



OPEN LESSEN KROKUSVAKANTIE 2026

ELEKTRONICA - hoorcollege
Prof. Jo Verhaevert
13:00 – 16:00



UNIVERSITEIT
GENT

Hoorcollege 3

**Handboek: Chapter 2,
Section 2.1 – 2.3,
2.9 – 2.10 (partim),
Chapter 3, Section 3.5**

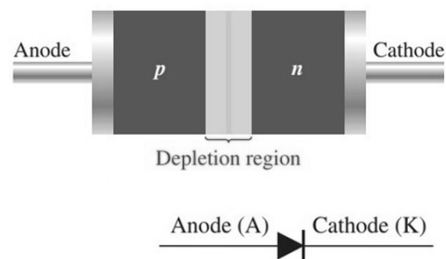
Inhoud

- Diode
 - Forward – reverse bias
- Stroomspanningskarakteristiek
- Diodemodellen
 - Ideaal – Praktisch – Compleet
- Datablad
- Troubleshooting
- Zonnecel

Elektronica – Hoorcollege 3 – Slide 3

Diode

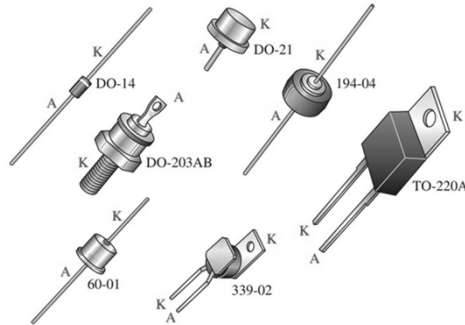
- PN-junctie
 - P-type: anode
 - N-type: kathode
 - KNAP



- Stroom slechts in 1 richting

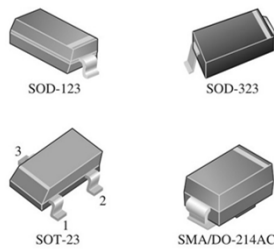
Elektronica – Hoorcollege 3 – Slide 4

- Verpakkingen: through-hole



- Kathode (K) aangeduid met streepje, randje...
- Slechts 1 pin: kathode is behuizing

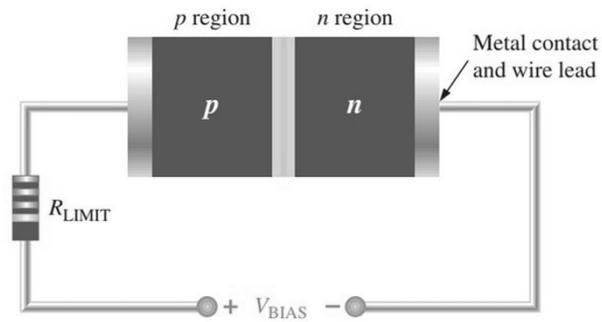
- Verpakkingen: SMD



- Kathode aangeduid met streepje, randje...
- Merk op: SOT-23 (Small-Outline Transistor) heeft 3 pinnen → 2 versies
 - 1 diode: pin 3 = K & pin 1 = A
 - 2 diodes: pin 3 = common A of K → datablad

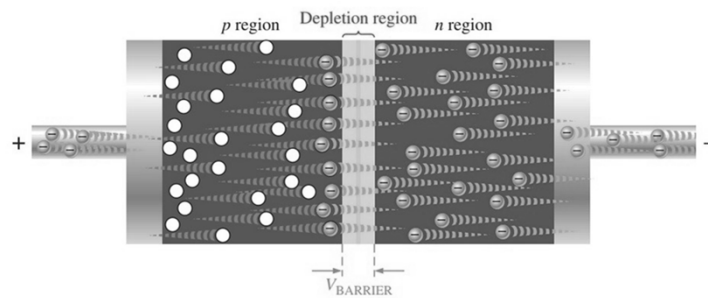
- Forward bias

- V_{BIAS} : -pool aan n-type & +pool aan p-type
- Weerstand beperkt stroom



Elektronica – Hoorcollege 3 – Slide 7

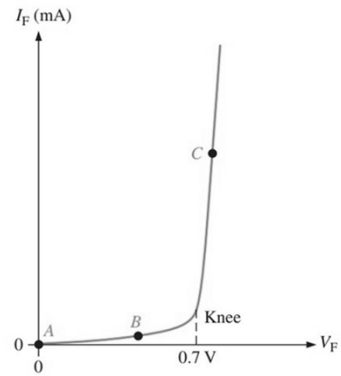
- $V_{BIAS} > V_B$ (= potentiaalbarrière)
- Elektronenstroom & gatenstroom



- Elektronen verliezen energie (= potentiaalbarrière)
- Spanningsval (silicium = 0.7 V)
- Bij germanium 0.2 V

Elektronica – Hoorcollege 3 – Slide 8

- V_F (*forward-bias voltage*)
- I_F (*forward current*)



- Punt C:
 - Geleidelijke toename V_F door interne dynamische weerstand (= materiaaleigenschap)

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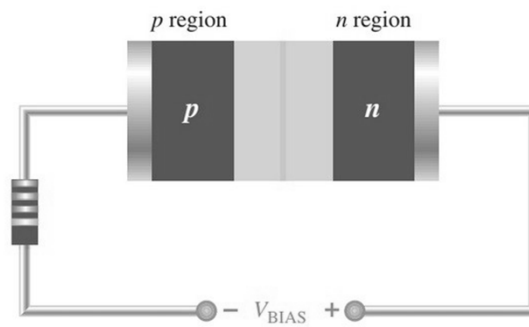
Demo

