Lecture 09
EE 2303/001-Electronics I
February 18, 2009

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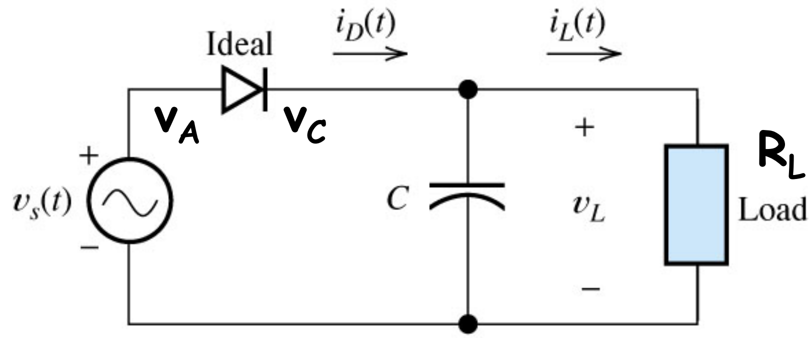
Half-wave rectifier



(a) Circuit diagram

Figure 3.12a Half-wave rectifier with smoothing capacitor.

- Maximum reverse bias on diode?
  - If $R_LC \gg T$, then $v_C = + V_m$ for all time
    - In negative half-cycle, $v_A \geq - V_m$
    - Thus the maximum reverse bias is

      $(v_C - v_A)_{max} = 2\ V_m$
  - For $C = 0$, $(v_C - v_A)_{max} = V_m$ because $i_LR_L = 0$ in the negative half-cycle

