Zener Linear Regulator with DC Inputs

Specify the Regulator Parameters

$V_o := 5 \cdot volt$ $\quad$ $I_o := 500 \cdot mA$

$V_{in\_min} := 10 \cdot volt$ $\quad$ $V_{in\_max} := 20 \cdot volt$

Specs for the Rev Polarity Diode

$V_{Dmax} := 1 \cdot volt$

$V_{Dmin} := 0.5 \cdot volt$

Calculate the equivalent load resistance $\quad R_L := \frac{V_o}{I_o}$ $\quad$ $R_L = 10 \, \Omega$

Choose a Zener Diode $\quad V_{ZK} := 5.1 \cdot volt$

Using the Thevenin equivalent voltage, find RS max. Note that Vth must be larger than Vzk

$R_S := 3 \cdot \Omega$

Given

$$\left(V_{in\_min} - V_{Dmax}\right) \cdot \left(\frac{R_L}{R_S + R_L}\right) = V_{ZK}$$

$R_S := find\left(R_S\right)$ $\quad$ $R_S = 7.647 \, \Omega$

$$\frac{R_S}{1.05} = 7.283 \, \Omega$$

Choose the next smallest standard 5% resistor. $\quad R_S := 6.8 \cdot \Omega$

$R_{S\_min} := R_S \cdot 0.95$ $\quad$ $R_{S\_max} := R_S \cdot 1.05$ $\quad$ $R_{S\_max} = 7.14 \, \Omega$

Calculate the input Power with Vin at maximum - Assume No load at the output

$$I_{in\_max} := \frac{V_{in\_max} - V_{Dmin} - V_o}{R_S} \qquad P_{in\_max} := V_{in\_max} \cdot I_{in\_max} \qquad P_{in\_max} = 42.647 \circ watt$$

$$P_{R\_max} := I_{in\_max}^{2} \cdot R_S \qquad P_{R\_max} = 30.919\ mass \cdot length^{2} \cdot time^{-3} \circ watt$$

$$P_{Z\_max} := V_o \cdot I_{in\_max} \qquad P_{Z\_max} = 10.662\ mass \cdot length^{2} \cdot time^{-3} \circ watt$$

$$P_{D\_max1} := V_{Dmin} \cdot I_{in\_max} \qquad P_{D\_max1} = 1.066 \circ watt$$

Calculate the diode dissipation assuming Vin max and VD min

$$P_{D\_min1} := V_{Dmax} \cdot \left(\frac{V_{in\_max} - V_{Dmax} - V_o}{R_S} \right) \qquad P_{D\_min1} = 2.059 \circ watt$$

Calculate the input Power with Vin at maximum - Assume No load at the output

$$I_{in\_min} := \frac{V_{in\_min} - V_{Dmin} - V_o}{R_S} \qquad P_{in\_min} := V_{in\_min} \cdot I_{in\_min} \qquad P_{in\_min} = 6.618 \circ watt$$

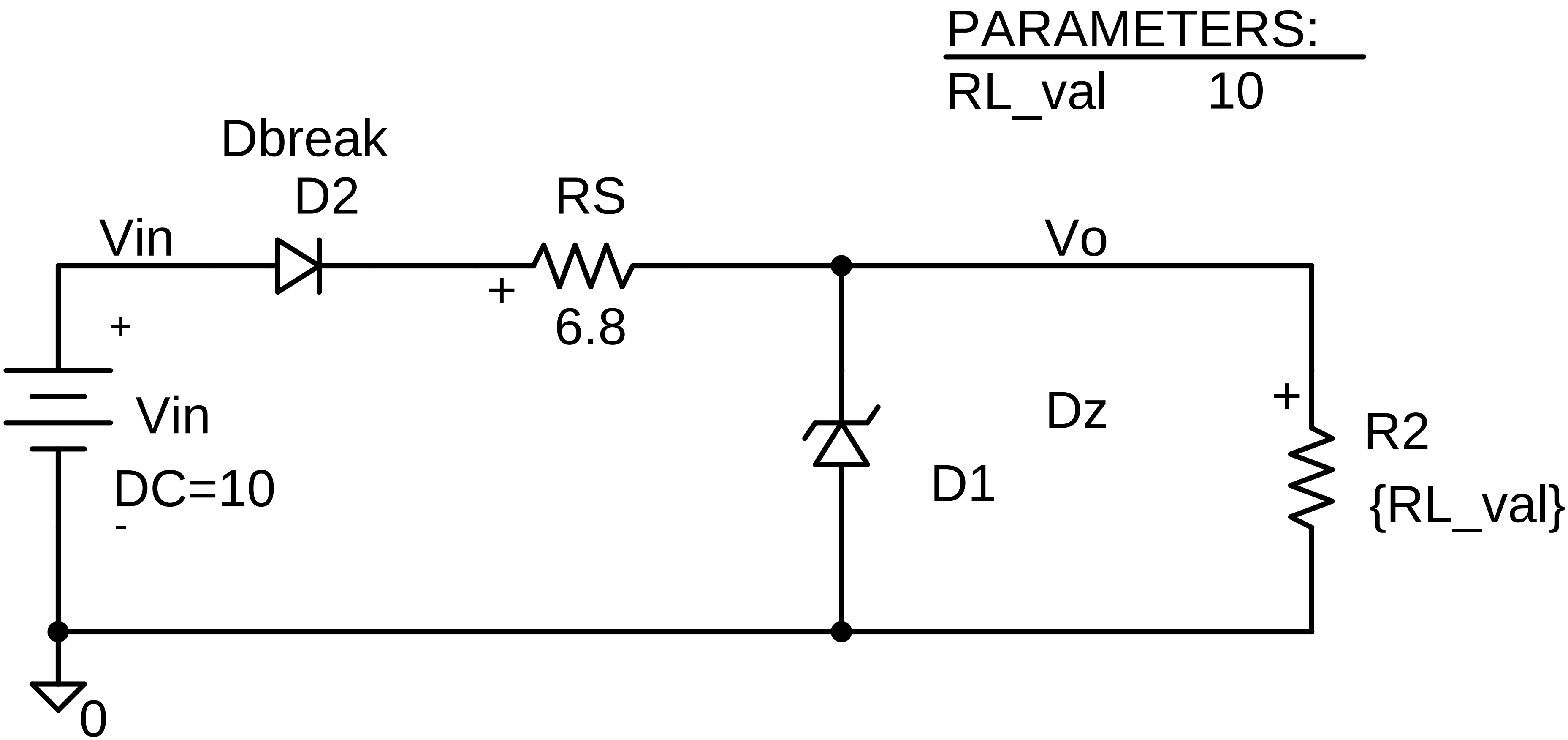
$$P_{R\_min} := I_{in\_min}^{2} \cdot R_S \qquad P_{R\_min} = 2.978 \circ watt$$

$$P_{Z\_min} := V_o \cdot I_{in\_min} \qquad P_{Z\_min} = 3.309 \circ watt$$

$$P_{D\_min2} := V_{Dmin} \cdot I_{in\_min} \qquad P_{D\_min2} = 0.331 \circ watt$$

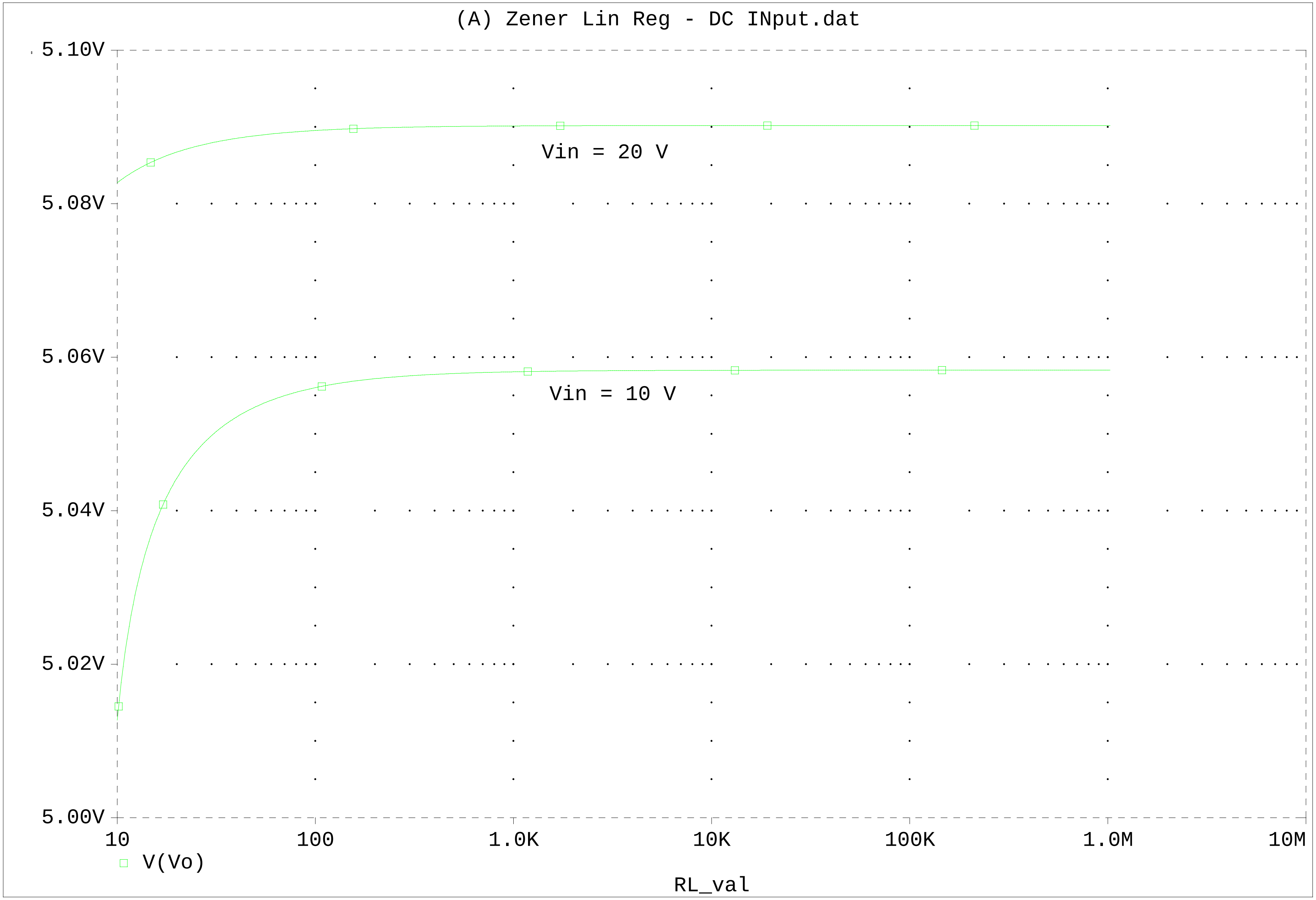
Calculate the diode dissipation assuming Vin min and VD min

$$P_{D\_max2} := V_{Dmax} \cdot \left(\frac{V_{in\_min} - V_{Dmax} - V_o}{R_S} \right) \qquad P_{D\_max2} = 0.588 \circ watt$$

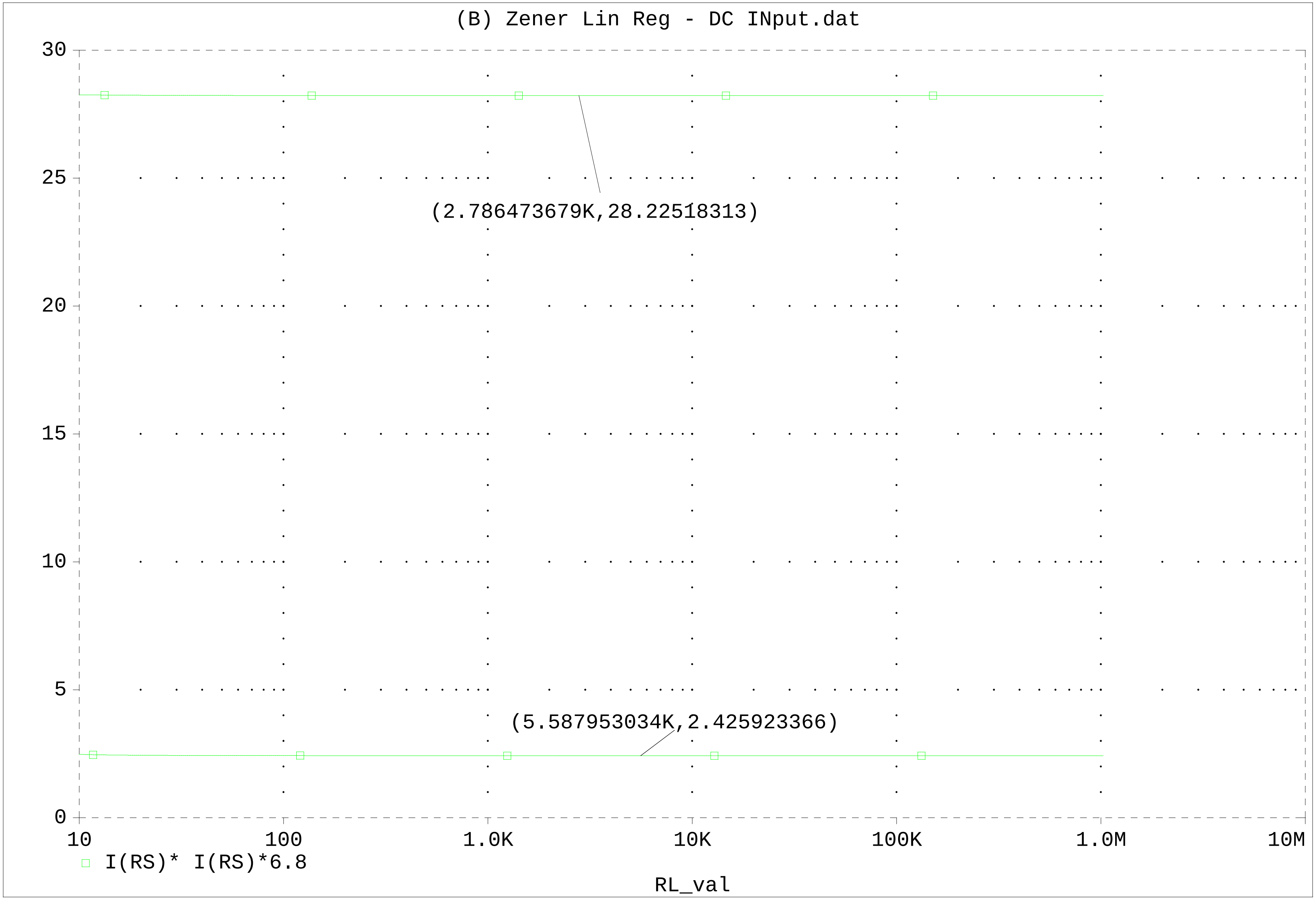

PARAMETERS:
RL_val 10
Dbreak
D2
RS
Vin
Vo
+
+
6.8
Vin
DC=10
-
Dz
D1
+
R2
{RL_val}
0