- <http://www.tinkercad.com/things/6CbX28eU9Aa>

Elektronica – Hoorcollege 3 – Slide 10

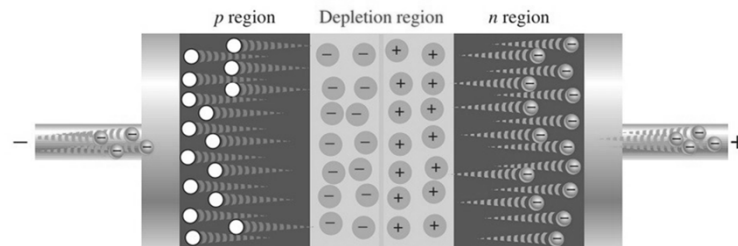
- Reverse bias

- V_{BIAS} : -pool aan p-type & +pool aan n-type
- Weerstand beperkt stroom



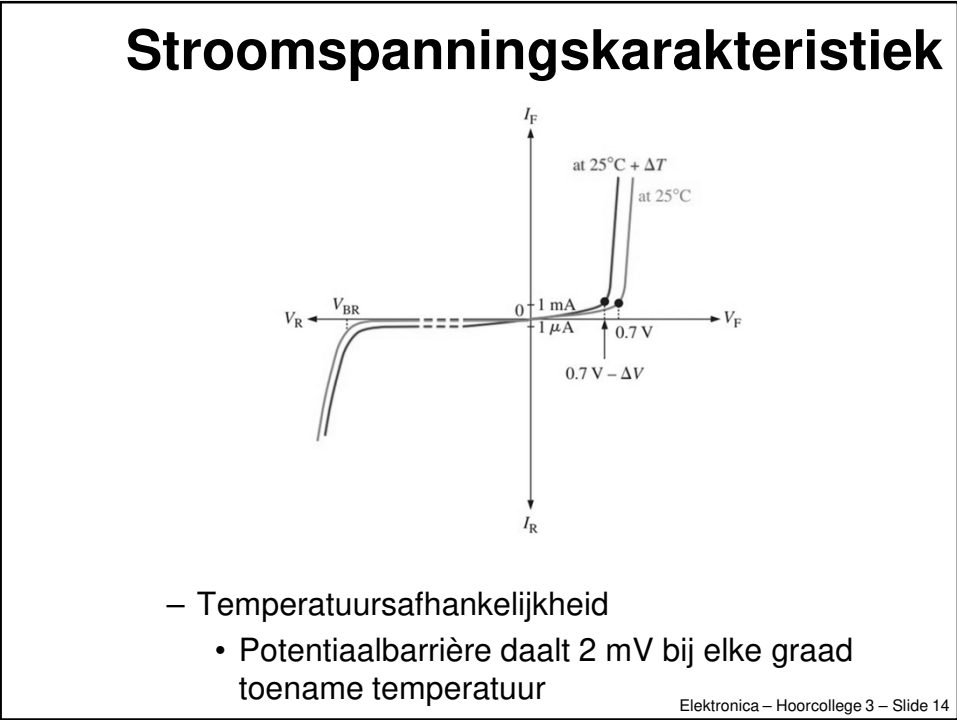
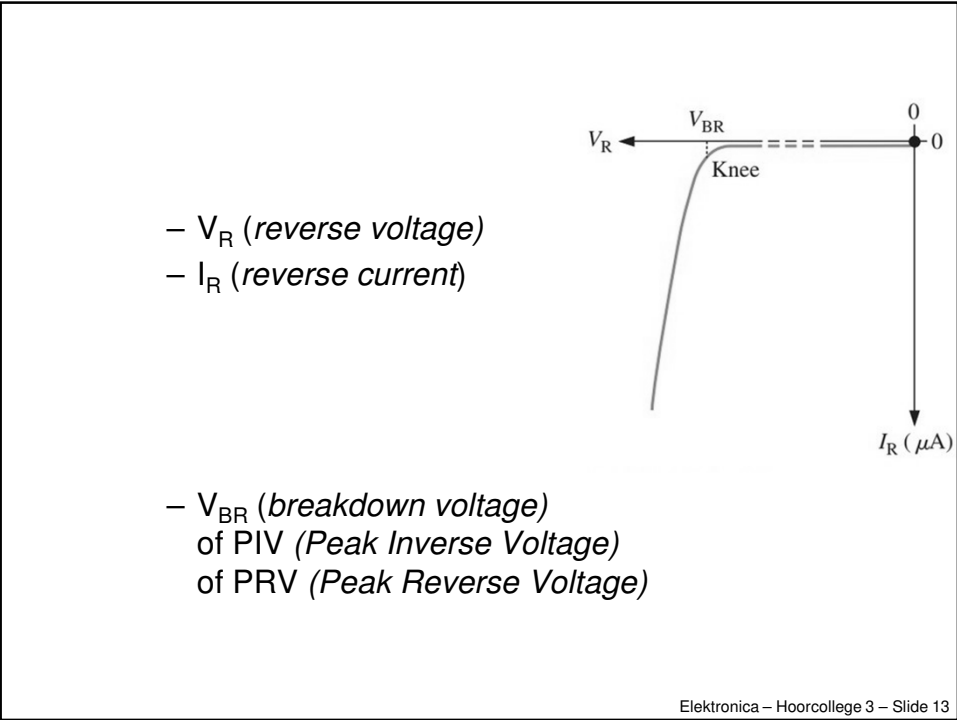
Elektronica – Hoorcollege 3 – Slide 11

- Elektronenstroom & gatenstroom



- $V_{BIAS} \gg V_{BD}$: doorslagspanning (*breakdown voltage*)
 - 1 elektron duwt meerdere elektronen uit valentielaag: lawine-effect (*avalanche effect*)