Full-wave rectifier

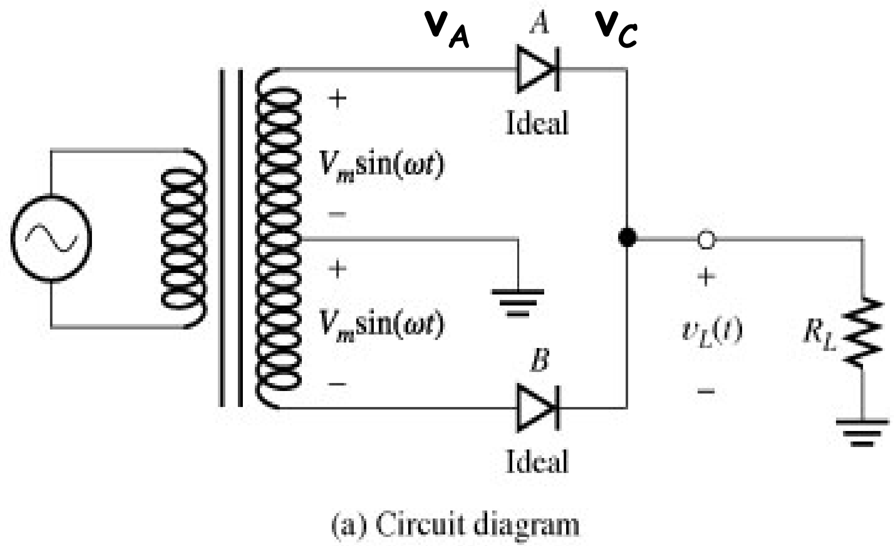
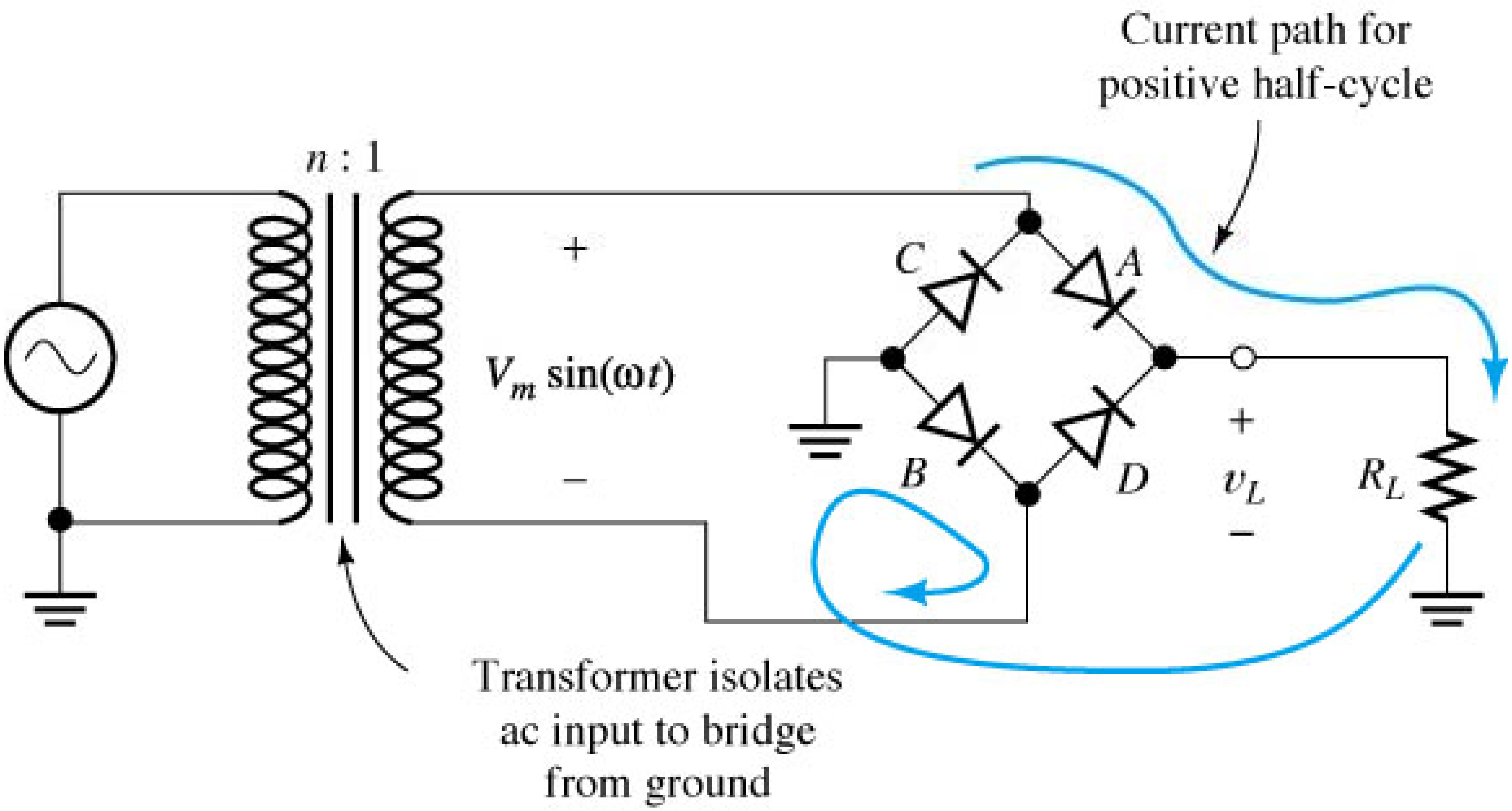


Figure 3.13 Full-wave rectifier.

- Effect on V_{rmax}?
  - If filter capacitor is used, the same argument as half-wave rectifier may be used, for the positive half-cycle.
  - For $C=0$, and since $v_L(t)$ always peaks at $+Vm$, then $(v_C - v_A)_{max} = 2\ V_m$ for each diode.