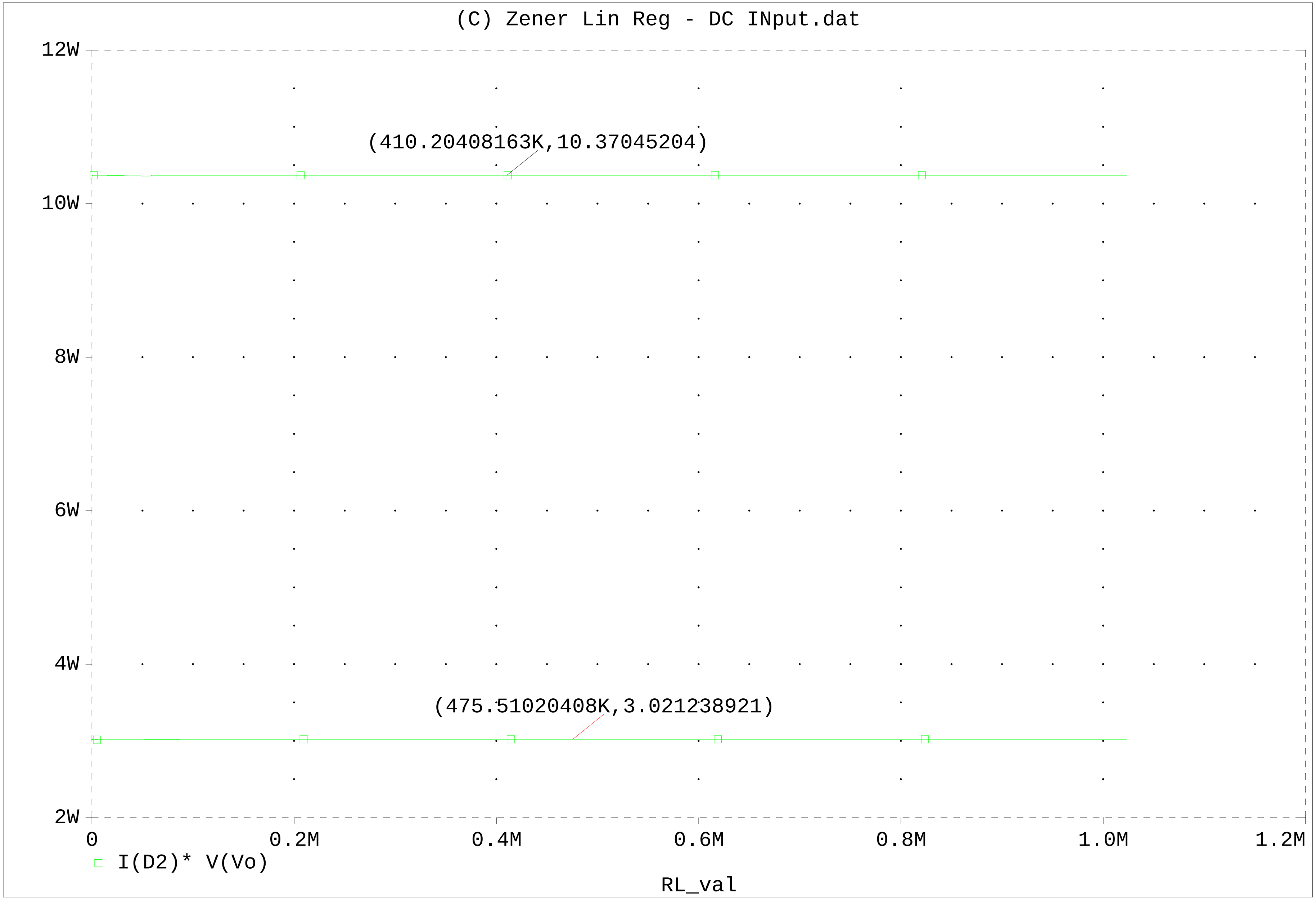
* D:\NAU\CLASS\egr456\SPICE_N\LIN_REG\Zener Lin Reg - DC INput.sch

Date/Time run: 09/26/100 10:08:47 Temperature: 27.0



Date: September 26, 2000 Page 1 Time: 10:13:39


(B) Zener Lin Reg - DC INput.dat
30
25
20
15
10
5
0
(2.786473679K,28.22518313)
(5.587953034K,2.425923366)
10
100
1.0K
10K
100K
1.0M
10M
I(RS)* I(RS)*6.8
RL_val


(C) Zener Lin Reg - DC INput.dat
12W
10W
8W
6W
4W
2W
(410.20408163K,10.37045204)
(475.51020408K,3.021238921)
0
0.2M
0.4M
0.6M
0.8M
1.0M
1.2M
I(D2)* V(Vo)
RL_val

Linear Voltage Regulator Design
With BJT and Zener

Regulator designed for Constant DC Input

Specify the Regulator Parameters

$V_o := 5 \cdot volt$ $\quad I_o := 0.5 \cdot amp$

$V_{in\_min} := 10 \cdot volt$ $\quad V_{in\_max} := 20 \cdot volt$

Specs for the Rev Polarity Diode

$V_{Dmax} := 1 \cdot volt$

$V_{Dmin} := 0.5 \cdot volt$

Specify β for the BJT at the maximum load $\quad \beta := 25$ $\quad$ For a TIP 31 at 1 Amp

$V_{BEmax} := 1.2 \cdot volt$

Calculate the base current $\quad I_B := \frac{I_o}{\beta + 1}$ $\quad I_B = 19.231 \cdot mA$

Now design the zener/resistor circuit

Choose a Zener Diode $\quad V_{ZK} := 5.6 \cdot volt$

Calculate the equivalent load resistance $\quad R_L := \frac{V_{ZK}}{I_B}$ $\quad R_L = 291.2 \cdot \Omega$

Using the Thevenin equivalent voltage, find RS max. Note that Vth must be larger than Vzk

$R_S := 3 \cdot \Omega$

Given

$$\left(V_{in\_min} - V_{Dmax}\right) \cdot \left(\frac{R_L}{R_S + R_L}\right) = V_{ZK}$$

$R_S := find(R_S)$ $\quad R_S = 176.8 \cdot \Omega$

$$\frac{R_S}{1.05} = 168.381 \cdot \Omega$$

Choose the next smallest standard 5% resistor. $R_S := 150 \cdot \Omega$

Calculate the power for the zenert

$$I_{z\_max} := \frac{V_{in\_max} - V_{Dmin} - V_{ZK}}{R_S} \qquad I_{z\_max} = 0.093 \cdot amp$$

$$P_{R\_max} := I_{z\_max}{}^2 \cdot R_S \qquad P_{R\_max} = 1.288 \cdot watt$$

$$P_{Z\_max} := V_o \cdot I_{z\_max} \qquad P_{Z\_max} = 0.463 \cdot watt$$

Calculate the Total input current

$$I_{in\_max} := I_{z\_max} + I_o \qquad P_{in} := I_{in\_max} \cdot V_{in\_max} \qquad P_{in} = 11.853 \cdot watt$$

Calculate the Max power for the BJT

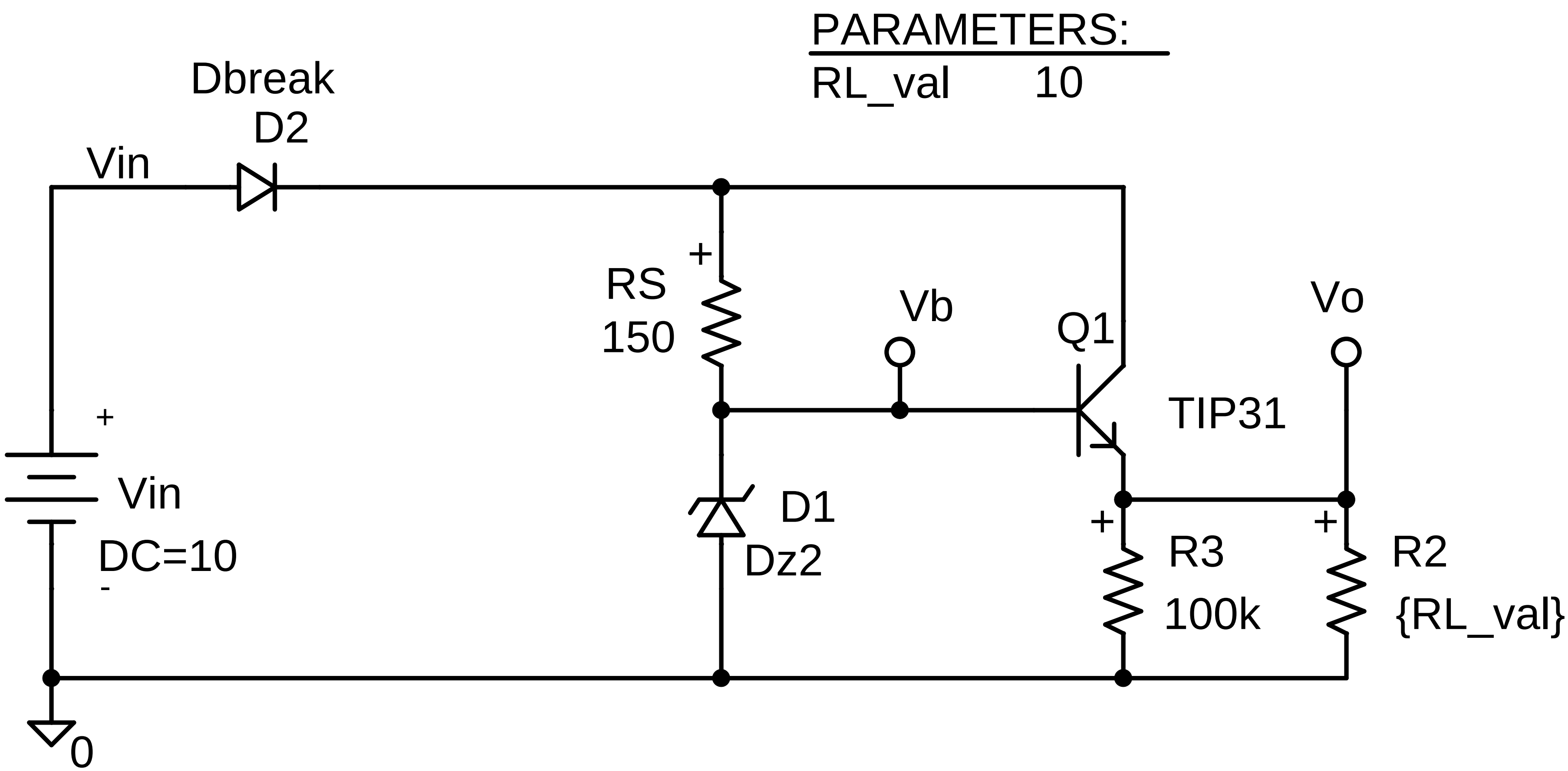
$$P_{Q\_max} := I_o \cdot \frac{\beta}{\beta + 1} \cdot \left(V_{in\_max} - V_{Dmin} - V_o\right) + \frac{I_o}{\beta + 1} \cdot V_{BEmax}$$

$$P_{Q\_max} = 6.994 \cdot watt$$

Calculate the Mx power dissipated by the diode

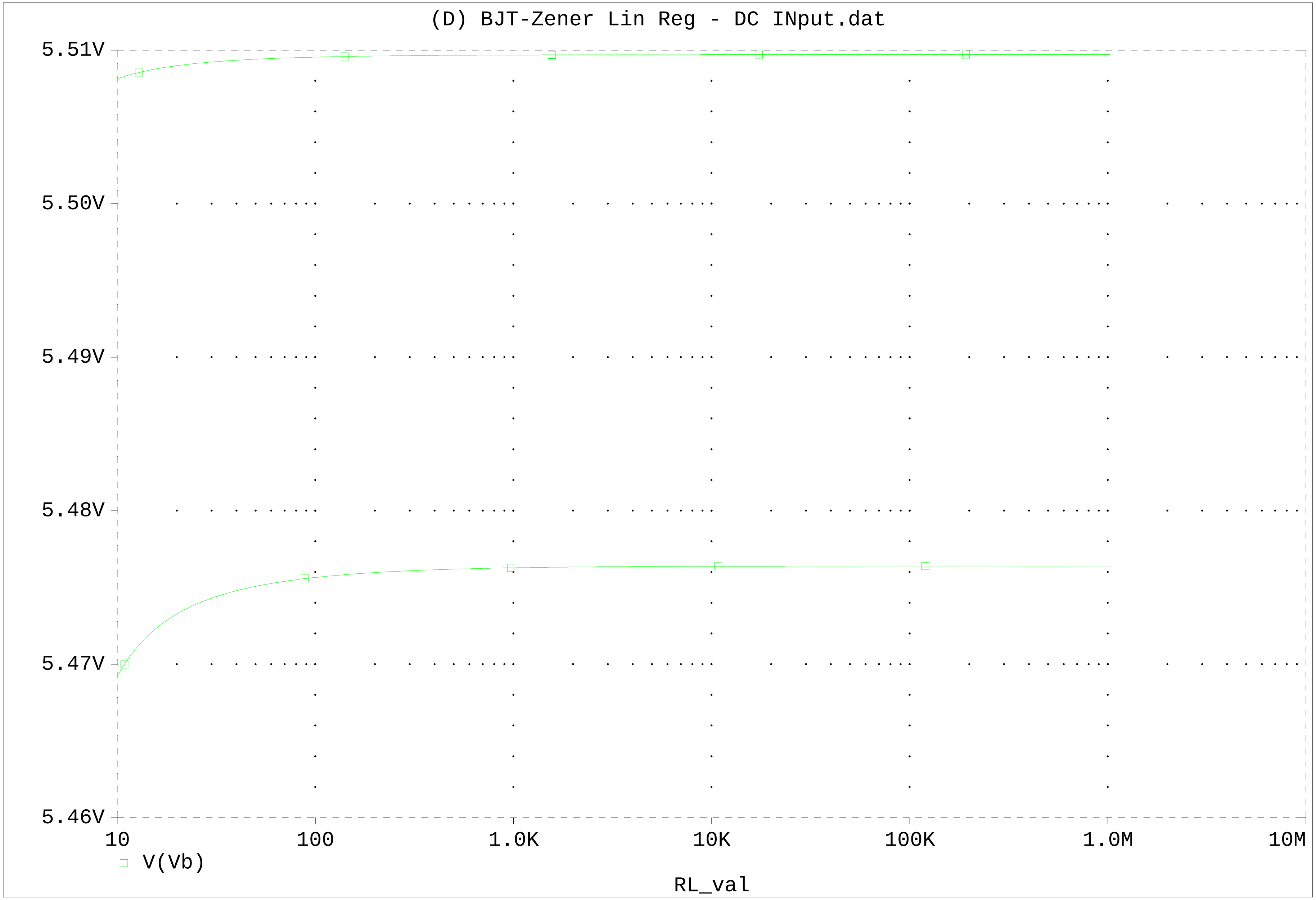
$$P_{Dmax} := V_{Dmax} \cdot \left[I_o + \left(\frac{V_{in\_max} - V_{Dmax} - V_{ZK}}{R_S}\right)\right]$$

$$P_{Dmax} = 0.589 \cdot watt$$


PARAMETERS:
RL_val 10
Dbreak
D2
Vin
RS
150
Vb
Q1
Vo
TIP31
Vin
DC=10
D1
Dz2
R3
100k
R2
{RL_val}
0