Elektronica – Hoorcollege 3 – Slide 12

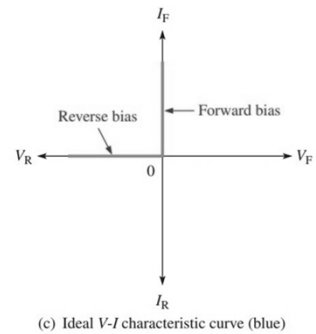
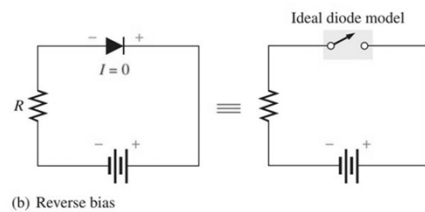
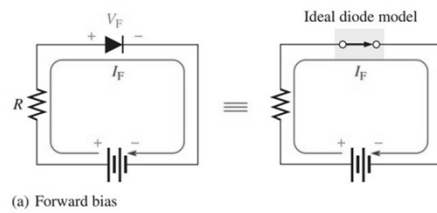


Diodemodellen

- Ideaal
- Praktisch
- Compleet

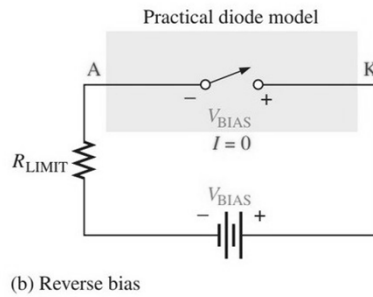
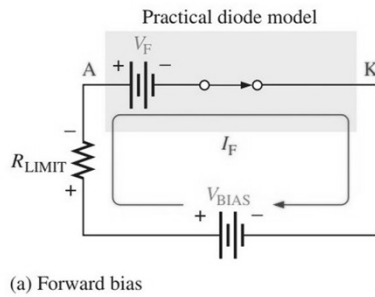
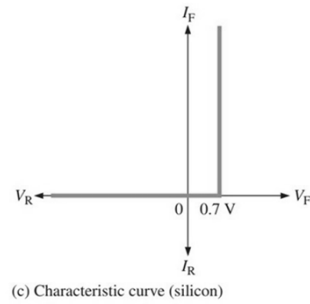
Elektronica – Hoorcollege 3 – Slide 15

- Ideaal → zoals schakelaar
 - $V_{\text{BIAS}} = 0$ & dynamische weerstand = 0

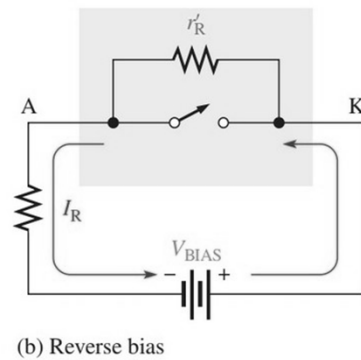
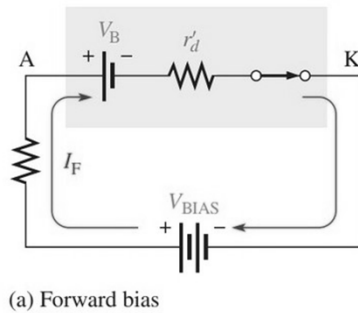
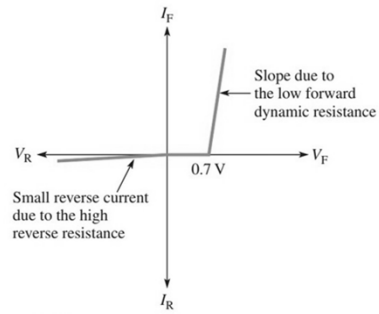


Elektronica – Hoorcollege 3 – Slide 16

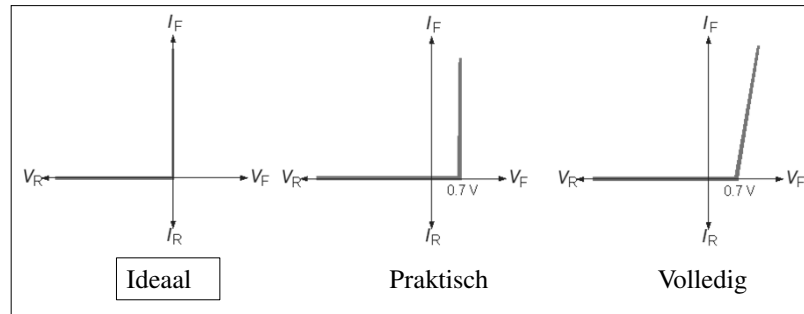
- Praktisch
 - zoals schakelaar
 - mét V_F (0.7 V)
 - Dynamische weerstand = 0



- Compleet
 - Extra: r_R'



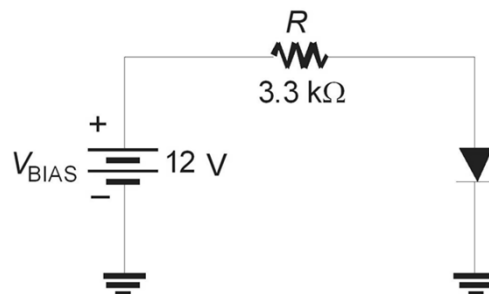
- Samengevat



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Oefening

- Hoeveel bedraagt de stroom door de weerstand? Maak eerst gebruik van het ideale model, nadien van het praktische model.



Elektronica – Hoorcollege 3 – Slide 20

Datablad

- 1N4001: eigenschappen
 - Maximale
 - V_{RRM} (peak reverse voltage) = 50 V
 - Thermische
 - Gemiddelde vermogensdissipatie = 3 W
 - Elektrische
 - $V_F @ 1 A = 1.1 V$



1N4001 - 1N4007

Features

- Low forward voltage drop.
- High surge current capability.