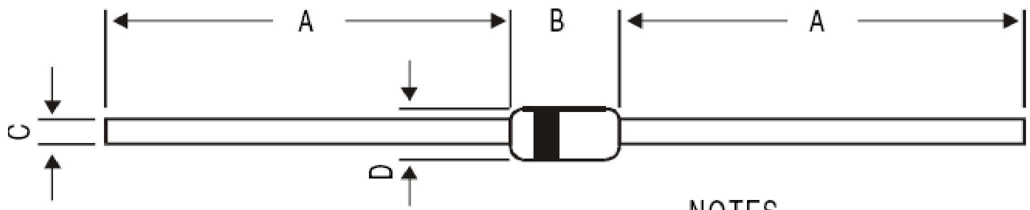
- Effect on V_{rmax}?
  - With and without C the maximum reverse bias is V_m.

Figure 3.14 Diode-bridge full-wave rectifier.

SILICON ZENER DIODES **1N746 to 1N759**

DO-35 400mW

DO-35 Glass Axial Package



NOTES
1. Cathode is marked by Band.
2. All dimensions are in mm.

DIM	MIN	MAX
A	25.40	—
B	3.03	4.44
C	0.46	0.56
D	1.52	2.29

Hermetically Sealed Glass Package Zener Diodes

ABSOLUTE MAXIMUM RATINGS

DESCRIPTION	SYMBOL	VALUE	UNIT
Zener Voltage	ZV	3.3 to 12	V
D C Power Dissipation	PD	400	mW
Derating Above 50 deg C		3.2	mW/deg C
Operating & Storage Junction Temperature Range	Tj,Tstg	-65 to +175	deg C

ELECTRICAL CHARACTERISTICS (Ta=25 deg C Unless otherwise Specified , VF <1.5V @ 200mA

Device Type# (1)	Nominal* Zener Voltage VZ @ IZT (V)	Zener Test Current IZT (mA)	Maximum Zener Impedance Zzt @ IZT (Ohms)	Maximum Reverse Current @25 deg C max (uA)	@ @ +150 deg C max (uA)	VR (V)	Maximum Zener Current IZM (mA)	Typ Temp Coeff of Zener Voltage *vz (% deg C)
1N750	4.7	20	19	2.0	30	1.0	75	-0.015

http://www.datasheetpro.com/316313_download_1N750_datasheet.html

Diode Equations for DC Current [1]

Id = area·(Ifwd - Irev)

Ifwd = forward current = Inrm·Kinj + Irec·Kgen

Inrm = normal current = IS·(eVd/(N·Vt)-1)

if: IKF > 0

then:

  Kinj = high-injection factor = $(IKF/(IKF+Inrm))^{1/2}$

else: Kinj = 1

Irec = recombination current = ISR·$(e^{Vd/(NR \cdot Vt)} - 1)$

Kgen = generation factor = ((1-Vd/VJ)2+0.005)M/2

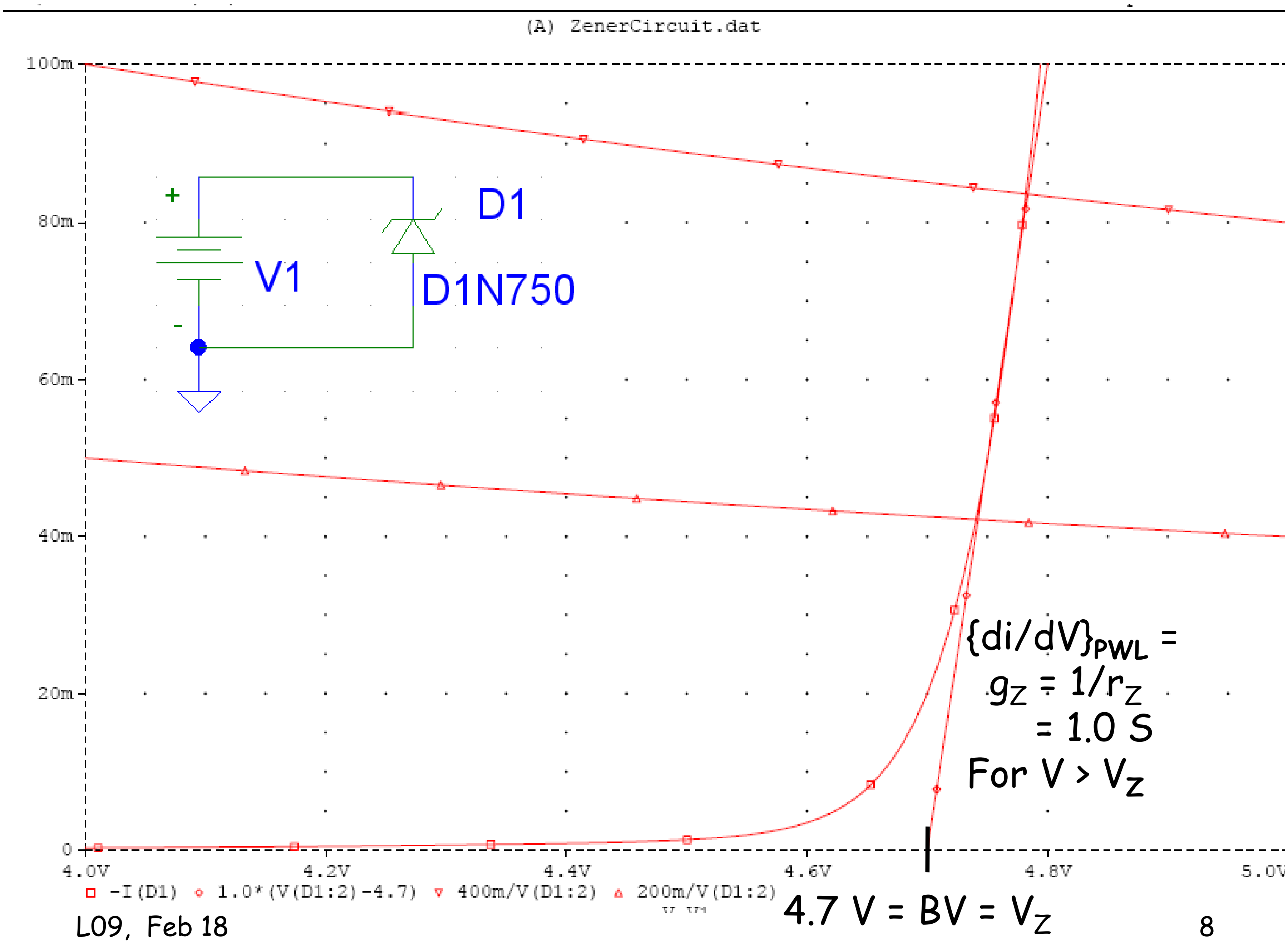
Irev = reverse current = Irevhigh + Irevlow