* D:\NAU\CLASS\egr456\SPICE_N\LIN_REG\BJT-Zener Lin Reg - DC INput.sch

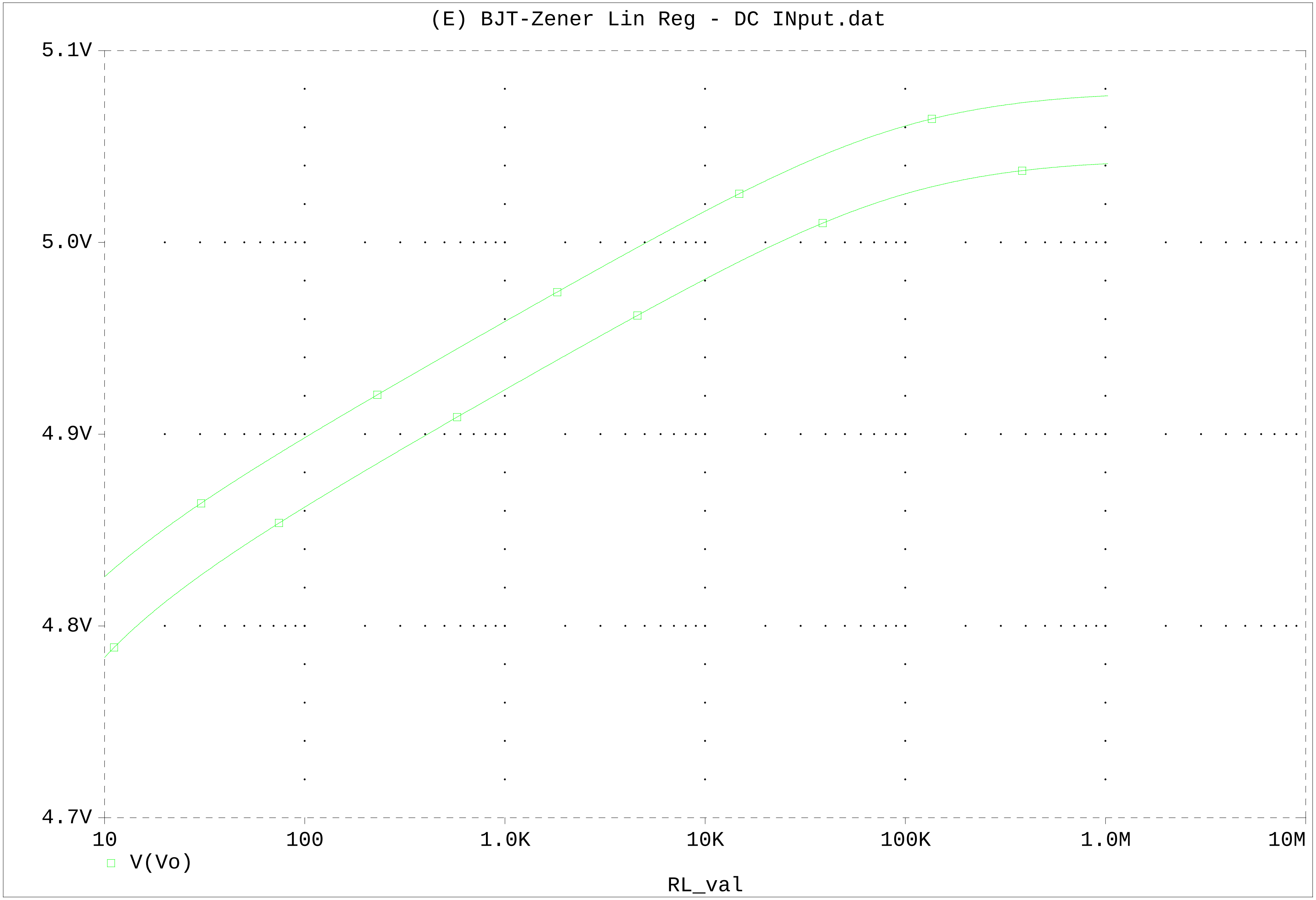
Date/Time run: 09/26/100 10:49:13 Temperature: 27.0



Date: September 26, 2000 Page 1 Time: 10:53:56

* D:\NAU\CLASS\egr456\SPICE_N\LIN_REG\BJT-Zener Lin Reg - DC INput.sch

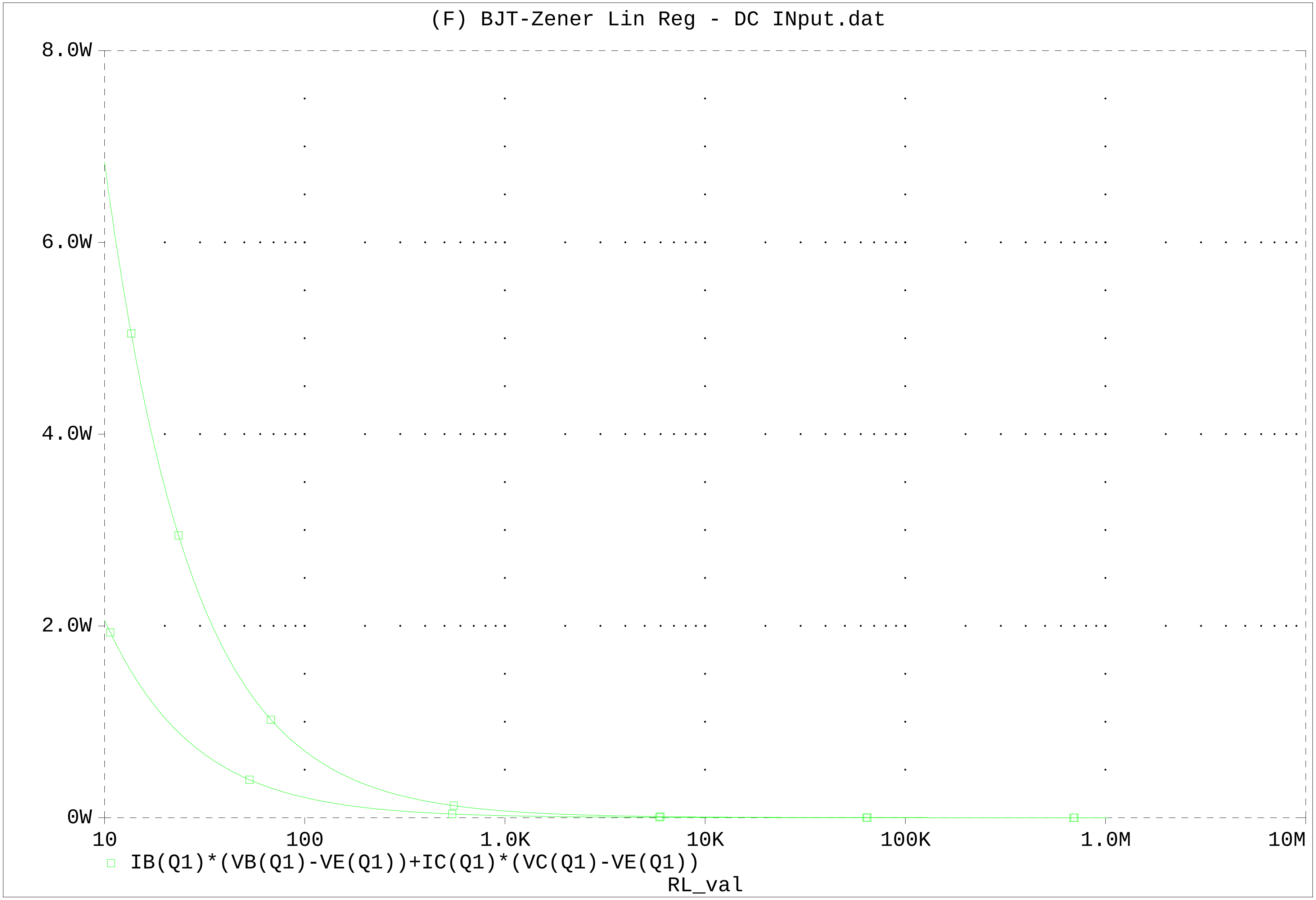
Date/Time run: 09/26/100 10:49:13 Temperature: 27.0

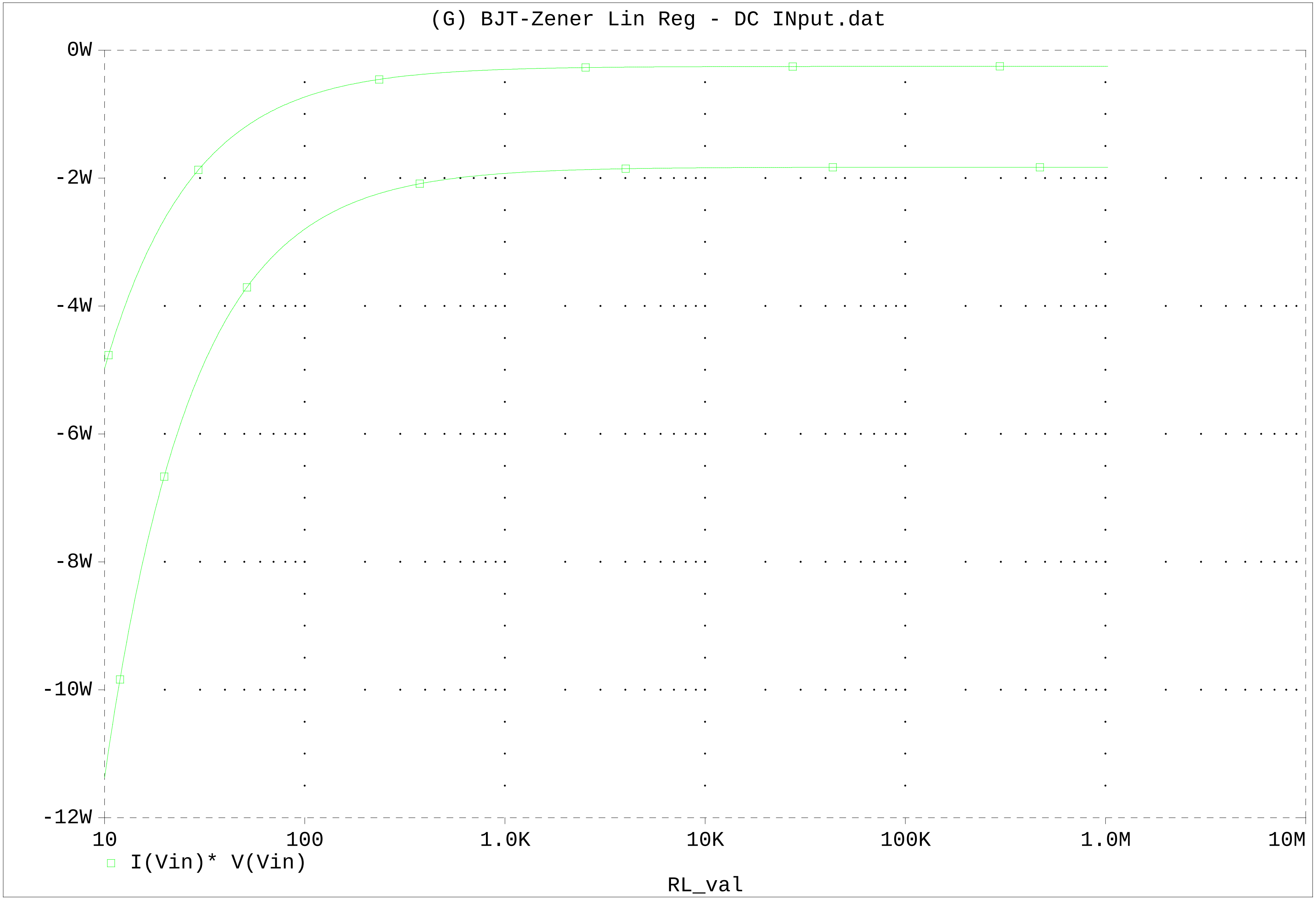


Date: September 26, 2000 Page 2 Time: 10:53:57

* D:\NAU\CLASS\egr456\SPICE_N\LIN_REG\BJT-Zener Lin Reg - DC INput.sch

Date/Time run: 09/26/100 10:49:13 Temperature: 27.0




(G) BJT-Zener Lin Reg - DC INput.dat
0W
-2W
-4W
-6W
-8W
-10W
-12W
10
100
1.0K
10K
100K
1.0M
10M
I(Vin)* V(Vin)
RL_val

Linear Voltage Regulator Design
With BJT and OPAMP

Regulator designed for Constant DC Input

Specify the Regulator Parameters

$V_o := 5 \cdot volt$ $\quad I_o := 0.5 \cdot amp$

$V_{in\_min} := 10 \cdot volt$ $\quad V_{in\_max} := 20 \cdot volt$

Specs for the Rev Polarity Diode

$V_{Dmax} := 1 \cdot volt$

$V_{Dmin} := 0.5 \cdot volt$

Specify β for the BJT at the maximum load $\quad \beta := 25 \quad$ For a TIP 31 at 1 Amp

$V_{BEmax} := 1.2 \cdot volt$

Calculate the base current $\quad I_B := \dfrac{I_o}{\beta + 1} \quad I_B = 19.231 \cdot mA$

Use a 3904 for the darlington transistor

$\beta_2 := 80$ $\quad$ HFE min at 10 mA was 100, HFE min at 50 mA wat 60.

Opamp output current $\quad I_{opamp} := \dfrac{I_B}{\beta_2 + 1}$

$I_{opamp} = 237.417 \cdot \mu A$

Specs and design of the Voltage Reference.