DO-41
COLOR BAND DENOTES CATHODE

General Purpose Rectifiers

Absolute Maximum Ratings*

*T_J = 25°C unless otherwise noted

Symbol	Parameter	Value							Units
		4001	4002	4003	4004	4005	4006	4007	
V _{RRM}	Peak Repetitive Reverse Voltage	50	100	200	400	600	800	1000	V
I _{AVG}	Average Rectified Forward Current, .375" lead length @ T _J = 75°C	1.0							A
I _{FSM}	Non-repetitive Peak Forward Surge Current, 8.3 ms Single Half-Sine-Wave	30							A
T _{STG}	Storage Temperature Range	-55 to +175							°C
T _J	Operating Junction Temperature	-55 to +175							°C

Thermal Characteristics

Symbol	Parameter	Value	Units
P _D	Power Dissipation	3.0	W
R _{θJA}	Thermal Resistance, Junction to Ambient	50	°C/W

Electrical Characteristics

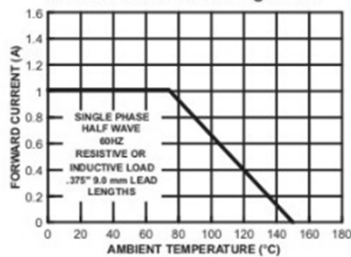
*T_J = 25°C unless otherwise noted

Symbol	Parameter	Device							Units
		4001	4002	4003	4004	4005	4006	4007	
V _F	Forward Voltage @ 1.0 A	1.1							V
I _L	Maximum Full Load Reverse Current, Full Cycle, T _J = 75°C	30							µA
I _R	Reverse Current @ rated V _R , T _J = 25°C	5.0							µA
		500							µA
C _T	Total Capacitance, V _B = 4.0 V, f = 1.0 MHz	15							pF

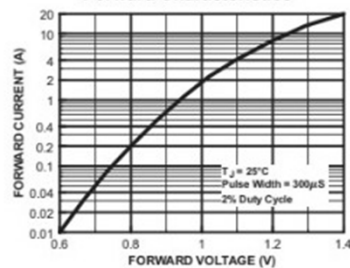
Elektronica – Hoorcollege 3 – Slide 21

Typical Characteristics

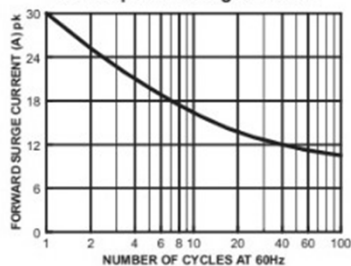
Forward Current Derating Curve



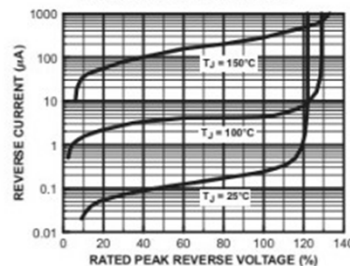
Forward Characteristics



Non-Repetitive Surge Current



Reverse Characteristics



Elektronica – Hoorcollege 3 – Slide 22

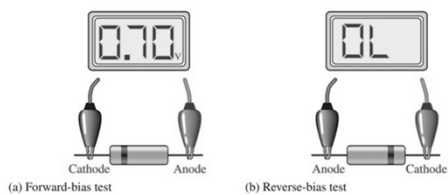
Troubleshooting

- Multimeter in weerstandsmeting
 - Werkend
 - Forward bias: lage weerstand
 - Reverse bias: hoge weerstand
 - Kapot
 - Forward & reverse bias: hoge weerstand
 - Forward & reverse bias: lage weerstand

Elektronica – Hoorcollege 3 – Slide 23

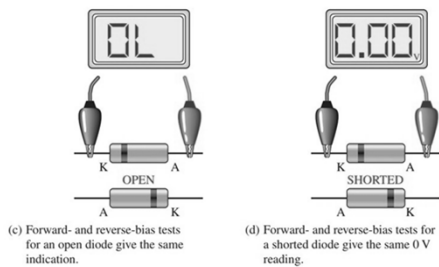
- Multimeter in diodemeting

- Werkend



- Kapot

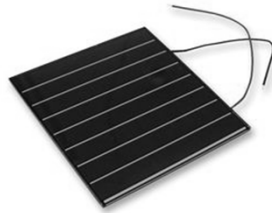
- Open
 - Kortgesloten



Elektronica – Hoorcollege 3 – Slide 24

Zonnecel

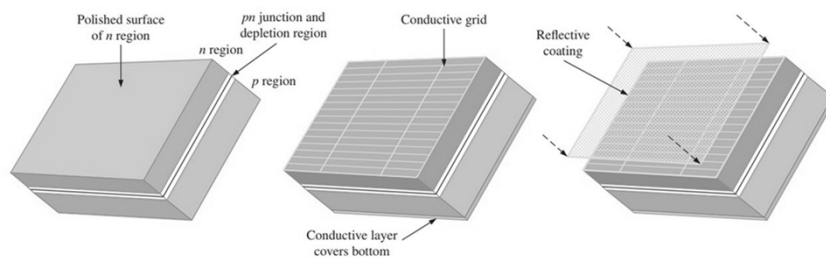
- Elk uur voldoende beschikbaar voor wereldwijde & jaarlijkse vraag elektriciteit
- Omzetten naar elektrische energie
 - Zeer efficiënt met halfgeleidermateriaal
 - In fotonvoltaïsche cel (*Photovoltaic Cell* of *PV-cell*)



