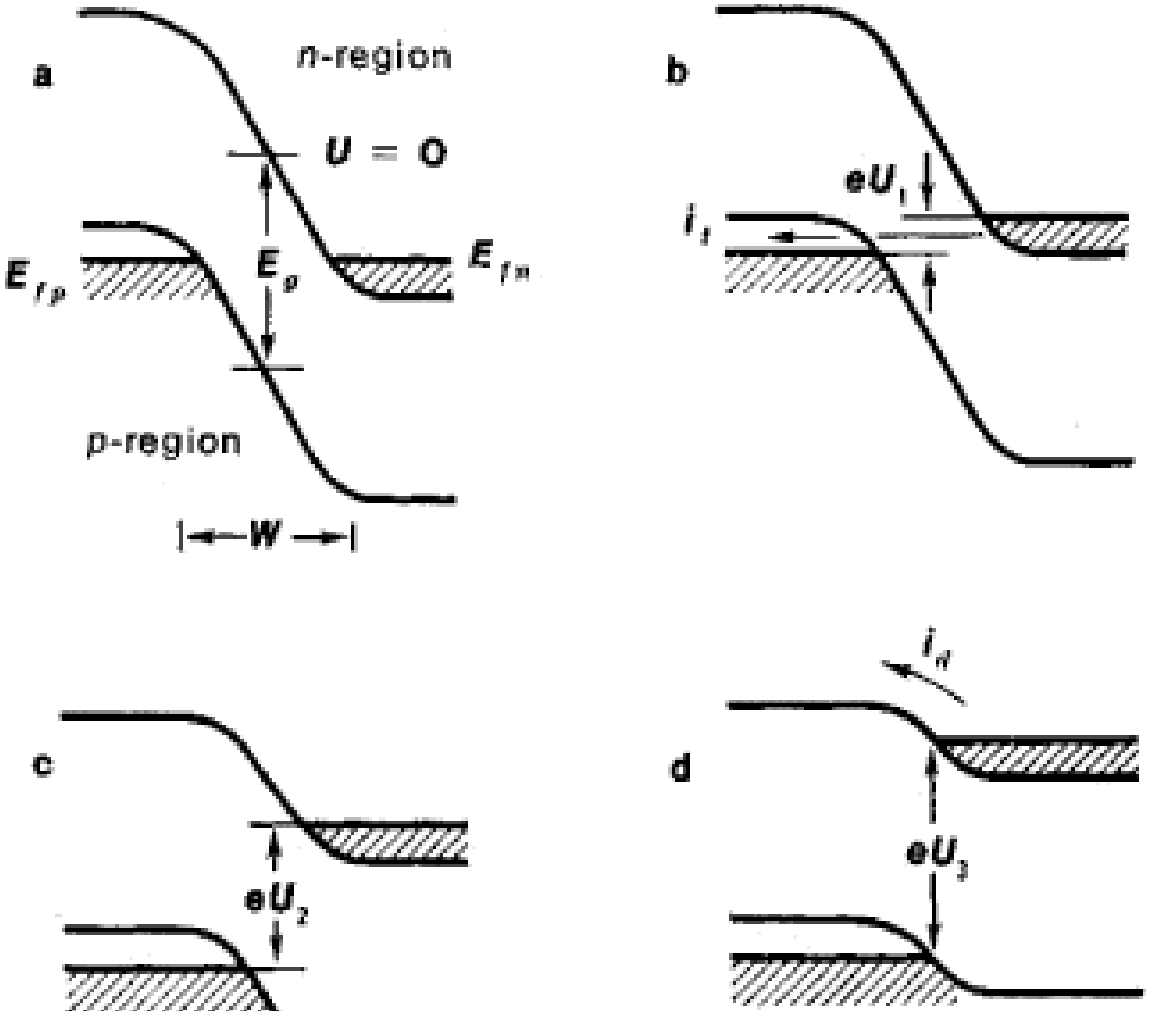
Tunell diode
Esaki 1958

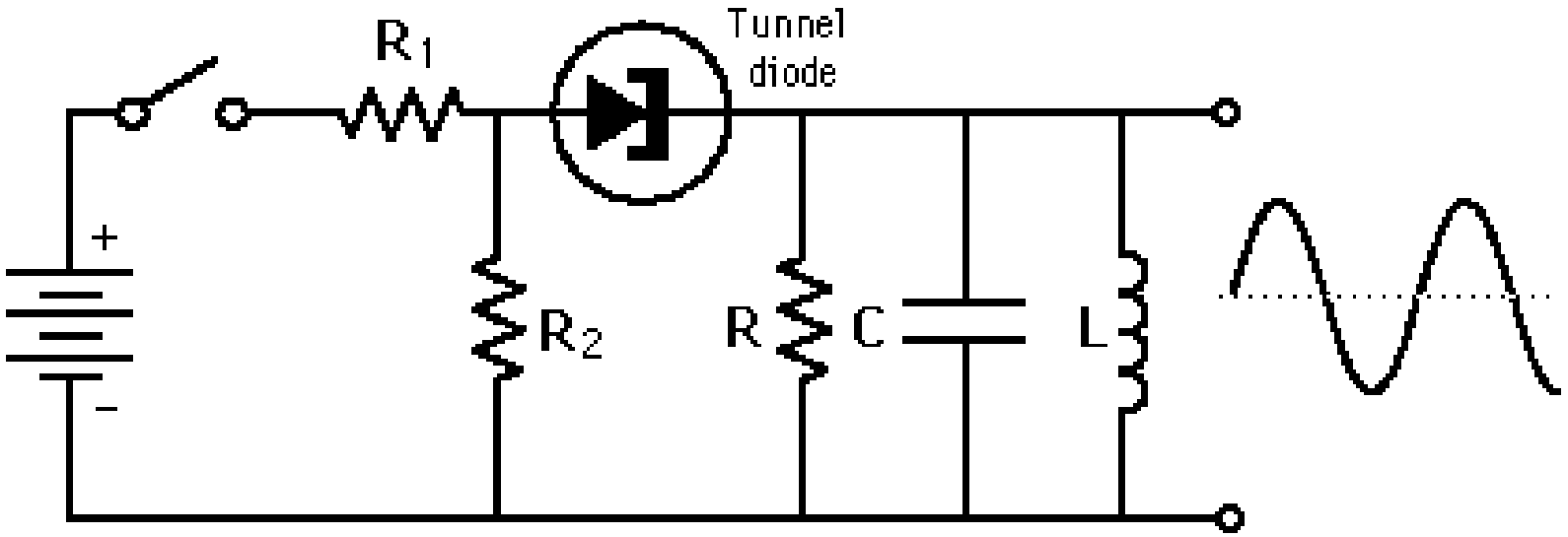
- Ph.D. research student Esaki in 1958

- structure
- very high doping levels
- depletion region 5-10 nm

Tunnel diode




a
n-region
U = 0
E_fp
E_g
E_fn
p-region
W
b
eU_1
i_t
c
eU_2
d
i_n
eU_2


R1
Tunnel
diode
+
−
R2
R
C
L

Shottky diode

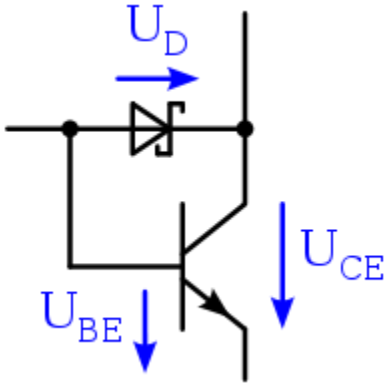
- Advantages
- Voltage drop in forvard direction is relativelly low (0 at 1 mA is in the range 0.15 V to 0.46 V, see the 1N5817, 1N5711)
- The reverse recovery time is relativelly short (up to 0.1 ns small signal diodes) / Si p-n diode up 100 ns

Shotky diode

- Disadvantages (silicon-metal) contrary (carbide silicon-metal)
- Relatively high leakage current (hundreds of nA)
- low reverse voltage (approx. 50 V up 200 V)/CSi-M up (1700 V)
- Thermal instability / Csi-M up to 200 C
- Low surge resistance