$V_{ref} := 2.5 \cdot volt$ $\quad I_{rev} := 100 \cdot \mu A$ $\quad R_{ref} := \dfrac{V_{in\_min} - V_{ref} - V_{Dmax}}{I_{rev}}$ $\quad R_{ref} = 65 \cdot k\Omega$

Choose the next smallest 5% resistor $\quad R_{ref} := 56\ k\Omega$

$I_{ref\_max} := \dfrac{V_{in\_max} - V_{ref} - V_{Dmin}}{R_{ref}}$ $\quad I_{ref\_max} = 0.304 \cdot mA$

Calculate the Total input current

$I_{in\_max} := I_o$ $P_{in} := I_{in\_max} \cdot V_{in\_max}$ $P_{in} = 10 \cdot watt$

Calculate the Max power for the BJT

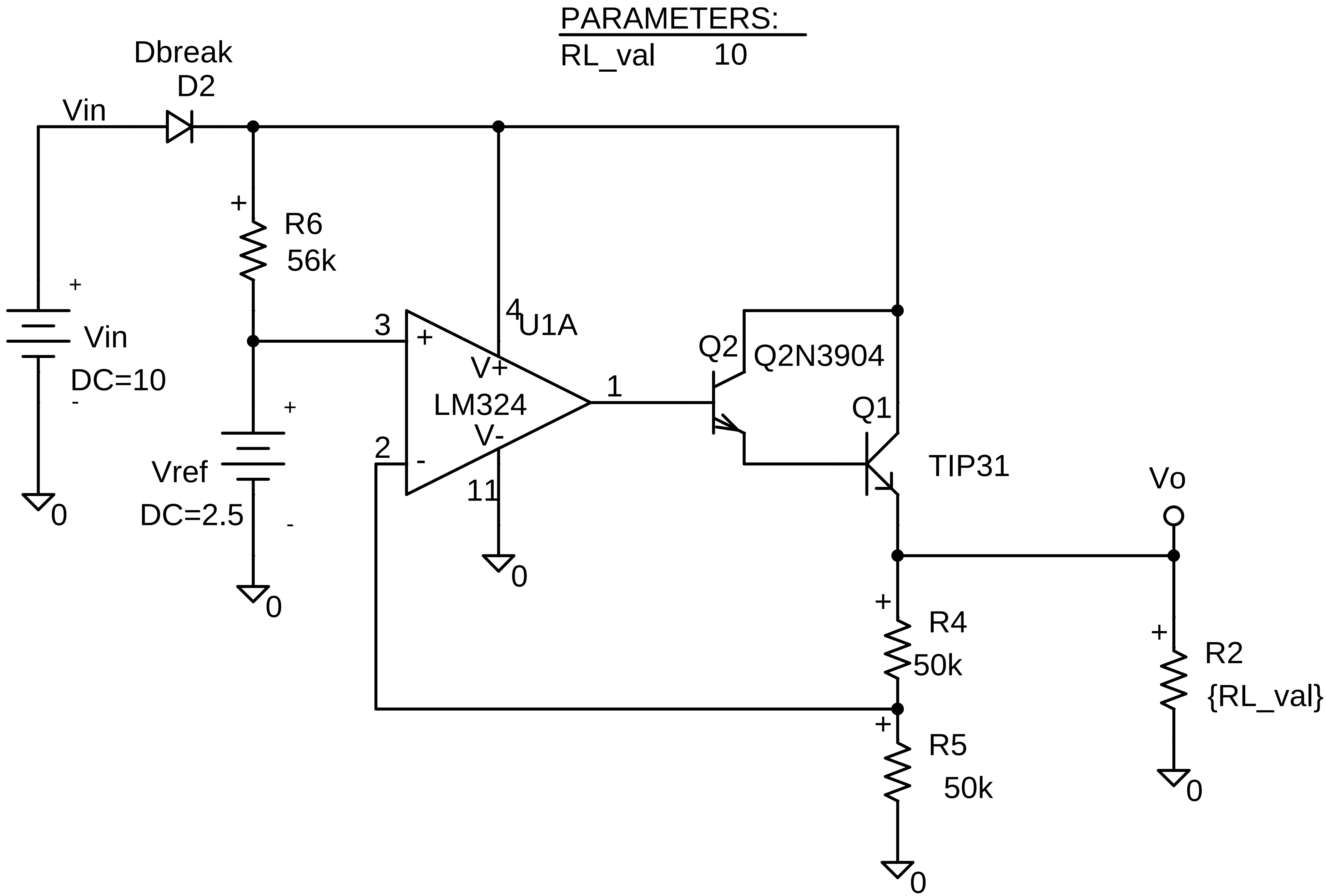
$$P_{Q\_max} := I_o \cdot \frac{\beta}{\beta + 1} \cdot \left(V_{in\_max} - V_{Dmin} - V_o\right) + \frac{I_o}{\beta + 1} \cdot V_{BEmax}$$

$P_{Q\_max} = 6.994 \cdot watt$

Calculate the Mx power dissipated by the diode

$P_{Dmax} := V_{Dmax} \cdot I_o$

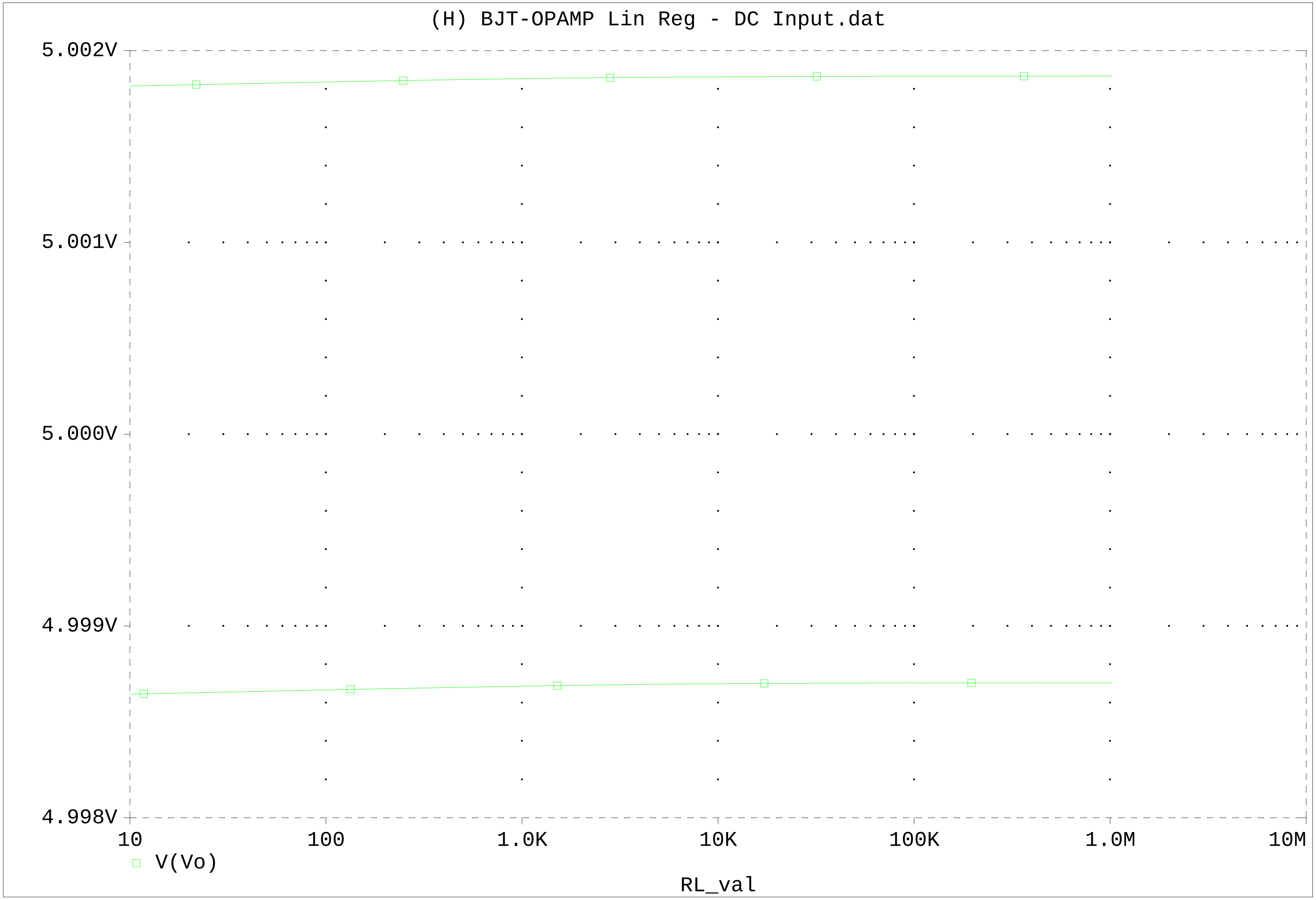
$P_{Dmax} = 0.5 \cdot watt$



PARAMETERS:
RL_val 10
Dbreak
D2
Vin
R6
56k
Vin
DC=10
0
3
2
4
U1A
V+
LM324
V-
11
1
Vref
DC=2.5
0
0
Q2
Q2N3904
Q1
TIP31
Vo
R4
50k
R5
50k
R2
{RL_val}
0
0

* D:\NAU\CLASS\egr456\SPICE_N\LIN_REG\BJT-OPAMP Lin Reg - DC Input.sch

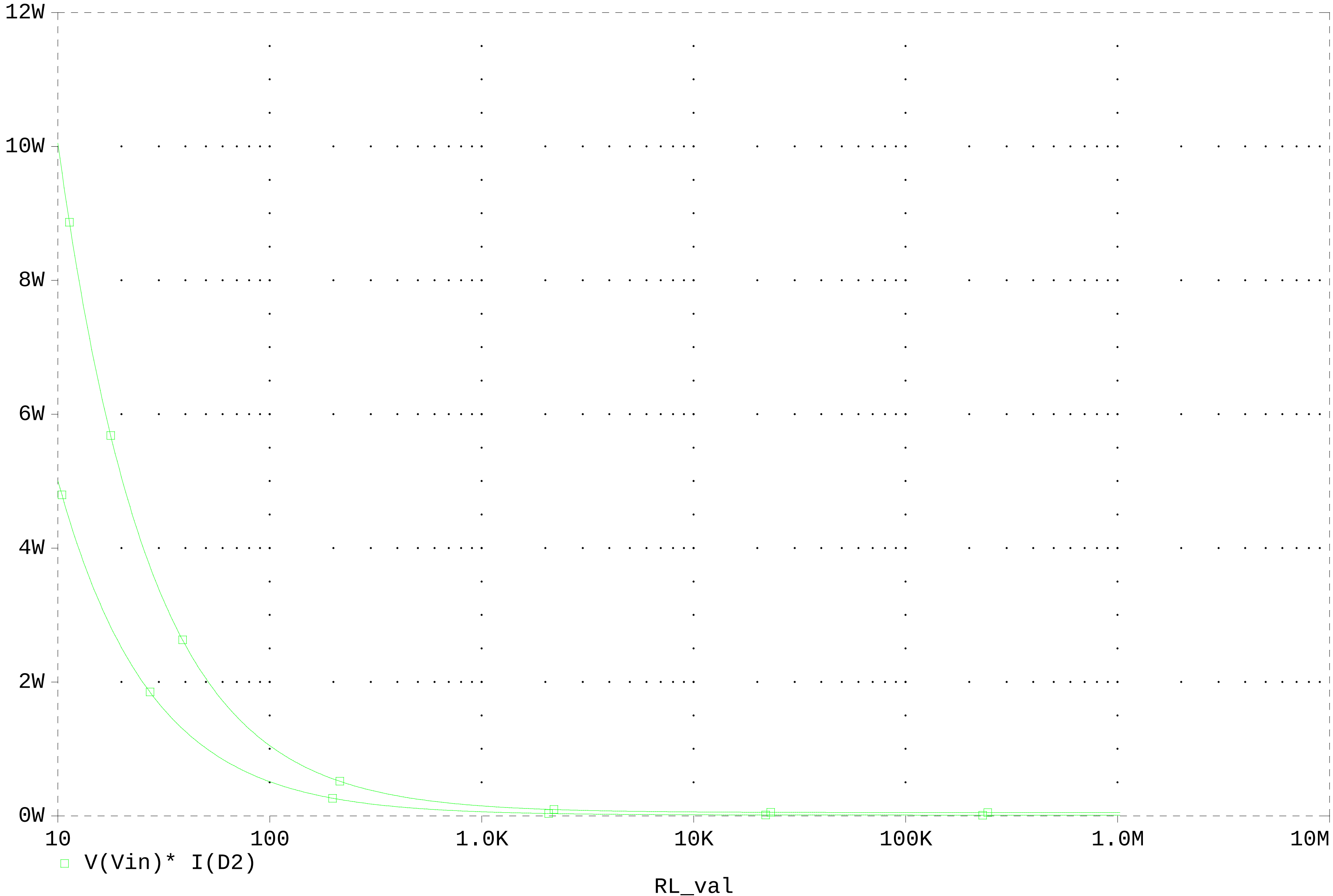
Date/Time run: 09/26/100 11:22:10 Temperature: 27.0



* D:\NAU\CLASS\egr456\SPICE_N\LIN_REG\BJT-OPAMP Lin Reg - DC Input.sch

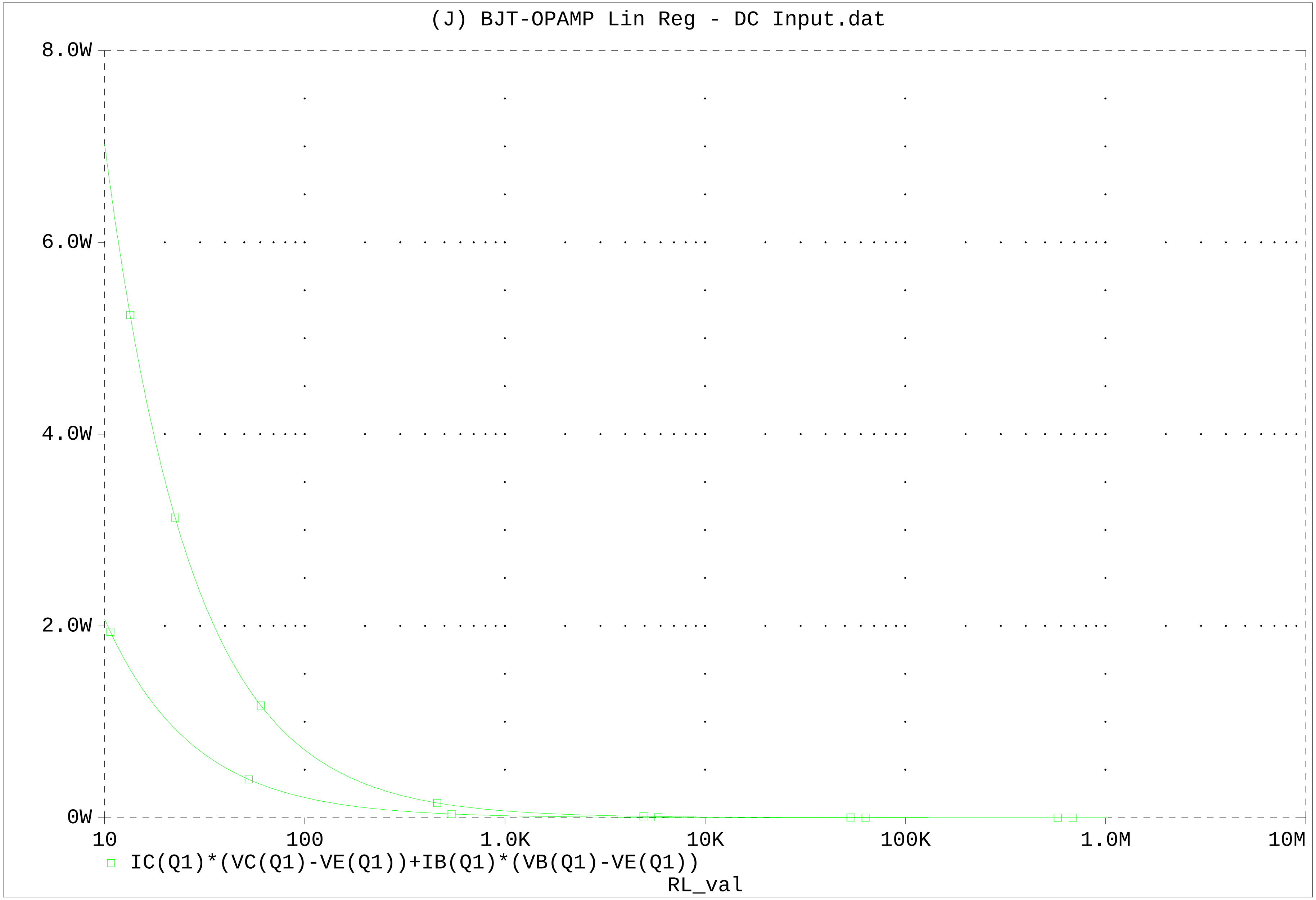
Date/Time run: 09/26/100 11:22:10 Temperature: 27.0

(I) BJT-OPAMP Lin Reg - DC Input.dat



* D:\NAU\CLASS\egr456\SPICE_N\LIN_REG\BJT-OPAMP Lin Reg - DC Input.sch

Date/Time run: 09/26/100 11:22:10 Temperature: 27.0



Order this document
by TIP31A/D

NPN
TIP31A
TIP31B*
TIP31C*
PNP
TIP32A
TIP32B*
TIP32C*

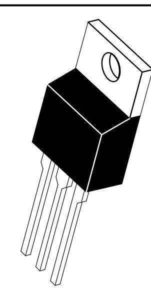
*Motorola Preferred Device

Complementary Silicon Plastic Power Transistors

. . . designed for use in general purpose amplifier and switching applications.