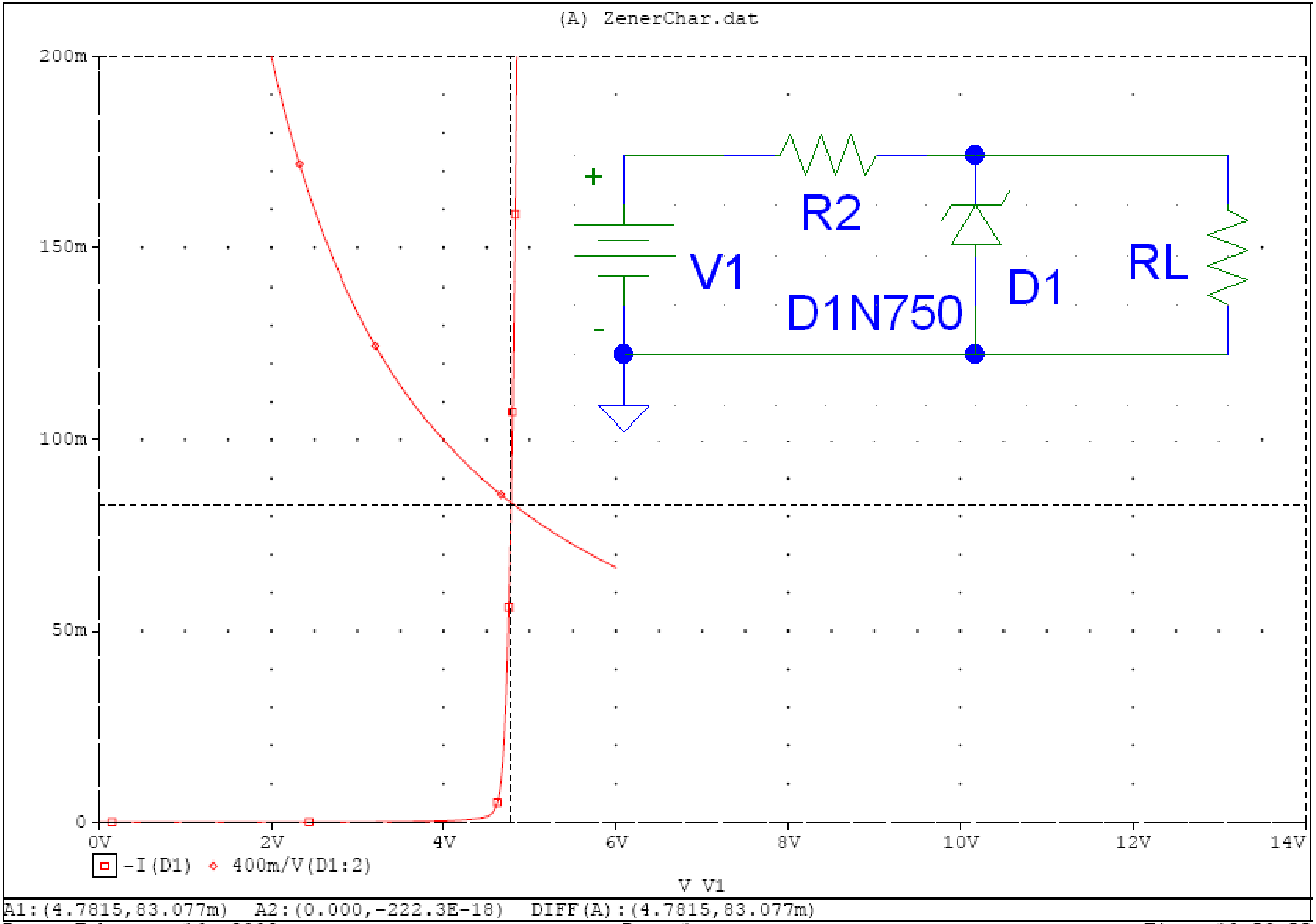
Irevhigh = IBV·exp{-(Vd+BV)/(NBV·Vt)}

Irevlow = IBVL·exp{-(Vd+BV)/(NBVL·Vt)}

```
.model D1N750-X   D(
Is=880.5E-18
Rs=.25
Ikf=0
N=1
Xti=3
Eg=1.11
Cjo=175p
M=.5516
Vj=.75
Fc=.5
Isr=1.859n
Nr=2
Bv=4.7
Ibv=20.245m
Nbv=1.6989
Ibvl=1.9556m
Nbvl=14.976
Tbv1=-21.277u)
*Motorola pid=1N750
   case=DO-35
*  89-9-18 gjg
*  Vz = 4.7 @ 20mA, Zz =
   300 @ 1mA, Zz = 12.5
   @ 5mA, Zz =2.6  @
   20mA

*$
```


(A) ZenerCircuit.dat
100m
80m
60m
40m
20m
0
4.0V
4.2V
4.4V
4.6V
4.8V
5.0V
-I(D1) 1.0*(V(D1:2)-4.7) 400m/V(D1:2) 200m/V(D1:2)
V1
D1
D1N750
+
-
{di/dV}PWL =
gZ = 1/rZ
= 1.0 S
For V > VZ
4.7 V = BV = VZ