Schottky diode

- Small-signal Schottky diodes 1N5711,1N6263, 1SS106, 1SS108, 41–43, 45–49

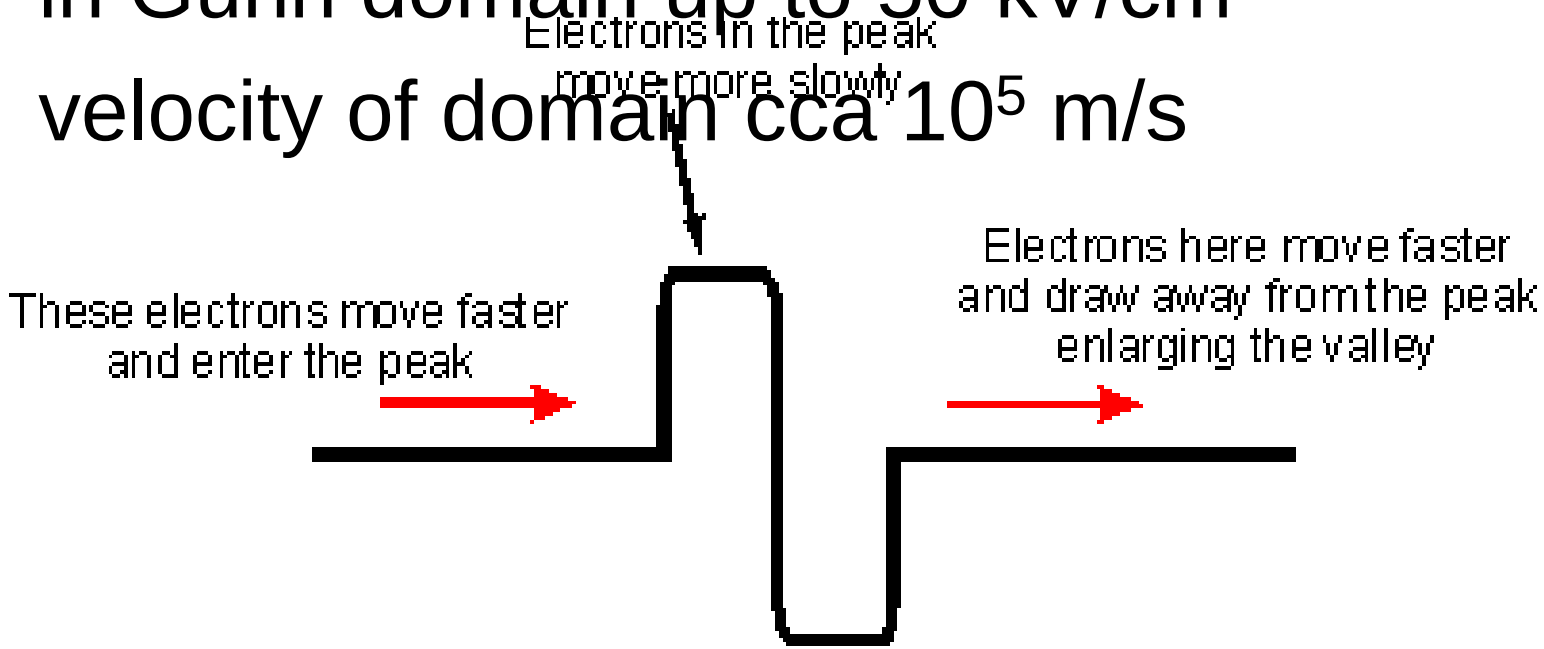


Gunn diode
transferred electron device (TED)