- Collector–Emitter Saturation Voltage — $V_{CE(sat)}$ = 1.2 Vdc (Max) @ I_C = 3.0 Adc
- Collector–Emitter Sustaining Voltage —
  $V_{CEO(sus)}$ = 60 Vdc (Min) — TIP31A, TIP32A
  = 80 Vdc (Min) — TIP31B, TIP32B
  = 100 Vdc (Min) — TIP31C, TIP32C
- High Current Gain — Bandwidth Product
  f_T = 3.0 MHz (Min) @ I_C = 500 mAdc
- Compact TO–220 AB Package

3 AMPERE
POWER TRANSISTORS
COMPLEMENTARY
SILICON
60–80–100 VOLTS
40 WATTS



CASE 221A–06
TO–220AB

*MAXIMUM RATINGS

Rating	Symbol	TIP31A TIP32A	TIP318 TIP32B	TIP31C TIP32C	Unit
Collector–Emitter Voltage	V_{CEO}	60	80	100	Vdc
Collector–Base Voltage	V_{CB}	60	80	100	Vdc
Emitter–Base Voltage	V_{EB}	5.0			Vdc
Collector Current — Continuous Peak	I_C	3.0 5.0			Adc
Base Current	I_B	1.0			Adc
Total Power Dissipation @ T_C = 25°C Derate above 25°C	P_D	40 0.32			Watts W/°C
Total Power Dissipation @ T_A = 25°C Derate above 25°C	P_D	2.0 0.016			Watts W/°C
Unclamped Inductive Load Energy (1)	E	32			mJ
Operating and Storage Junction Temperature Range	T_J, T_{stg}	–65 to +150			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	62.5	°C/W
Thermal Resistance, Junction to Case	$R_{\theta JC}$	3.125	°C/W

(1) I_C = 1.8 A, L = 20 mH, P.R.F. = 10 Hz, V_{CC} = 10 V, R_{BE} = 100 Ω..

Preferred devices are Motorola recommended choices for future use and best overall value.

REV 1

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector–Emitter Sustaining Voltage (1) (I_C = 30 mAdc, I_B = 0)	TIP31A, TIP32A TIP31B, TIP32B TIP31C, TIP32C	$V_{CEO(sus)}$	60 80 100	— — —	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, I_B = 0) (V_{CE} = 60 Vdc, I_B = 0)	TIP31A, TIP32A TIP31B, TIP31C TIP32B, TIP32C	I_{CEO}	— — —	0.3 0.3 0.3	mAdc
Collector Cutoff Current (V_{CE} = 60 Vdc, V_{EB} = 0) (V_{CE} = 80 Vdc, V_{EB} = 0) (V_{CE} = 100 Vdc, V_{EB} = 0)	TIP31A, TIP32A TIP31B, TIP32B TIP31C, TIP32C	I_{CES}	— — —	200 200 200	μAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)		I_{EBO}	—	1.0	mAdc
ON CHARACTERISTICS (1)					
DC Current Gain (I_C = 1.0 Adc, V_{CE} = 4.0 Vdc) (I_C = 3.0 Adc, V_{CE} = 4.0 Vdc)		h_{FE}	25 10	— 50	—
Collector–Emitter Saturation Voltage (I_C = 3.0 Adc, I_B = 375 mAdc)		$V_{CE(sat)}$	—	1.2	Vdc
Base–Emitter On Voltage (I_C = 3.0 Adc, V_{CE} = 4.0 Vdc)		$V_{BE(on)}$	—	1.8	Vdc
DYNAMIC CHARACTERISTICS					
Current–Gain — Bandwidth Product (I_C = 500 mAdc, V_{CE} = 10 Vdc, f_{test} = 1.0 MHz)		f_T	3.0	—	MHz
Small–Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{fe}	20	—	—

(1) Pulse Test: Pulse Width $\leq$ 300 μs, Duty Cycle $\leq$ 2.0%.

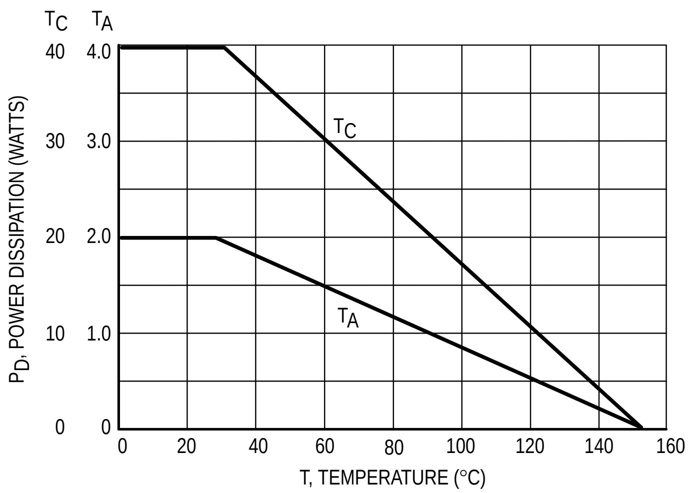
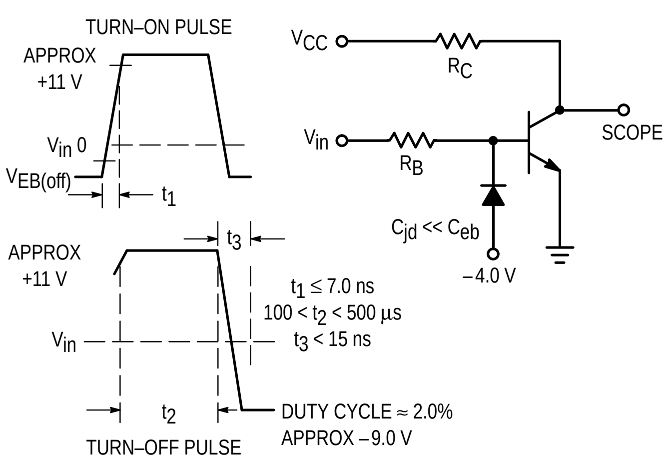


Figure 1. Power Derating



R_B and R_C VARIED TO OBTAIN DESIRED CURRENT LEVELS.

Figure 2. Switching Time Equivalent Circuit

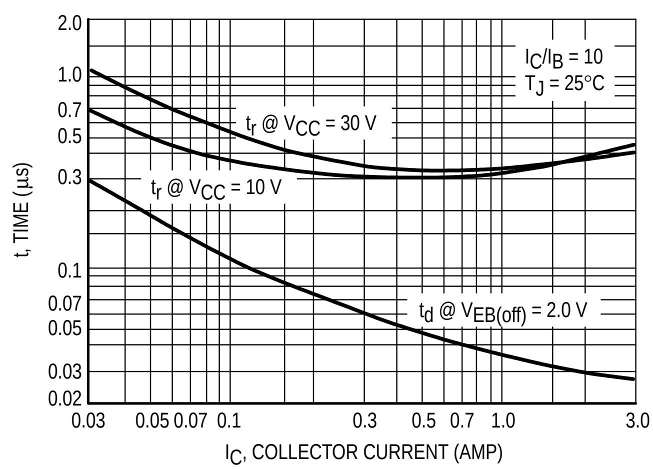


Figure 3. Turn–On Time

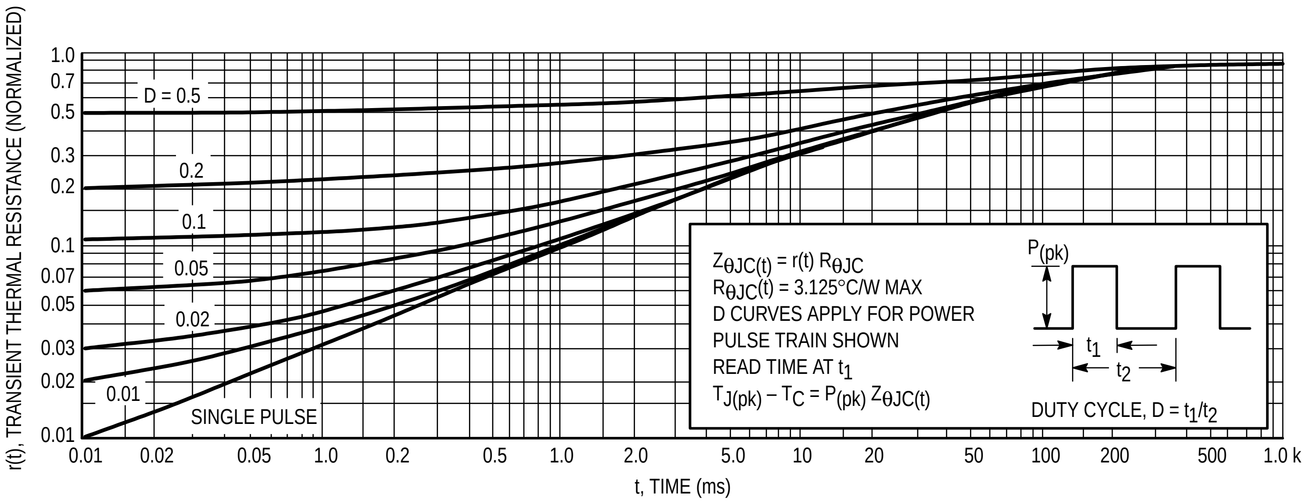


Figure 4. Thermal Response

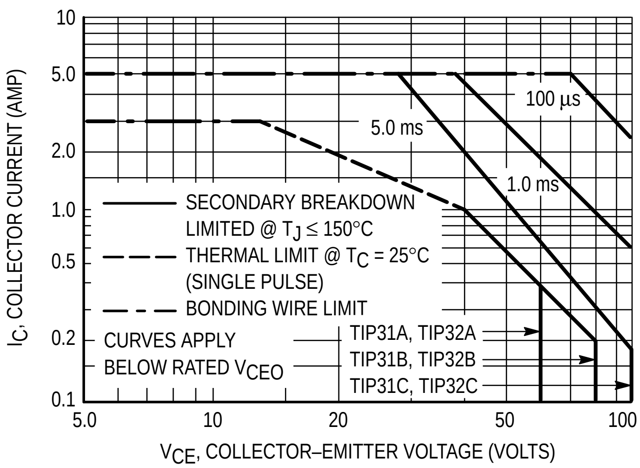


Figure 5. Active Region Safe Operating Area

There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 5 is based on $T_{J(pk)} = 150°C$; T_C is variable depending on conditions. Second breakdown pulse limits are valid for duty cycles to 10% provided $T_{J(pk)} \leq 150°C$. $T_{J(pk)}$ may be calculated from the data in Figure 4. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown.