- Demo

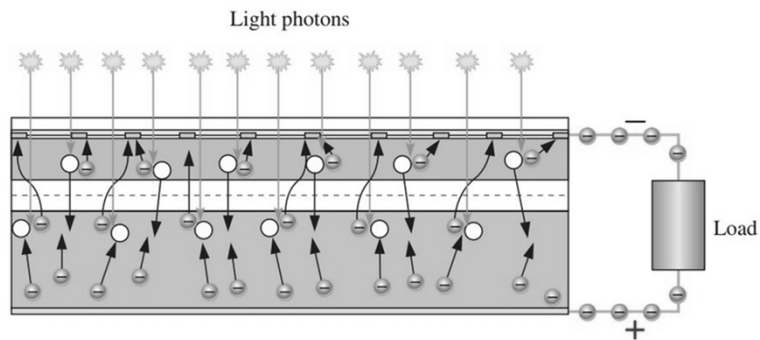
Elektronica – Hoorcollege 3 – Slide 25

- Kristallijne siliciumzonnecel
 - Bovenop n-type geleidend rooster
 - + antireflecterende laag (absorptie maximaliseren)
 - + glazen (of plexiglazen) plaat als bescherming
 - Onderkant p-type vlakke, metalen plaat



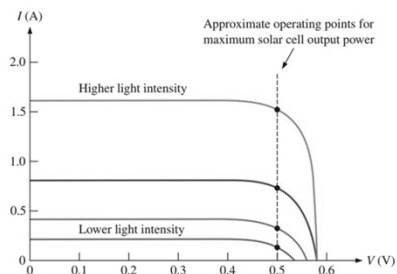
Elektronica – Hoorcollege 3 – Slide 26

- Fotovoltaïsch effect
 - Foton (energiepakket)
 - maakt elektronen los & gaat naar n-type
 - laat gat in p-type achter
 - Terug combineren via belasting = stroom!



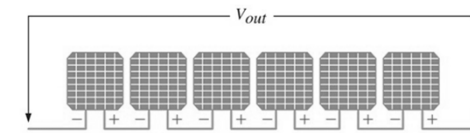
Elektronica – Hoorcollege 3 – Slide 27

- Grootte 100 cm² tot 225 cm²
 - Met bruikbare spanning 0.5 tot 0.6 V
- Bij 1000 W/m² lichtintensiteit: 2 A stroom
 - Hoe meer zonlicht, hoe meer stroom
 - Spanning daarbij ongeveer constant
 - Aanpassen R_L door laadregelaar (*charge controller*)

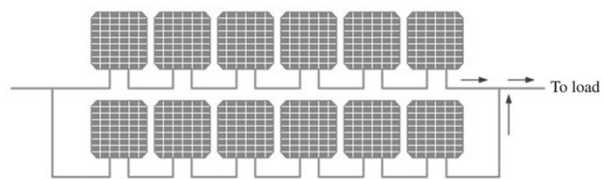


Elektronica – Hoorcollege 3 – Slide 28

- Serieschakeling
 - Spanning optellen – stroom blijft identiek
- Zonnepaneel
 - Meestal combinatie serie- & parallelschakeling



(a) Series connection increases voltage



(b) Series-parallel connection increases current and voltage

Hoorcollege 4

**Handboek: Chapter 2,
Section 2.4 – 2.6, 2.7 (partim),
Chapter 3, Section 3.3**

Elektronica – Hoorcollege 4 – Slide 1

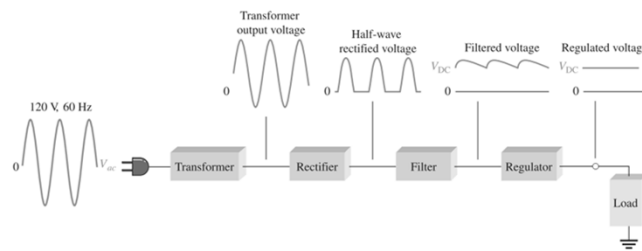
Inhoud

- Inleiding
- Gelijkrichter
 - Enkelzijdig – dubbelzijdig – brug
- Afvlakfilter
- Spanningsregelaar
- Diodebegrenzer
- Varactor

Elektronica – Hoorcollege 4 – Slide 2

Inleiding

- Elektriciteitsnetwerk: AC (230 V – 50 Hz)
 - Elektronica: DC
- Omzetting van AC naar DC nodig
 - Lader – adapter – pc-voeding

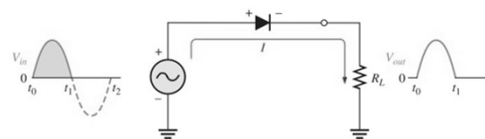


- Transformator – gelijkrichter – afvlakfilter – spanningsregelaar

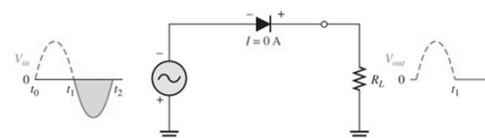
Elektronica – Hoorcollege 4 – Slide 3

Enkelzijdige gelijkrichter

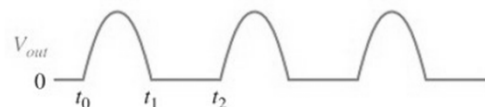
- Positieve alternantie
 - Diode geleidt



- Negatieve alternantie
 - Diode spert



- Resultaat = DC

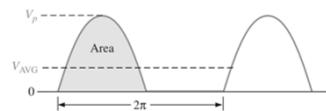


Elektronica – Hoorcollege 4 – Slide 4

- Opmerkingen:

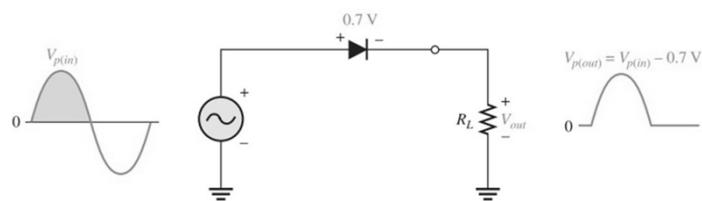
- Gemiddelde uitgangsspanning (= 31,8% V_{in})

$$V_{AVG} = \frac{V_p}{\pi}$$



- Praktisch diodemodel (ipv ideaal)

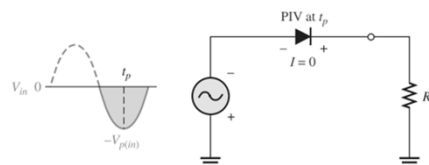
- Diodedrop: $V_{p(out)} = V_{p(in)} - 0.7 \text{ V}$



Elektronica – Hoorcollege 4 – Slide 5

- PIV diode = $-V_{p(in)}$

- Kies 20% marge bij PIV



- Transformator

- Step up (spanningstoename, 1:x)
- Step down (spanningsafname, x:1)

Elektronica – Hoorcollege 4 – Slide 6

Oefening

- Bereken de uitgangsspanning over de belastingsweerstand van $220\ \Omega$, die in serie staat met een gelijkrichterdiode. De ingangsspanning bedraagt 15 V.

Elektronica – Hoorcollege 4 – Slide 7

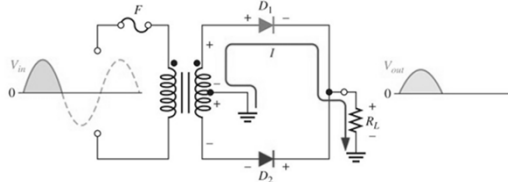
Demo

- <https://www.tinkercad.com/things/jXC6nLuFnWy-enkelzijdige-gelijkrichter>
- <https://www.systemvision.com/design/enkelzijdige-gelijkrichter-zonder-afvlak>
- Met eigen hardware

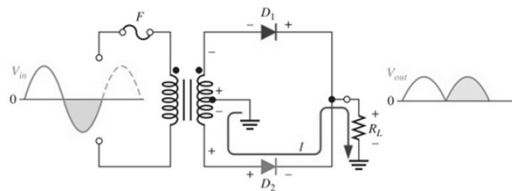
Elektronica – Hoorcollege 4 – Slide 8

Dubbelzijdige gelijkrichter

- Positieve alternantie: bovenste diode geleidt



- Negatieve alternantie: onderste diode geleidt



Elektronica – Hoorcollege 4 – Slide 9

- Opmerkingen:
 - Gemiddelde uitgangsspanning (= 63,7% V_{in})

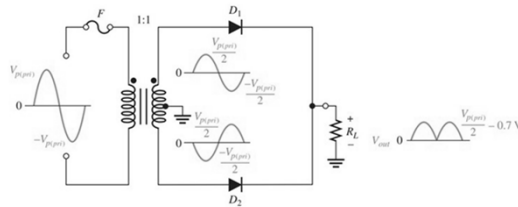
$$V_{AVG} = \frac{2V_p}{\pi}$$

- Uitgangssignaal **dubbele freq**

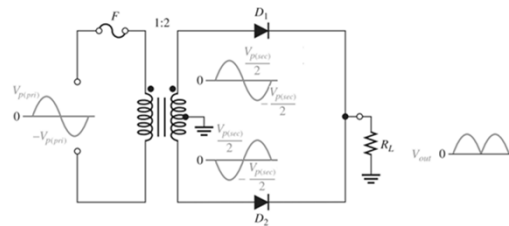
Elektronica – Hoorcollege 4 – Slide 10

– Door centrale aftakking transformator

- Verhouding 1:1 (n=1)

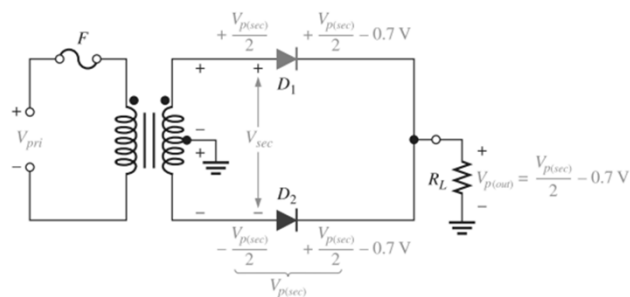


- Verhouding 1:2 (n=2)



- Algemeen $V_{out} = \frac{V_{sec}}{2} - 0.7 V$

– PIV diode



$$PIV = \left(\frac{V_{p(sec)}}{2} - 0.7 V \right) - \left(-\frac{V_{p(sec)}}{2} \right) = V_{p(sec)} - 0.7 V$$

$$PIV = 2V_{p(out)} + 0.7 V$$

Oefening

- Bereken uitgangsspanning voor een dubbelzijdige gelijkrichter. De transformatorverhouding van de gebruikte transformator is 1. De ingangsspanning bedraagt 170 V.