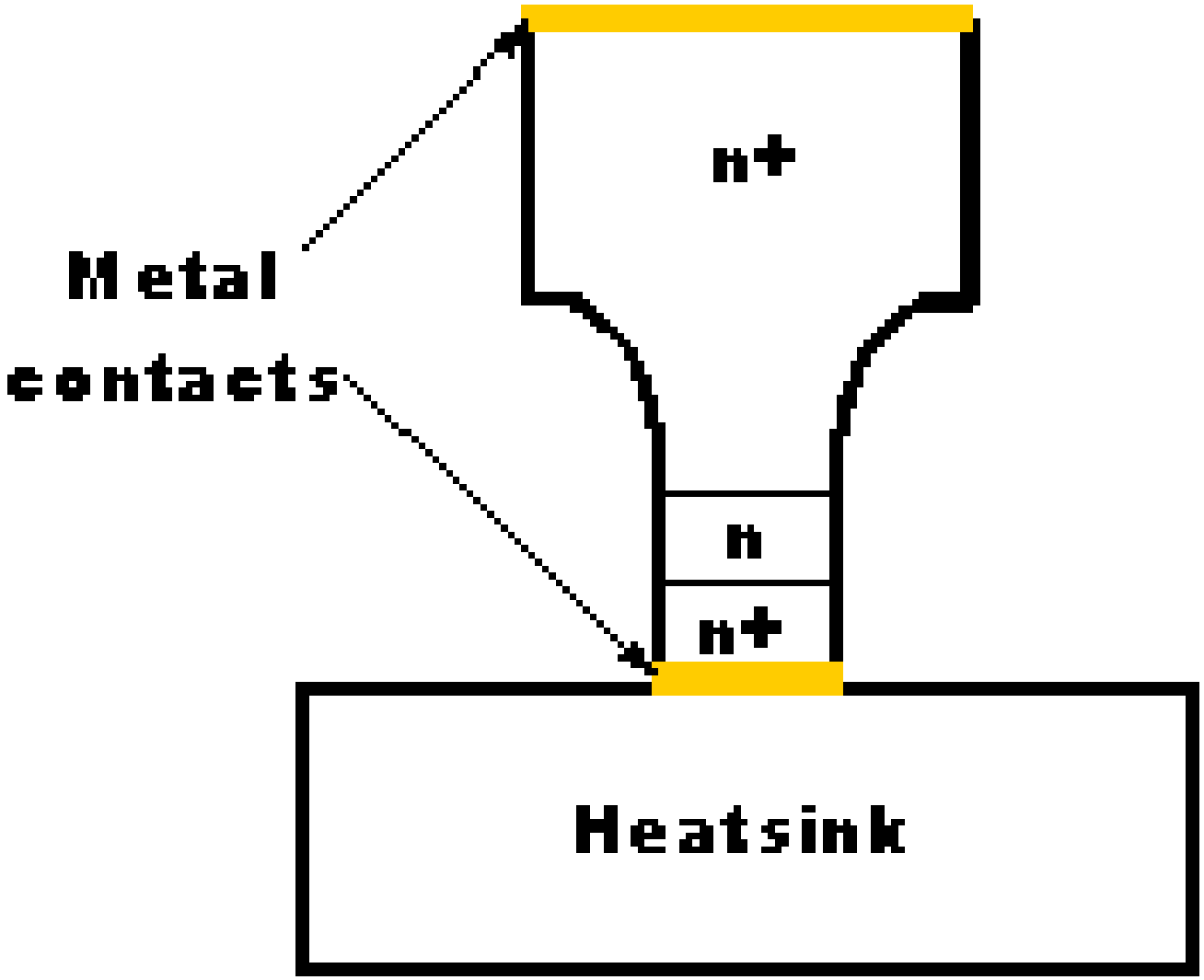
- 1963 John Battiscombe Gunn
- osciace pro intenzitu řádově několik 1000 V/cm
- microwave oscilator

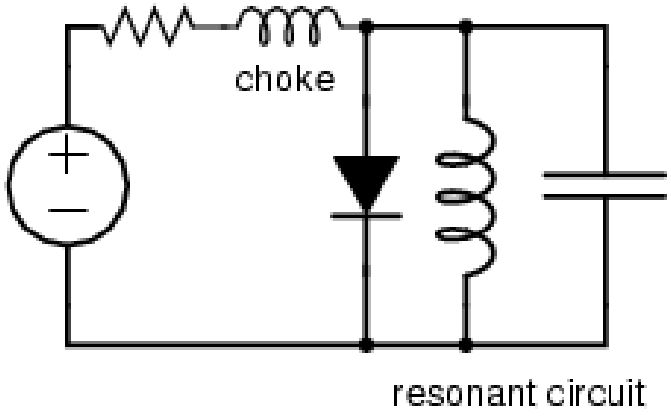
Gunn diode, operation principle

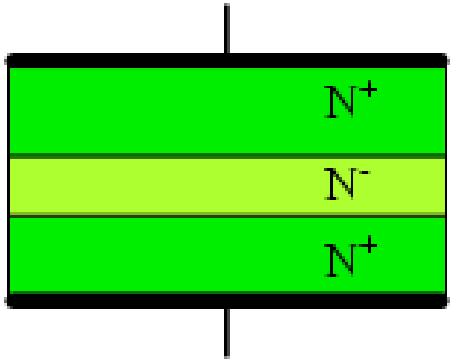
- elektron velocity in GaAs
- 3.2 kV/cm low mobility valley
- in Gunn domain up to 50 kV/cm
- velocity of domain cca 10^5 m/s