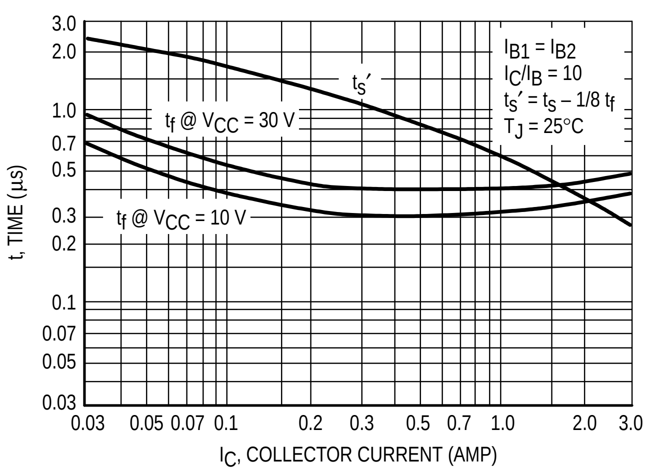


Figure 6. Turn–Off Time

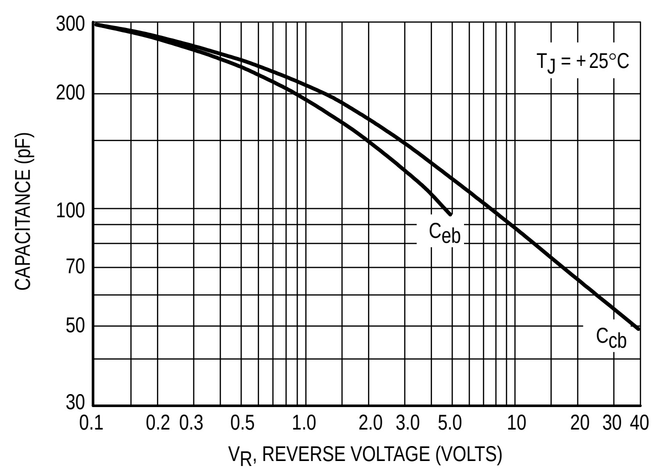


Figure 7. Capacitance

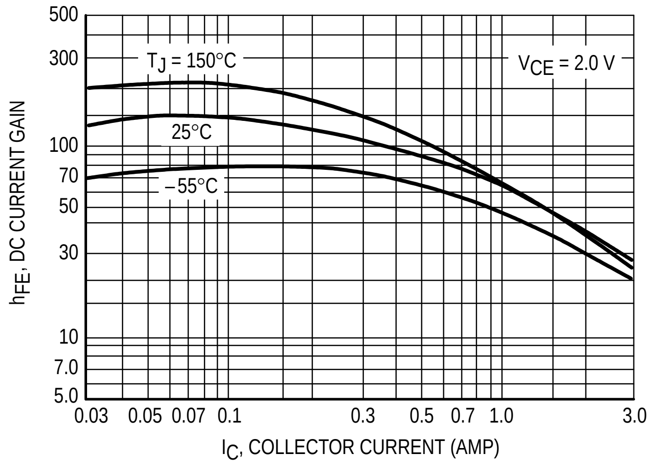


Figure 8. DC Current Gain

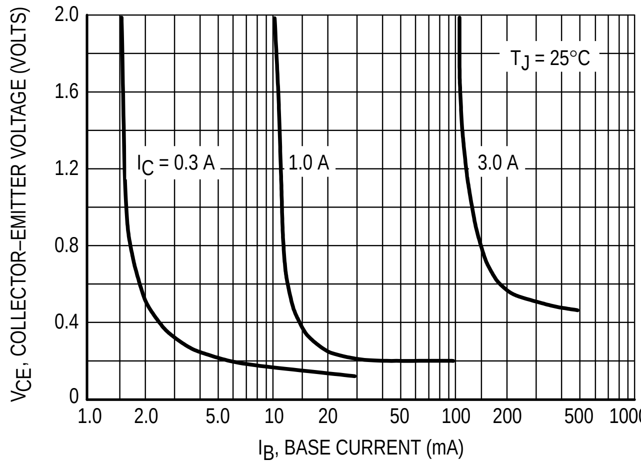


Figure 9. Collector Saturation Region

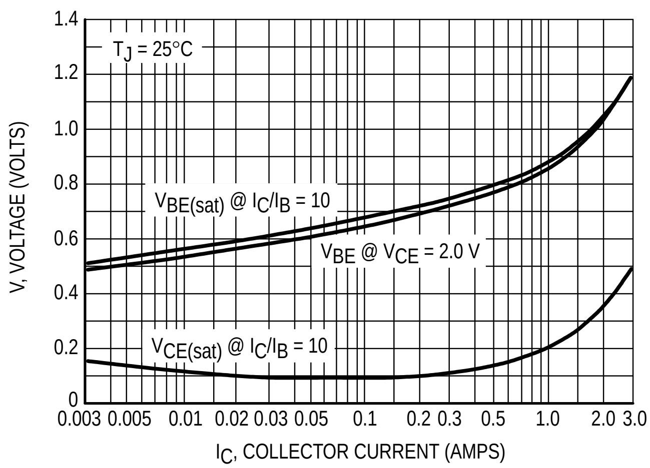


Figure 10. “On” Voltages

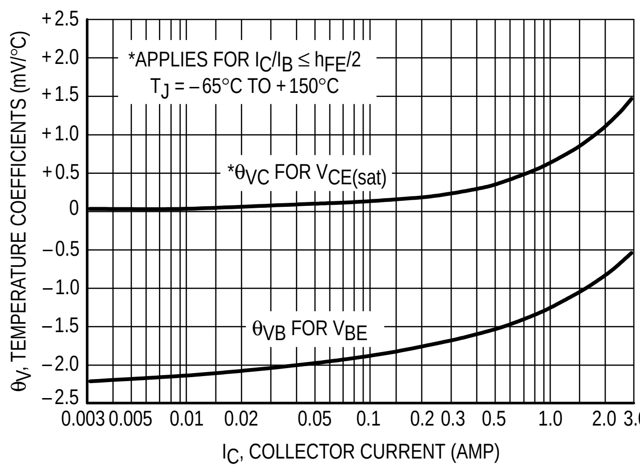


Figure 11. Temperature Coefficients

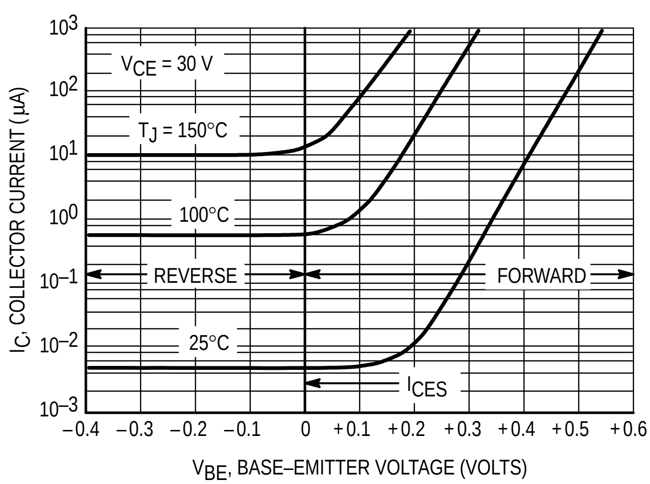


Figure 12. Collector Cut−Off Region

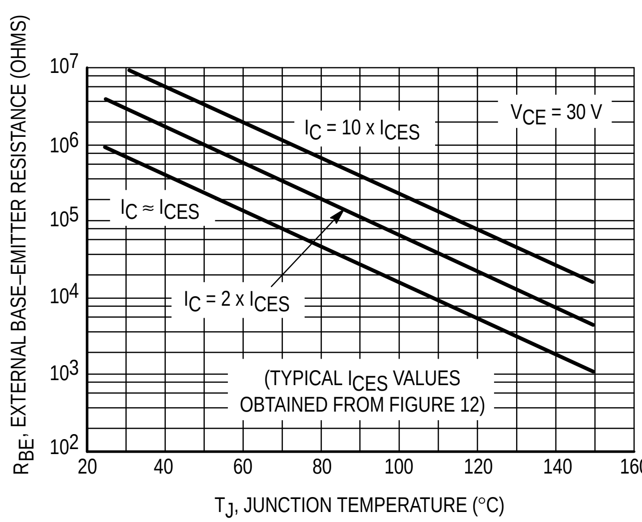
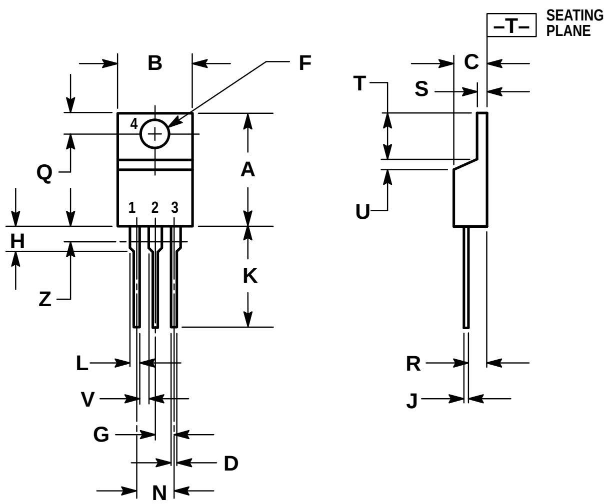


Figure 13. Effects of Base−Emitter Resistance

PACKAGE DIMENSIONS



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION Z DEFINES A ZONE WHERE ALL BODY AND LEAD IRREGULARITIES ARE ALLOWED.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.570	0.620	14.48	15.75
B	0.380	0.405	9.66	10.28
C	0.160	0.190	4.07	4.82
D	0.025	0.035	0.64	0.88
F	0.142	0.147	3.61	3.73
G	0.095	0.105	2.42	2.66
H	0.110	0.155	2.80	3.93
J	0.018	0.025	0.46	0.64
K	0.500	0.562	12.70	14.27
L	0.045	0.060	1.15	1.52
N	0.190	0.210	4.83	5.33
Q	0.100	0.120	2.54	3.04
R	0.080	0.110	2.04	2.79
S	0.045	0.055	1.15	1.39
T	0.235	0.255	5.97	6.47
U	0.000	0.050	0.00	1.27
V	0.045	—	1.15	—
Z	—	0.080	—	2.04

STYLE 1:
PIN 1. BASE
2. COLLECTOR
3. EMITTER
4. COLLECTOR

CASE 221A–06
TO–220AB
ISSUE Y

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Order this document by LM285/D

MOTOROLA

Micropower Voltage Reference Diodes

LM285
LM385, B

The LM285/LM385 series are micropower two–terminal bandgap voltage regulator diodes. Designed to operate over a wide current range of 10 µA to 20 mA, these devices feature exceptionally low dynamic impedance, low noise and stable operation over time and temperature. Tight voltage tolerances are achieved by on–chip trimming. The large dynamic operating range enables these devices to be used in applications with widely varying supplies with excellent regulation. Extremely low operating current make these devices ideal for micropower circuitry like portable instrumentation, regulators and other analog circuitry where extended battery life is required.

The LM285/LM385 series are packaged in a low cost TO–226AA plastic case and are available in two voltage versions of 1.235 and 2.500 V as denoted by the device suffix (see Ordering Information table). The LM285 is specified over a –40°C to +85°C temperature range while the LM385 is rated from 0°C to +70°C.

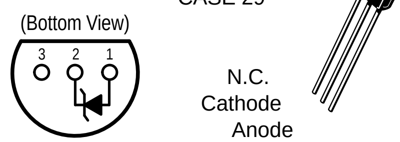
The LM385 is also available in a surface mount plastic package in voltages of 1.235 and 2.500 V.

- Operating Current from 10 µA to 20 mA
- 1.0%, 1.5%, 2.0% and 3.0% Initial Tolerance Grades
- Low Temperature Coefficient
- 1.0 Ω Dynamic Impedance
- Surface Mount Package Available

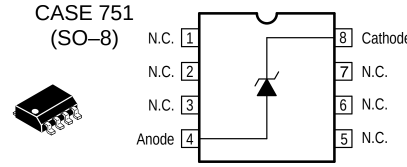
MICROPOWER VOLTAGE REFERENCE DIODES

SEMICONDUCTOR TECHNICAL DATA

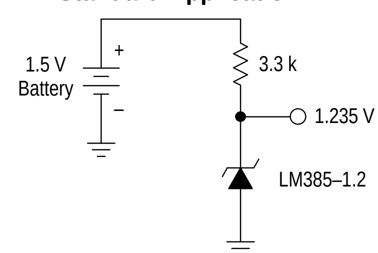
Z SUFFIX
PLASTIC PACKAGE
CASE 29



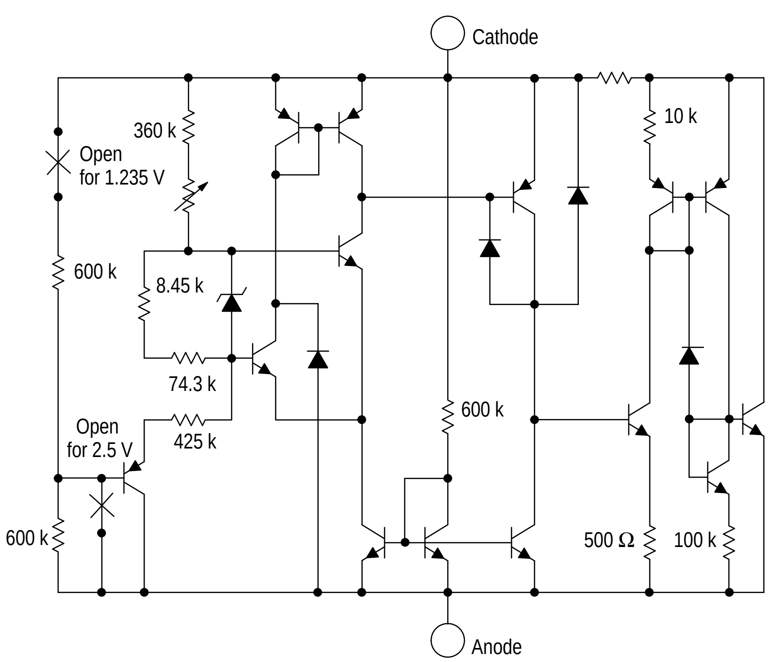
D SUFFIX
PLASTIC PACKAGE
CASE 751
(SO–8)



Standard Application



Representative Schematic Diagram



ORDERING INFORMATION

Device	Operating Temperature Range	Reverse Break–down Voltage	Tolerance
LM285D–1.2 LM285Z–1.2	T_A = –40° to +85°C	1.235 V	±1.0%
LM285D–2.5 LM285Z–2.5		2.500 V	±1.5%
LM385BD–1.2 LM385BZ–1.2	T_A = 0° to +70°C	1.235 V	±1.0%
LM385D–1.2 LM385Z–1.2		1.235 V	±2.0%
LM385BD–2.5 LM385BZ–2.5		2.500 V	±1.5%
LM385D–2.5 LM385Z–2.5		2.500 V	±3.0%

MAXIMUM RATINGS (T_A = 25°C, unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Current	I_R	30	mA
Forward Current	I_F	10	mA
Operating Ambient Temperature Range LM285 LM385	T_A	 – 40 to + 85 0 to +70	°C
Operating Junction Temperature	T_J	+ 150	°C
Storage Temperature Range	T_{stg}	– 65 to + 150	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C, unless otherwise noted)

Characteristic	Symbol	LM285–1.2			LM385–1.2/LM385B–1.2			Unit
		Min	Typ	Max	Min	Typ	Max	
Reverse Breakdown Voltage ($I_{Rmin} \leqslant I_R \leqslant$ 20 mA)	$V_{(BR)R}$							V
LM285–1.2/LM385B–1.2		1.223	1.235	1.247	1.223	1.235	1.247	
$T_A = T_{low}$ to T_{high} (Note 1)		1.200	–	1.270	1.210	–	1.260	
LM385–1.2		–	–	–	1.205	1.235	1.260	
$T_A = T_{low}$ to T_{high} (Note 1)		–	–	–	1.192	–	1.273	
Minimum Operating Current	I_{Rmin}							µA
T_A = 25°C		–	8.0	10	–	8.0	15	
$T_A = T_{low}$ to T_{high} (Note 1)		–	–	20	–	–	20	
Reverse Breakdown Voltage Change with Current	$\Delta V_{(BR)R}$							mV
$I_{Rmin} \leqslant I_R \leqslant$ 1.0 mA, T_A = +25°C		–	–	1.0	–	–	1.0	
$T_A = T_{low}$ to T_{high} (Note 1)		–	–	1.5	–	–	1.5	
1.0 mA $\leqslant I_R \leqslant$ 20 mA, T_A = +25°C		–	–	10	–	–	20	
$T_A = T_{low}$ to T_{high} (Note 1)		–	–	20	–	–	25	
Reverse Dynamic Impedance I_R = 100 µA, T_A = +25°C	Z		0.6	–	–	0.6	–	W
Average Temperature Coefficient 10 µA $\leqslant I_R \leqslant$ 20 mA, $T_A = T_{low}$ to T_{high} (Note 1)	$\Delta V_{(BR)}/\Delta T$	–	80	–	–	80	–	ppm/°C
Wideband Noise (RMS) I_R = 100 µA, 10 Hz $\leqslant$ f $\leqslant$ 10 kHz	n	–	60	–	–	60	–	µV
Long Term Stability I_R = 100 µA, T_A = +25°C ± 0.1°C	S	–	20	–	–	20	–	ppm/ kHR