Elektronica – Hoorcollege 4 – Slide 13

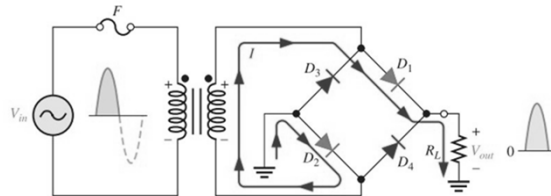
Demo

- <https://www.systemvision.com/design/dubbelzijdige-gelijkrichter-zonder-afvlak/>

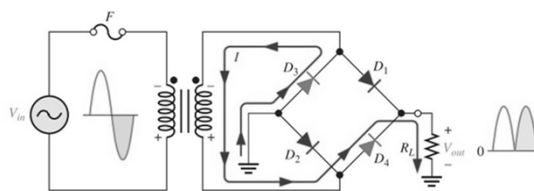
Elektronica – Hoorcollege 4 – Slide 14

Bruggelijkrichter

- Positieve alternantie: D_1 & D_2 geleiden



- Negatieve alternantie: D_3 & D_4 geleiden



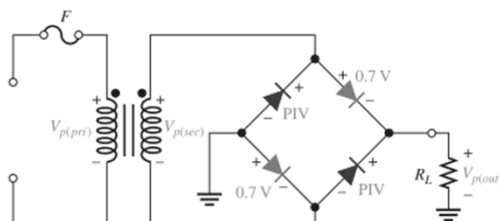
Elektronica – Hoorcollege 4 – Slide 15

- Opmerkingen:

– Diode drop $V_{p(out)} = V_{p(sec)} - 1.4 \text{ V}$

– PIV diode

$$\text{PIV} = V_{p(out)} + 0.7 \text{ V}$$

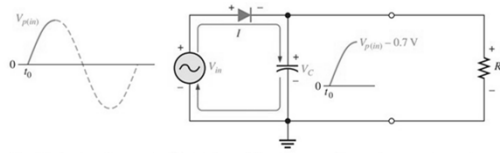


– $\text{PIV}_{\text{bruggelijkrichter}} \ll \text{PIV}_{\text{dubbelzijdige gelijkrichter}}$

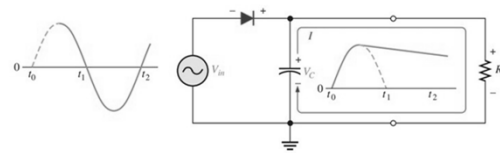
Elektronica – Hoorcollege 4 – Slide 16

Afvlakfilter

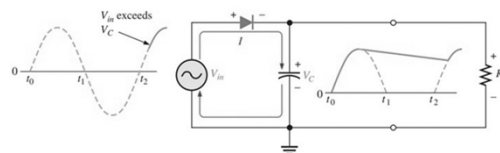
- D geleidt
C laadt tot 0.7 V
onder ingangsspanning



- D spert
C ontladtd

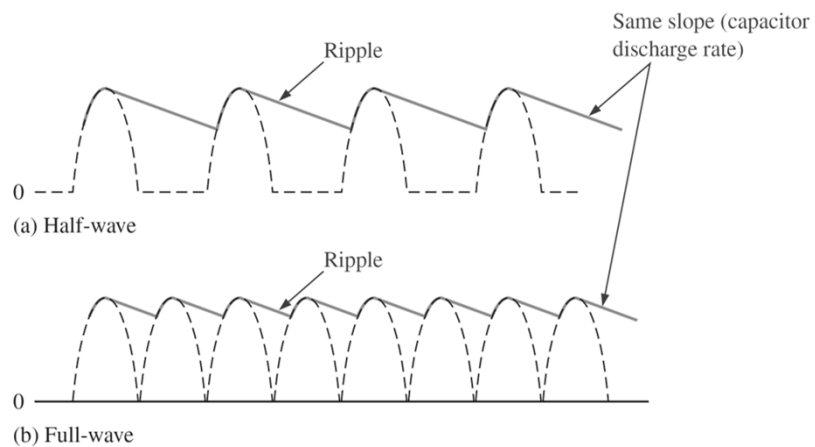


- D geleidt
opnieuw



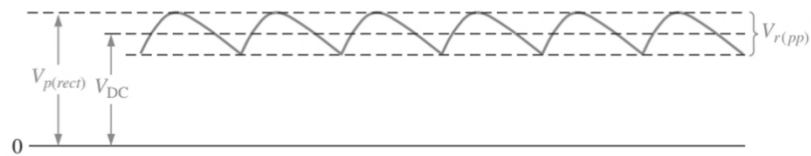
Elektronica – Hoorcollege 4 – Slide 17

- Opmerkingen:
 - Rimpelspanning (*ripple voltage*)



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– Rimpelfactor (*ripple factor*)



$$r = \frac{V_{r(pp)}}{V_{DC}}$$
$$V_{r(pp)} \cong \left(\frac{1}{fR_L C} \right) V_{p(rect)}$$
$$V_{DC} \cong \left(1 - \frac{1}{2fR_L C} \right) V_{p(rect)}$$

Hoe kleiner r, hoe beter het filter

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Oefening

- Op een enkelzijdige gelijkrichter wordt een effectieve spanning aangesloten van 230 V AC 50 Hz. De afvlakcondensator heeft een waarde van 200 μ F. De belastingsweerstand is 1 k Ω .
- Bereken de volgende parameters
 - $V_{p(out)}$
 - PIV
 - V_{avg}
 - $V_{r(pp)}$
 - V_{DC}
 - r

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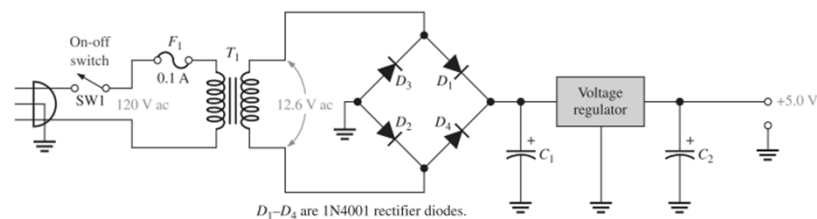
Demo

- <https://www.systemvision.com/design/enkelzijdige-gelijkrichter>
- <https://www.systemvision.com/design/bruggelijkrichter/>
- Met eigen hardware