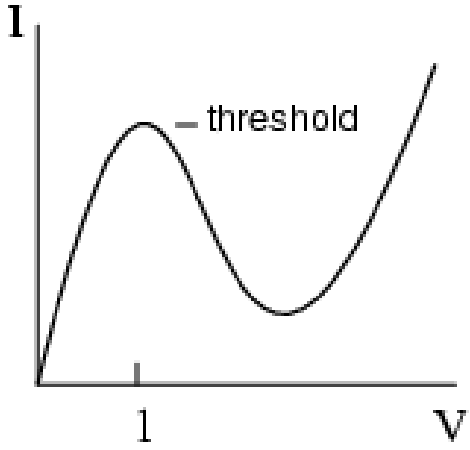


Gallium arsenide Gunn diodes frequencies up to 200 GHz gallium nitride materials can reach up to 3 terahertz.




choke
resonant circuit


N+
N-
N+

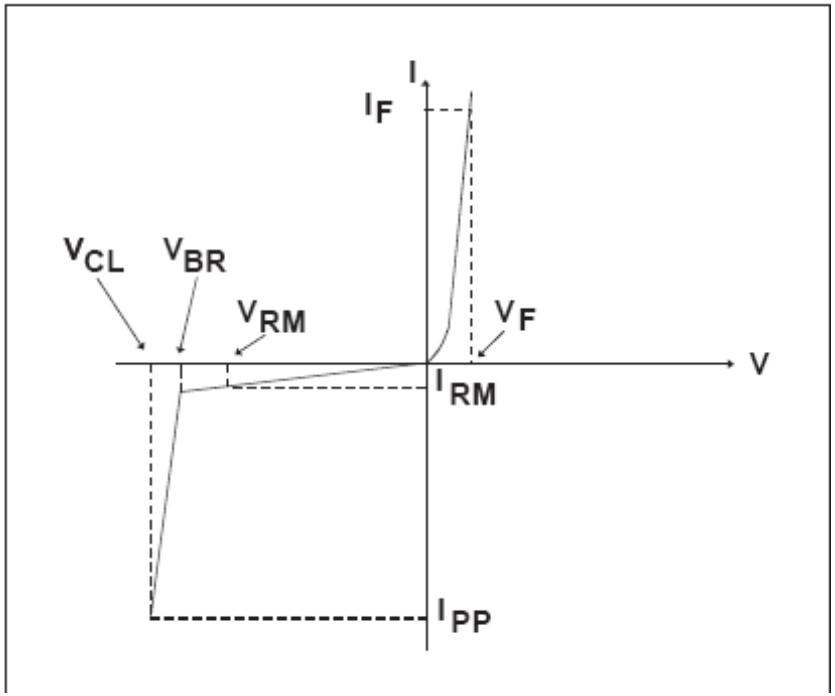

I
threshold
1
V

Transil

- Leakage current.
- Maximum reverse standoff voltage
- Breakdown voltage
- Clamping voltage: the voltage at which the device will conduct its fully rated current (hundreds to thousands of amperes).
- Parasitic capacitance
- Parasitic inductance
- Amount of energy it can absorb

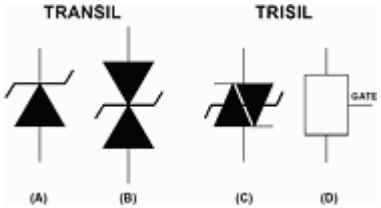
ELECTRICAL CHARACTERISTICS (T_{amb} = 25°C)

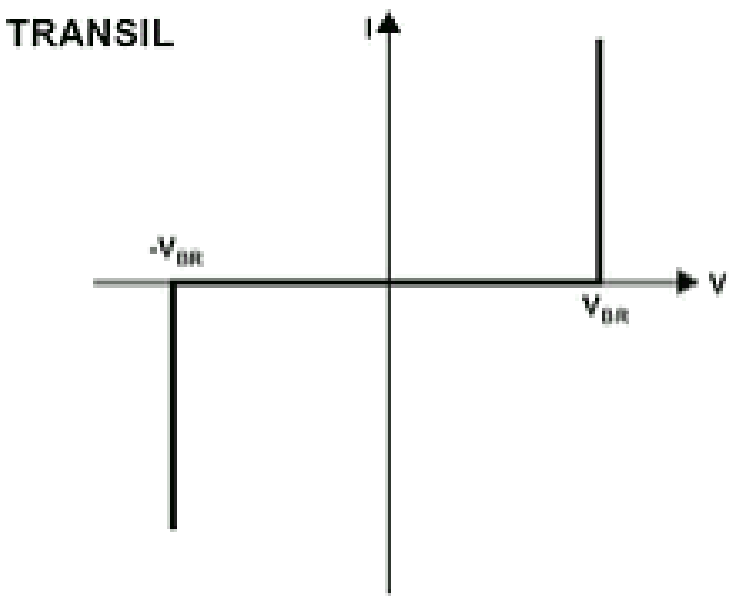
Symbol	Parameter
V_{RM}	Stand-off voltage
V_{BR}	Breakdown voltage
V_{CL}	Clamping voltage
I_{RM}	Leakage current @ V_{RM}
I_{PP}	Peak pulse current
αT	Voltage temperature coefficient
V_F	Forward voltage drop