ELECTRICAL CHARACTERISTICS (T_A = 25°C, unless otherwise noted)

Characteristic	Symbol	LM285–2.5			LM385–2.5/LM385B–2.5			Unit
		Min	Typ	Max	Min	Typ	Max	
Reverse Breakdown Voltage ($I_{Rmin} \leqslant I_R \leqslant$ 20 mA)	$V_{(BR)R}$							V
LM285–2.5/LM385B–2.5		2.462	2.5	2.538	2.462	2.5	2.538	
$T_A = T_{low}$ to T_{high} (Note 1)		2.415	–	2.585	2.436	–	2.564	
LM385–2.5		–	–	–	2.425	2.5	2.575	
$T_A = T_{low}$ to T_{high} (Note 1)		–	–	–	2.400	–	2.600	
Minimum Operating Current	I_{Rmin}							µA
T_A = 25°C		–	13	20	–	13	20	
$T_A = T_{low}$ to T_{high} (Note 1)		–	–	30	–	–	30	
Reverse Breakdown Voltage Change with Current	$\Delta V_{(BR)R}$							mV
$I_{Rmin} \leqslant I_R \leqslant$ 1.0 mA, T_A = +25°C		–	–	1.0	–	–	2.0	
$T_A = T_{low}$ to T_{high} (Note 1)		–	–	1.5	–	–	2.5	
1.0 mA $\leqslant I_R \leqslant$ 20 mA, T_A = +25°C		–	–	10	–	–	20	
$T_A = T_{low}$ to T_{high} (Note 1)		–	–	20	–	–	25	
Reverse Dynamic Impedance I_R = 100 µA, T_A = +25°C	Z		0.6	–	–	0.6	–	W
Average Temperature Coefficient 20 µA $\leqslant I_R \leqslant$ 20 mA, $T_A = T_{low}$ to T_{high} (Note 1)	$\Delta V_{(BR)}/\Delta T$	–	80	–	–	80	–	ppm/°C
Wideband Noise (RMS) I_R = 100 µA, 10 Hz $\leqslant$ f $\leqslant$ 10 kHz	n	–	120	–	–	120	–	µV
Long Term Stability I_R = 100 µA, T_A = +25°C ± 0.1°C	S	–	20	–	–	20	–	ppm/ kHR

NOTES: 1. T_{low} = – 40°C for LM285–1.2, LM285–2.5
= 0°C for LM385–1.2, LM385B–1.2, LM385–2.5, LM385B–2.5
T_{high} = +85°C for LM285–1.2, LM285–2.5
= +70°C for LM385–1.2, LM385B–1.2, LM385–2.5, LM385B–2.5

TYPICAL PERFORMANCE CURVES FOR LM285–1.2/385–1.2/385B–1.2

Figure 1. Reverse Characteristics

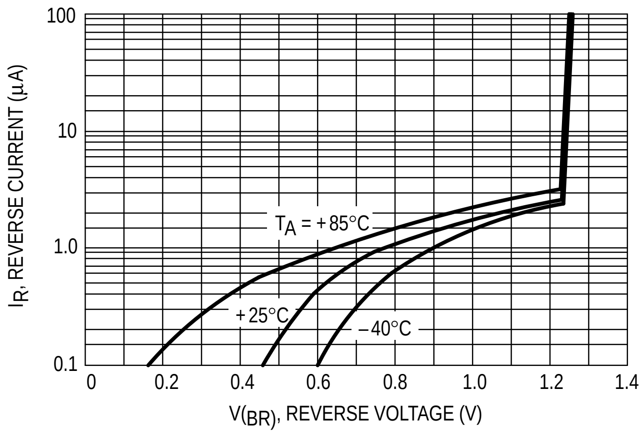


Figure 2. Reverse Characteristics

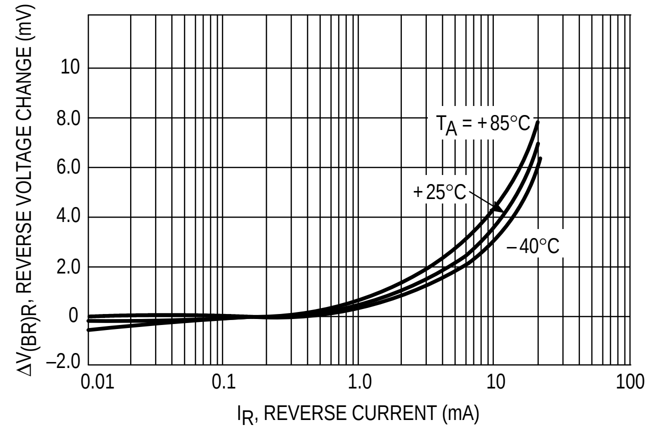


Figure 3. Forward Characteristics

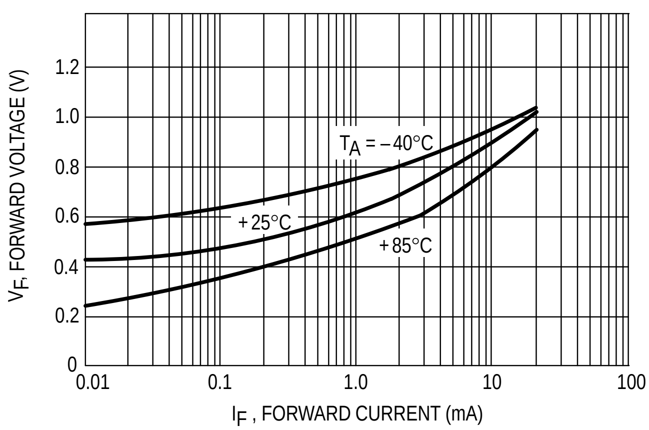


Figure 4. Temperature Drift

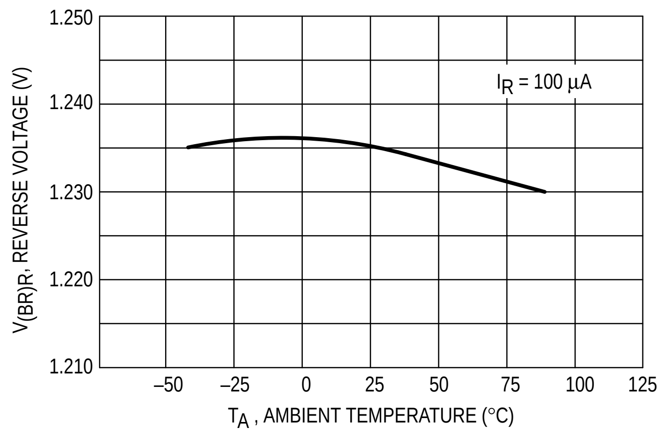


Figure 5. Noise Voltage

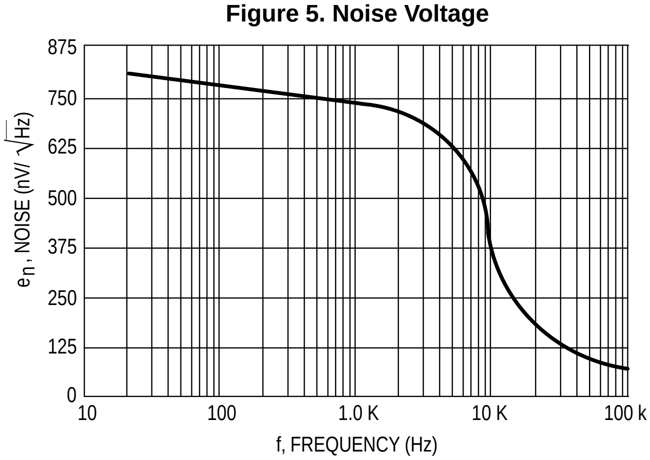
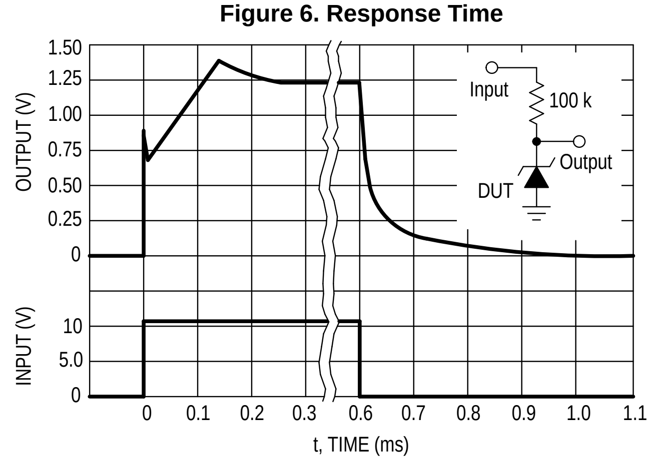


Figure 6. Response Time



TYPICAL PERFORMANCE CURVES FOR LM285–2.5/385–2.5/385B–2.5

Figure 7. Reverse Characteristics

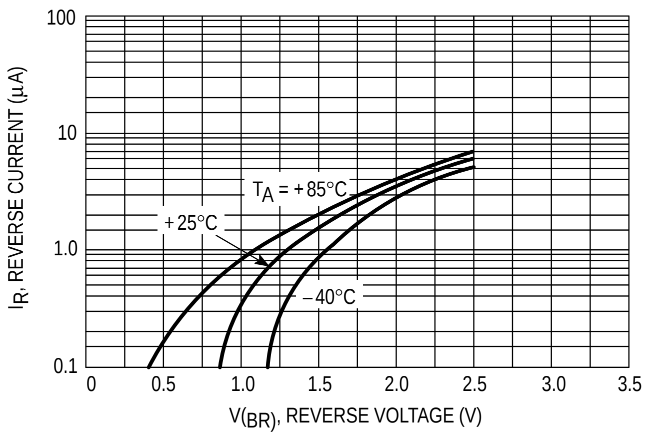


Figure 8. Reverse Characteristics

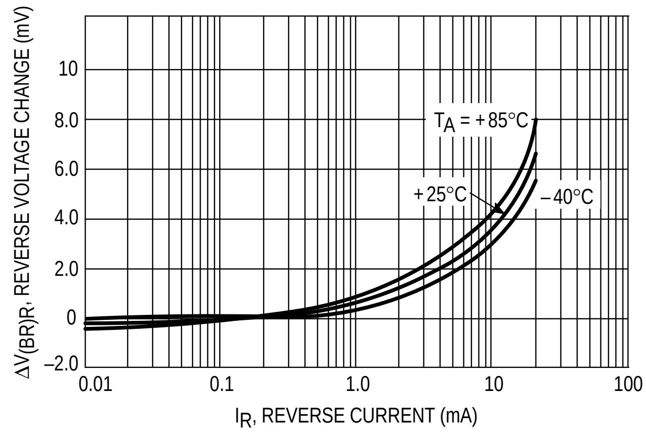


Figure 9. Forward Characteristics

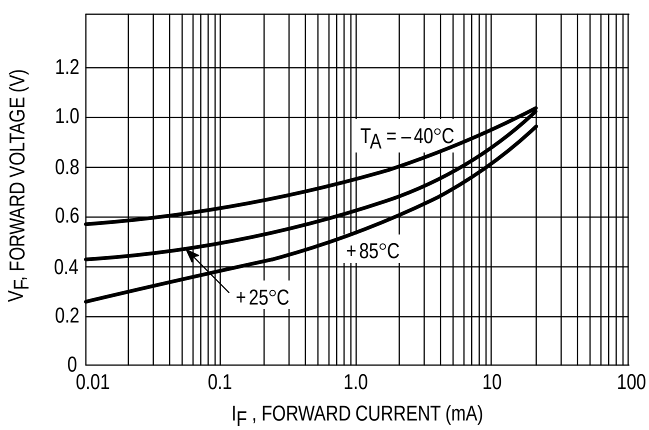


Figure 10. Temperature Drift

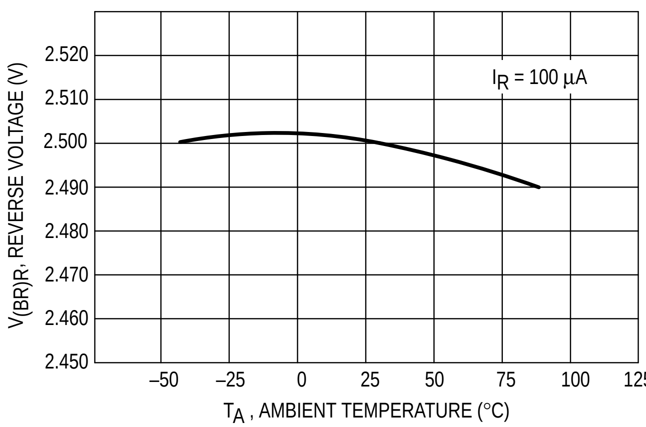


Figure 11. Noise Voltage

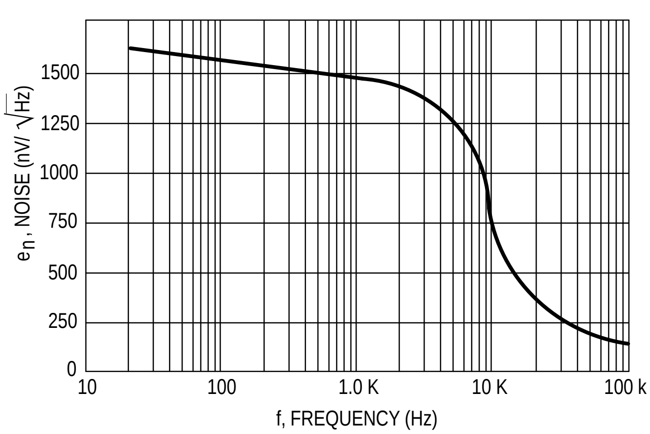
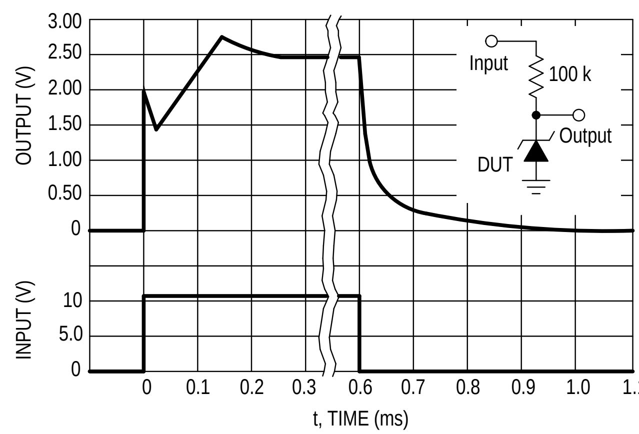
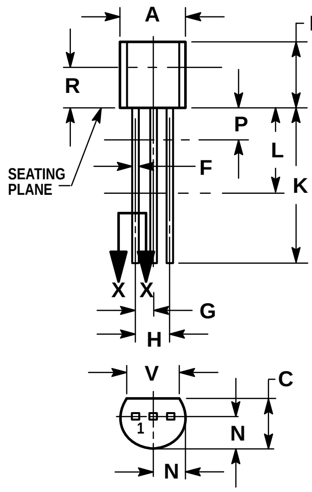