(A) ZenerChar.dat
200m
150m
100m
50m
0
0V
2V
4V
6V
8V
10V
12V
14V
-I(D1)
400m/V(D1:2)
V_V1
A1:(4.7815,83.077m) A2:(0.000,-222.3E-18) DIFF(A):(4.7815,83.077m)
+
-
V1
R2
D1N750
D1
RL

Zener Diode Regulator Design

- 13.5 < V1 < 14.5V … range of auto system

$$\mathrm{LL}:\ I_{LL} = \frac{V_{Th} - v_{D,R}}{R_{Th}}$$

$$\mathrm{PWL}:\ I_{D,R} = \frac{v_{D,R} - BV}{r_Z},\ v_{D,R} > BV$$

- Should design for $P \leq P_D$ = 400 mW (will use 90%). This usually means we can ignore the finite value of r_z, so $v_D = BV$, for $i_D > 0$.

Zener Regulator Design (cont.)

- The load line intercepts and slopes are

$$V_{Th} = V_1 \frac{R_L}{R_2 + R_L}$$

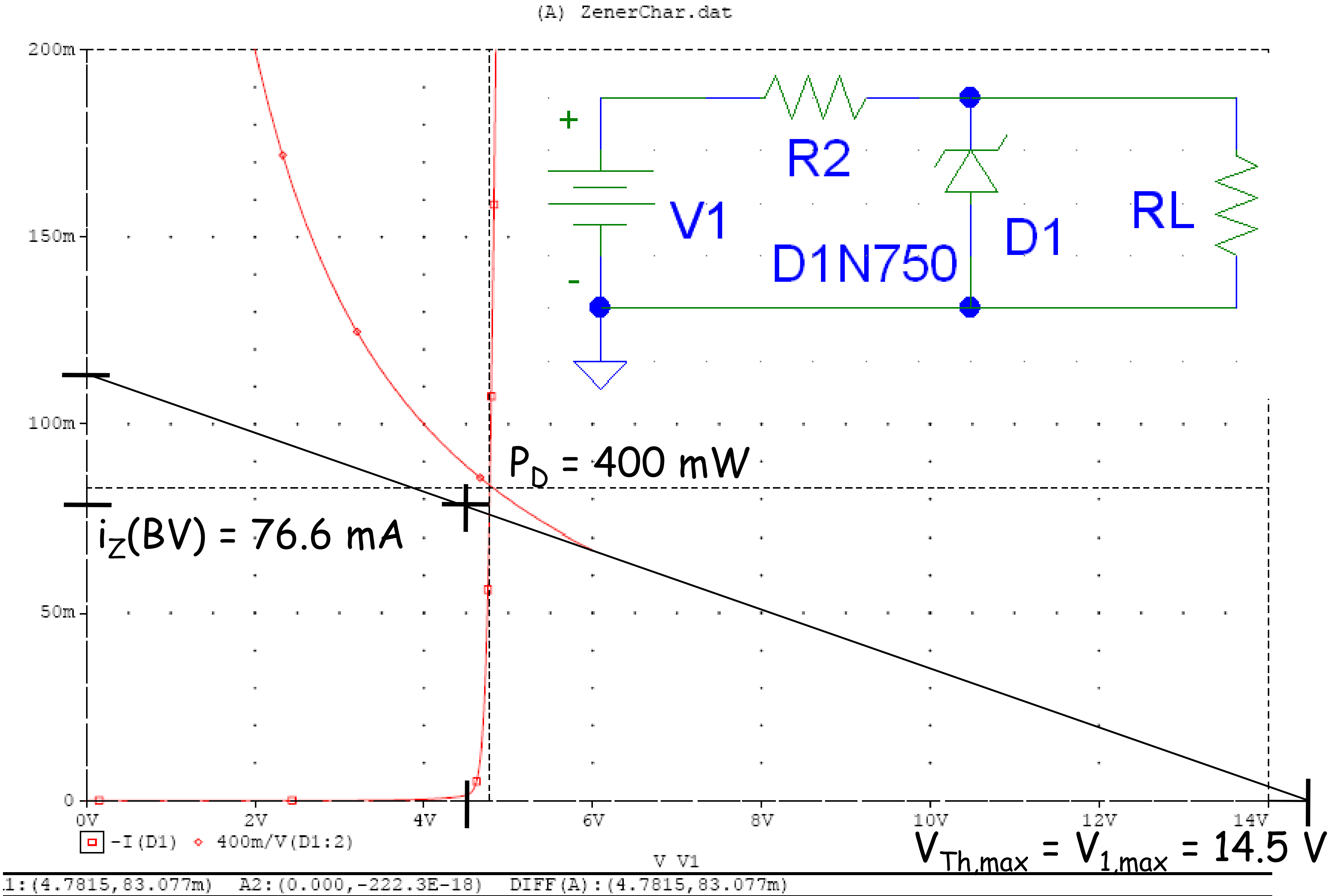
$$R_{Th} = \frac{R_2 R_L}{R_2 + R_L} \Rightarrow G_{Th} = \frac{R_2 + R_L}{R_2 R_L}$$