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Spanningsregelaar

- Doel: constante V of I, ongeacht last



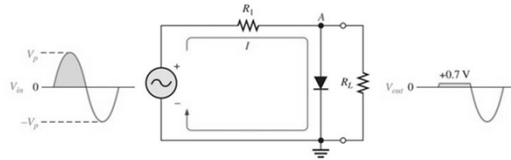
- Lijnregeling
$$\text{Line regulation} = \left(\frac{\Delta V_{\text{OUT}}}{\Delta V_{\text{IN}}} \right) 100\%$$
- Lastregeling
$$\text{Load regulation} = \left(\frac{V_{\text{NL}} - V_{\text{FL}}}{V_{\text{FL}}} \right) 100\%$$

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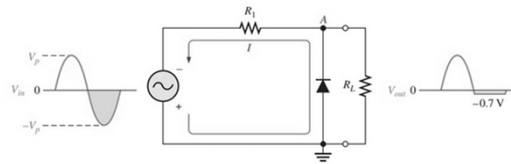
Diodebegrenzer

- *Limiter of clipper*
= stukken wegknippen boven/onder grens

- Positieve diodebegrenzer



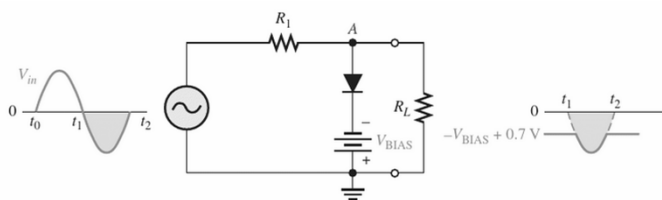
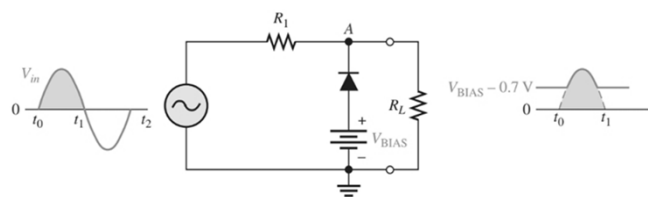
- Negatieve diodebegrenzer



$$V_{out} = \left(\frac{R_L}{R_1 + R_L} \right) V_{in}$$

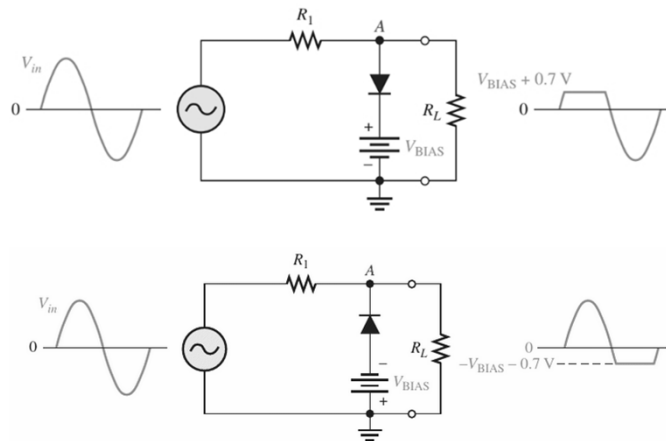
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- Opmerkingen:
– Met DC-offset



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– Met diode omgedraaid



Elektronica – Hoorcollege 4 – Slide 25

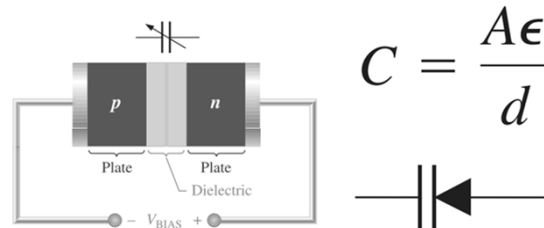
Demo

- <http://www.tinkercad.com/things/55sGtYzMA2k>
- <https://www.systemvision.com/design/diodebegrenzer>
- Eigen hardware

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Varactor diode

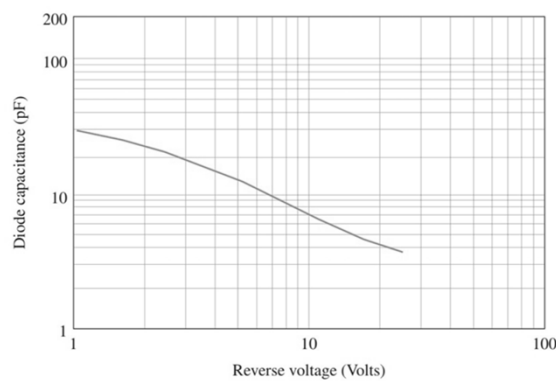
- Of nog: *varicap – tuning diode*
- Werkt in sper
- Spanningsgecontroleerde condensator
 - Platen: p-type & n-type
 - Diëlektricum: uitputtingszone
 - $V_{\text{BIAS}} \uparrow \rightarrow$ uitputtingszone $\uparrow \rightarrow$ condensator \downarrow



$$C = \frac{A\epsilon}{d}$$

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- Capaciteitsverhouding CR
 - *Capacitance ratio of tuning ratio*
 - C_{MAX} = condensatorwaarde bij min reverse spanning
 - C_{MIN} = condensatorwaarde bij max reverse spanning



$$CR = \frac{C_{\text{MAX}}}{C_{\text{MIN}}}$$

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- Toepassing: afstemming (*tuning*)
 - Parallel resonant banddoorlaatfilter

- f_r ingesteld via R_2
 - spanning varactor
 - condensatorwaarde

$$f_r \cong \frac{1}{2\pi\sqrt{LC}}$$