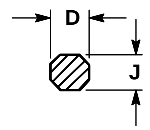
Figure 12. Response Time



OUTLINE DIMENSIONS

Z SUFFIX
PLASTIC PACKAGE
CASE 29–04
ISSUE AD



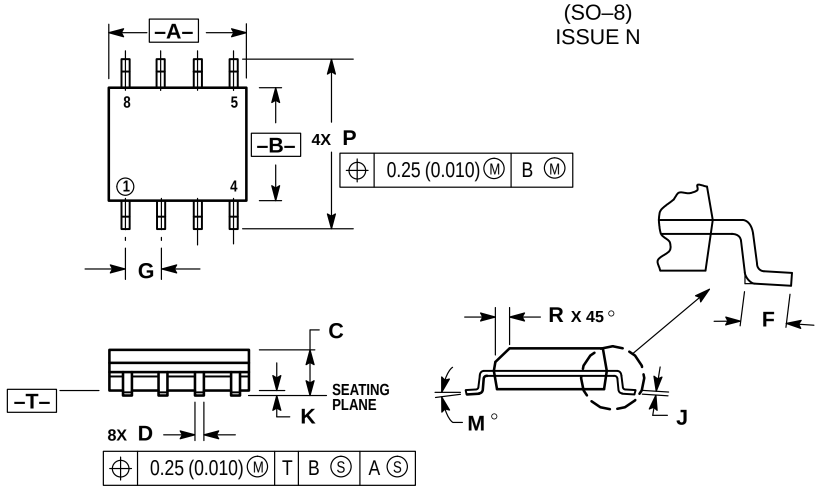


SECTION X–X

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. CONTOUR OF PACKAGE BEYOND DIMENSION R IS UNCONTROLLED.
4. DIMENSION F APPLIES BETWEEN P AND L. DIMENSION D AND J APPLY BETWEEN L AND K MINIMUM. LEAD DIMENSION IS UNCONTROLLED IN P AND BEYOND DIMENSION K MINIMUM.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.175	0.205	4.45	5.20
B	0.170	0.210	4.32	5.33
C	0.125	0.165	3.18	4.19
D	0.016	0.022	0.41	0.55
F	0.016	0.019	0.41	0.48
G	0.045	0.055	1.15	1.39
H	0.095	0.105	2.42	2.66
J	0.015	0.020	0.39	0.50
K	0.500	—–	12.70	—–
L	0.250	—–	6.35	—–
N	0.080	0.105	2.04	2.66
P	—–	0.100	—–	2.54
R	0.115	—–	2.93	—–
V	0.135	—–	3.43	—–

D SUFFIX
PLASTIC PACKAGE
CASE 751–05
(SO–8)
ISSUE N



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSIONS A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	4.80	5.00	0.189	0.196
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.054	0.068
D	0.35	0.49	0.014	0.019
F	0.40	1.25	0.016	0.049
G	1.27 BSC		0.050 BSC	
J	0.18	0.25	0.007	0.009
K	0.10	0.25	0.004	0.009
M	0°	7°	0°	7°
P	5.80	6.20	0.229	0.244
R	0.25	0.50	0.010	0.019

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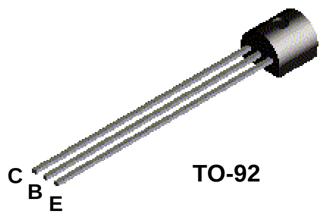
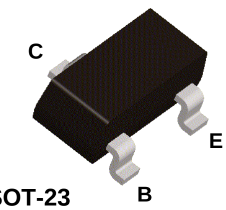
Discrete Power & Signal Technologies

2N3904

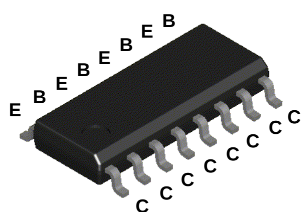


MMBT3904



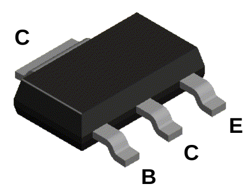
SOT-23
Mark: 1A

MMPQ3904



SOIC-16

PZT3904



SOT-223

NPN General Purpose Amplifier

This device is designed as a general purpose amplifier and switch. The useful dynamic range extends to 100 mA as a switch and to 100 MHz as an amplifier. Sourced from Process 23.

Absolute Maximum Ratings*

TA = 25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{CEO}	Collector-Emitter Voltage	40	V
V_{CBO}	Collector-Base Voltage	60	V
V_{EBO}	Emitter-Base Voltage	6.0	V
I_C	Collector Current - Continuous	200	mA
T_J, T_{stg}	Operating and Storage Junction Temperature Range	-55 to +150	°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

NOTES:
1) These ratings are based on a maximum junction temperature of 150 degrees C.
2) These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

NPN General Purpose Amplifier
(continued)

Electrical Characteristics

TA = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions	Min	Max	Units
OFF CHARACTERISTICS					
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 10 mA, I_B = 0	40		V
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	I_C = 10 μA, I_E = 0	60		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	I_E = 10 μA, I_C = 0	6.0		V
I_{BL}	Base Cutoff Current	V_{CE} = 30 V, V_{EB} = 0		50	nA
I_{CEX}	Collector Cutoff Current	V_{CE} = 30 V, V_{EB} = 0		50	nA
ON CHARACTERISTICS*					
h_{FE}	DC Current Gain	I_C = 0.1 mA, V_{CE} = 1.0 V I_C = 1.0 mA, V_{CE} = 1.0 V I_C = 10 mA, V_{CE} = 1.0 V I_C = 50 mA, V_{CE} = 1.0 V I_C = 100 mA, V_{CE} = 1.0 V	40 70 100 60 30	 300 	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 10 mA, I_B = 1.0 mA I_C = 50 mA, I_B = 5.0 mA		0.2 0.3	V V
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	I_C = 10 mA, I_B = 1.0 mA I_C = 50 mA, I_B = 5.0 mA	0.65	0.85 0.95	V V
SMALL SIGNAL CHARACTERISTICS					
f_T	Current Gain - Bandwidth Product	I_C = 10 mA, V_{CE} = 20 V, f = 100 MHz	300		MHz
C_{obo}	Output Capacitance	V_{CB} = 5.0 V, I_E = 0, f = 1.0 MHz		4.0	pF
C_{ibo}	Input Capacitance	V_{EB} = 0.5 V, I_C = 0, f = 1.0 MHz		8.0	pF
NF	Noise Figure (except MMPQ3904)	I_C = 100 μA, V_{CE} = 5.0 V, R_S =1.0kΩ, f=10 Hz to 15.7 kHz		5.0	dB
SWITCHING CHARACTERISTICS (except MMPQ3904)					
t_d	Delay Time	V_{CC} = 3.0 V, V_{BE} = 0.5 V,		35	ns
t_r	Rise Time	I_C = 10 mA, I_{B1} = 1.0 mA		35	ns
t_s	Storage Time	V_{CC} = 3.0 V, I_C = 10mA		200	ns
t_f	Fall Time	I_{B1} = I_{B2} = 1.0 mA		50	ns

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%

Spice Model

NPN (Is=6.734f Xti=3 Eg=1.11 Vaf=74.03 Bf=416.4 Ne=1.259 Ise=6.734 Ikf=66.78m Xtb=1.5 Br=.7371 Nc=2 Isc=0 Ikr=0 Rc=1 Cjc=3.638p Mjc=.3085 Vjc=.75 Fc=.5 Cje=4.493p Mje=.2593 Vje=.75 Tr=239.5n Tf=301.2p Itf=.4 Vtf=4 Xtf=2 Rb=10)

NPN General Purpose Amplifier
(continued)

Thermal Characteristics
TA = 25°C unless otherwise noted

Symbol	Characteristic	Max		Units
		2N3904	*PZT3904	
P_D	Total Device Dissipation Derate above 25°C	625 5.0	1,000 8.0	mW mW/°C
$R_{\theta JC}$	Thermal Resistance, Junction to Case	83.3		°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	200	125	°C/W

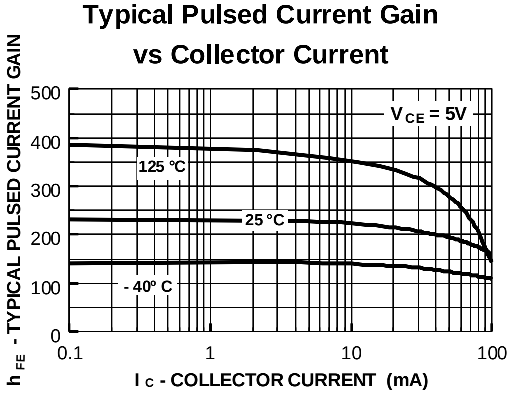
Symbol	Characteristic	Max		Units
		**MMBT3904	MMPQ3904	
P_D	Total Device Dissipation Derate above 25°C	350 2.8	1,000 8.0	mW mW/°C
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient Effective 4 Die Each Die	357	 125 240	°C/W °C/W °C/W

*Device mounted on FR-4 PCB 36 mm X 18 mm X 1.5 mm; mounting pad for the collector lead min. 6 cm^2.

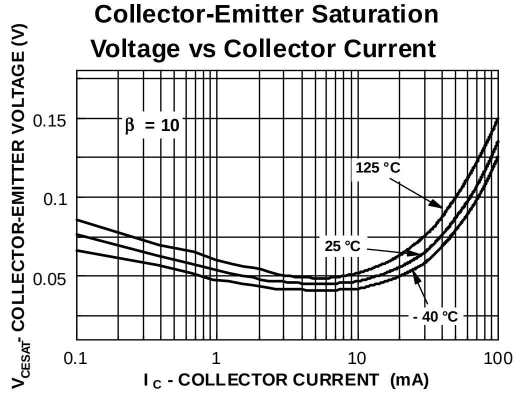
**Device mounted on FR-4 PCB 1.6" X 1.6" X 0.06."

Typical Characteristics

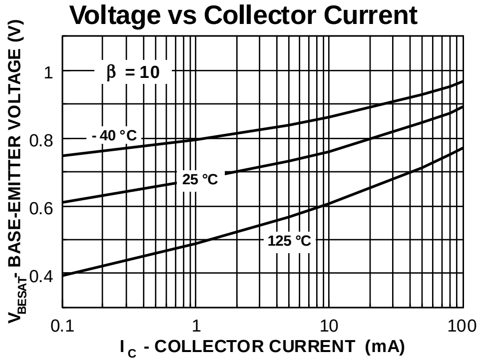
Typical Pulsed Current Gain vs Collector Current



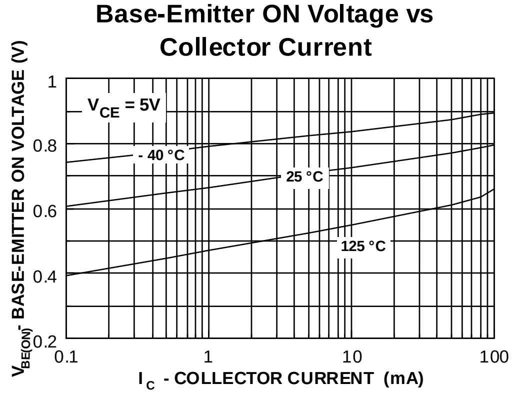
Collector-Emitter Saturation Voltage vs Collector Current



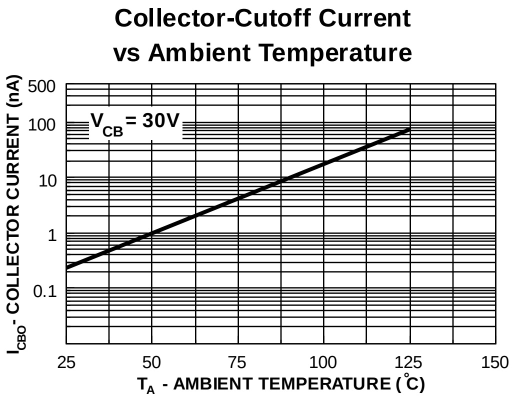
Base-Emitter Saturation Voltage vs Collector Current

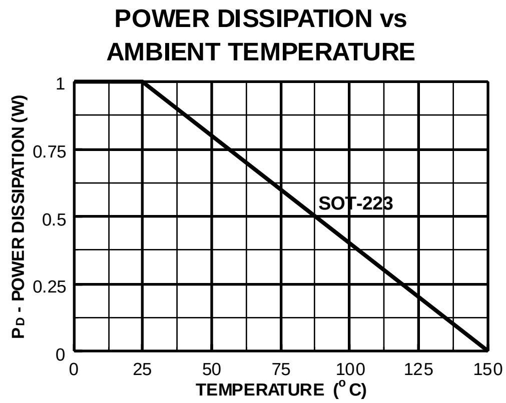


Base-Emitter ON Voltage vs Collector Current



Typical Characteristics (continued)





Test Circuits

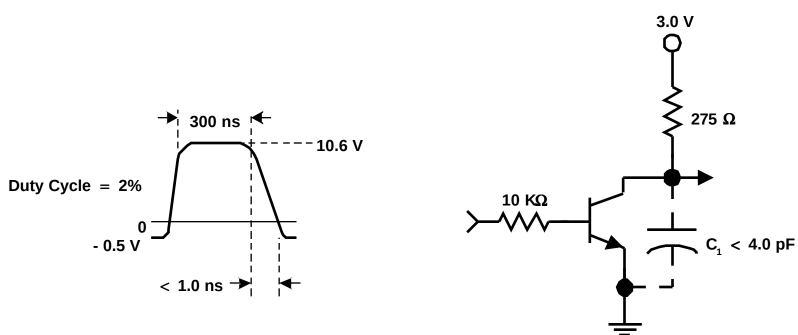


FIGURE 1: Delay and Rise Time Equivalent Test Circuit

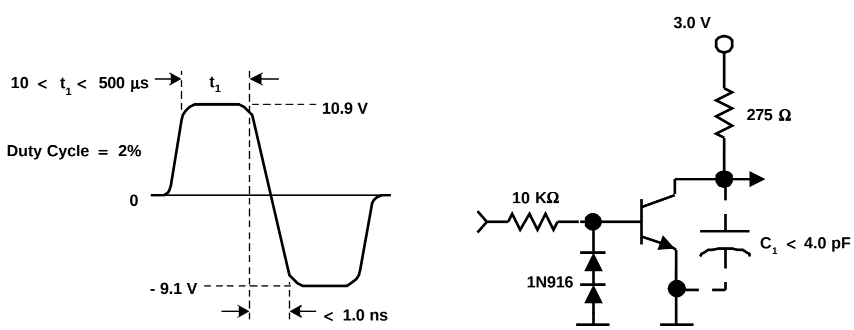


FIGURE 2: Storage and Fall Time Equivalent Test Circuit