$$I_N = V_1 \frac{R_L}{R_2 + R_L} \Big/ \frac{R_1 R_L}{R_2 + R_L} = \frac{V_1}{R_2}$$

- $V_{Th,max} = V_{1,max}$ for RL → ∞, (open-cir.)
- R_2 is set for I_N such that at $V_1 = 14.5$

  $i_Z(BV) \cdot BV = 90\%$ PD = 360 mW

  $i_Z(BV)$ = 360 mW/4.7V = 76.6 mA


(A) ZenerChar.dat
200m
150m
100m
50m
0
0V
2V
4V
6V
8V
10V
12V
14V
-I(D1)
400m/V(D1:2)
V_V1
+
-
R2
V1
D1N750
D1
RL
P_D = 400 mW
$i_Z(BV)$ = 76.6 mA
$V_{Th,max} = V_{1,max}$ = 14.5 V
1:(4.7815,83.077m) A2:(0.000,-222.3E-18) DIFF(A):(4.7815,83.077m)

Zener Regulator Design (cont.)

- 76.6 mA at v_Z = BV gives 90% PD
- For $V_{Th,max}$ = 14.5 = $V_{1,max}$
- 113.33 mA = IN = V_1/R_2
- 127.9 Ohm = R_2 = V_1/I_n
- 5% resistors are available at 120Ω and 130Ω. Which should be chosen? Why?
- What about Pdmax curve going below the load line?

Zener Regulator Design (cont.)