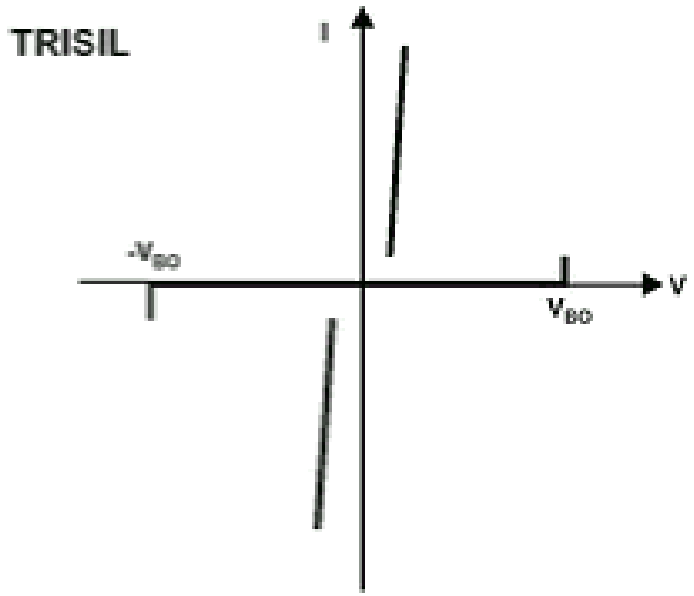


Types		I_{RM} @ V_{RM} max		V_{BR} @ I_R min	nom	max		V_{CL} @ I_{PP} max		V_{CL} @ I_{PP} max		αT max	C typ
				note2				10/1000µs		8/20µs		note3	note4
Unidirectional	**Bidirectional**	**µA**	**V**	**V**	**V**	**V**	**mA**	**V**	**A**	**V**	**A**	**10^{-4}/ °C**	**pF**
1.5KE6V8A	1.5KE6V8CA	1000	5.8	6.45	6.8	7.14	10	10.5	143	13.4	746	5.7	9500
1.5KE7V5A	1.5KE7V5CA	500	6.4	7.13	7.5	7.88	10	11.3	132	14.5	690	6.1	8500
1.5KE10A	1.5KE10CA	10	8.55	9.5	10	10.5	1	14.5	100	18.6	538	7.3	7000
1.5KE12A	1.5KE12CA	5	10.2	11.4	12	12.6	1	16.7	90	21.7	461	7.8	6000
1.5KE15A	1.5KE15CA	1	12.8	14.3	15	15.8	1	21.2	71	27.2	368	8.4	5000
1.5KE18A	1.5KE18CA	1	15.3	17.1	18	18.9	1	25.2	59.5	32.5	308	8.8	4300
1.5KE22A	1.5KE22CA	1	18.8	20.9	22	23.1	1	30.6	49	39.3	254	9.2	3700
1.5KE24A	1.5KE24CA	1	20.5	22.8	24	25.2	1	33.2	45	42.8	234	9.4	3500
1.5KE27A	1.5KE27CA	1	23.1	25.7	27	28.4	1	37.5	40	48.3	207	9.6	3200
1.5KE30A	1.5KE30CA	1	25.6	28.5	30	31.5	1	41.5	36	53.5	187	9.7	2900
1.5KE33A	1.5KE33CA	1	28.2	31.4	33	34.7	1	45.7	33	59.0	169	9.8	2700