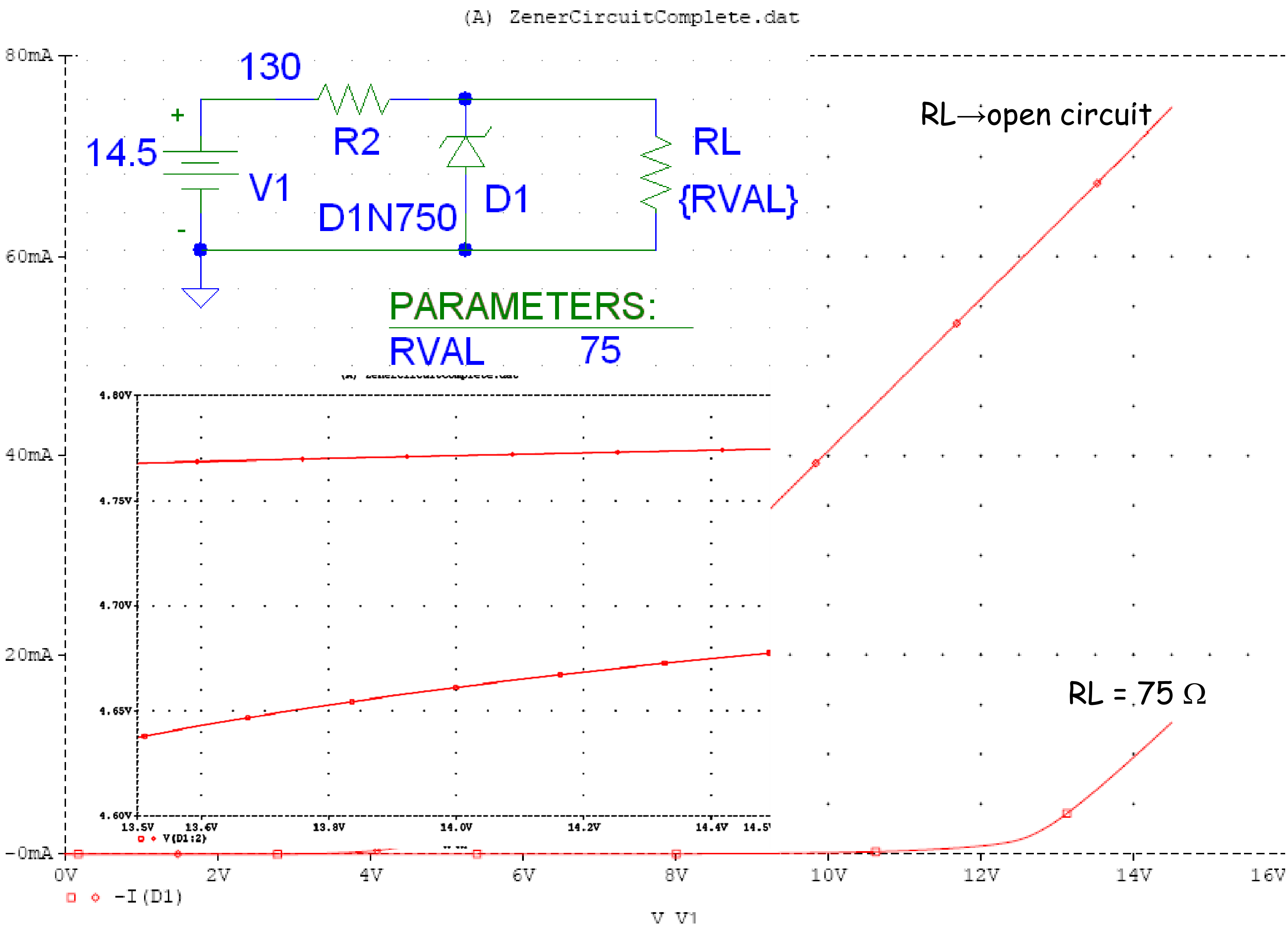
- What is the minimum value for R_L?

Zener Regulator Design (cont.)

- What is V_{Th} for 13.5 V at R_{Lmin}?

Zener Regulator Design (cont.)

- What is I_N for 13.5 V at R_{Lmin}?


(A) ZenerCircuitComplete.dat
80mA
60mA
40mA
20mA
-0mA
0V
2V
4V
6V
8V
10V
12V
14V
16V
-I(D1)
V_V1
130
R2
14.5
+
-
V1
D1N750
D1
RL
{RVAL}
PARAMETERS:
RVAL 75
4.80V
4.75V
4.70V
4.65V
4.60V
13.5V
13.6V
13.8V
14.0V
14.2V
14.4V
14.5V
V(D1:2)
RL→open circuit
RL = 75 Ω

References and Endnotes

- Where not otherwise noted, Figures are taken from:
  - Electronics, 2nd edition, by Allan R. Hambley, Prentice Hall, Upper Saddle River, NJ, © 2000.

(1) Microsim PSpice Reference Manual, Version 8.0, June, 1997. © 1997, MicroSim Corporation. [pspref.pdf]