Transil-trisil

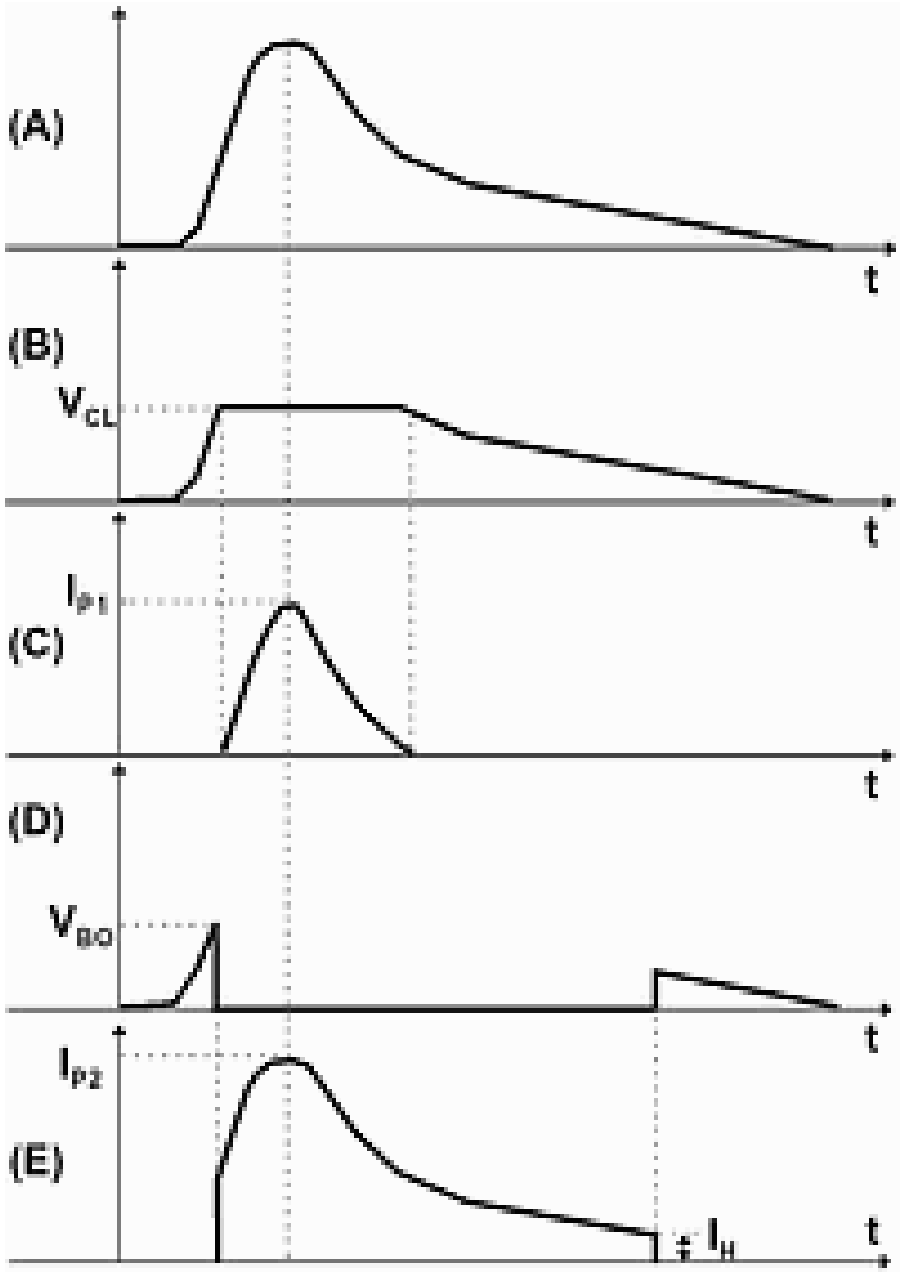




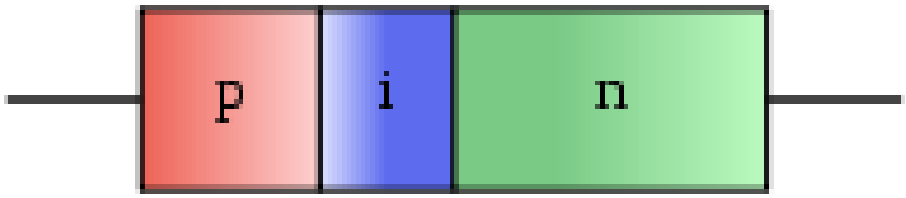


(A),(B),(C)
transil

(D),(E)
trisil



PIN diode



- RF switches, attenuators, photodetectors.
- RF switches -1us
- photodetector
- photovoltaic cell
- capacitance 1 pF (at 320MHz reactance 500 Ω)