Lecture 12 - 2EI4

- Analysis with mathematical model of diode
- Some Diode Circuits
- Zener Voltage Regulator Circuit
- Limiter/clipper circuits
- Clamping and peak detection circuits

2. Analysis with mathematical model of diode

$i_D = I_s \cdot \left(e^{qv_D/nkT} - 1\right)$ and $I_s = 10^{-13}A$, $n = 1$ and $V_T = 0.025V$.

$i_D = 10^{-13} \cdot \left(e^{40v_D} - 1\right)$ or $v_D = V_T \cdot \ln\left(\frac{i_D}{I_s} + 1\right)$.

$10V = 10^{-13} \cdot \left(e^{40v_D} - 1\right) \cdot R + v_D$ or $10V = 10^4 \cdot I_D + 0.025\ln\left(\frac{i_D}{I_s} + 1\right)$.

Use the Newton's method to solve for I_D or V_D (should know Newton's method from first year calculus).

$f = 10V - \left(10^4 \cdot 10^{-13} \cdot \left(e^{40v_D} - 1\right) + v_D\right)$; $f' = -4 \cdot 10^{-8} \cdot e^{40v_D} - 1$.

$$f'(V_D^0) = \frac{f(V_D^0) - 0}{V_D^0 - V_D^1} \text{ or } V_D^1 = V_D^0 - \frac{f(V_D^0)}{f'(V_D^0)}.$$

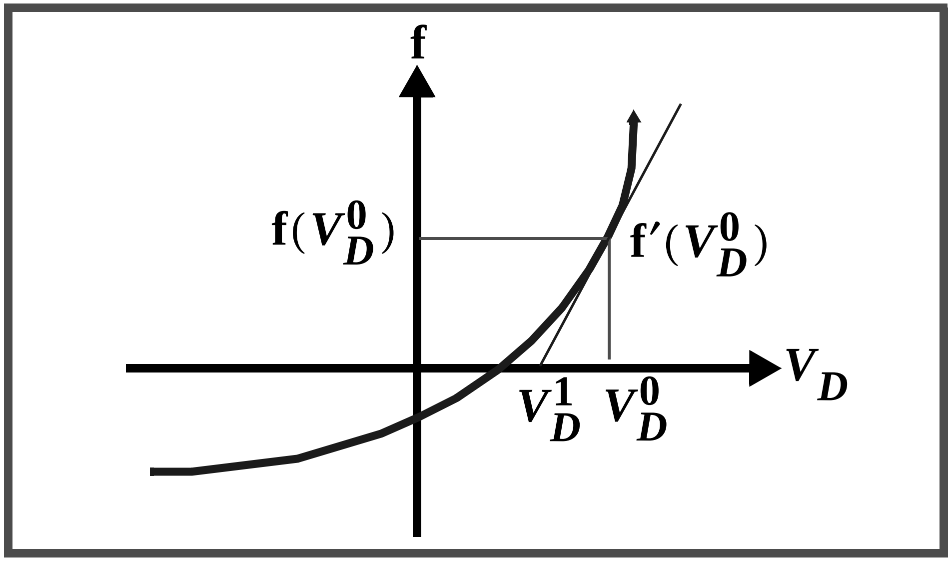
1. Make an initial guess V_D^0.

2. Evaluate f and f' for this value of V_D.

3. Calculate a new guess for V_D using $V_D^1 = V_D^0 - \frac{f(V_D^0)}{f'(V_D^0)}$.

4. Repeat #2 and #3 until convergence is obtained.

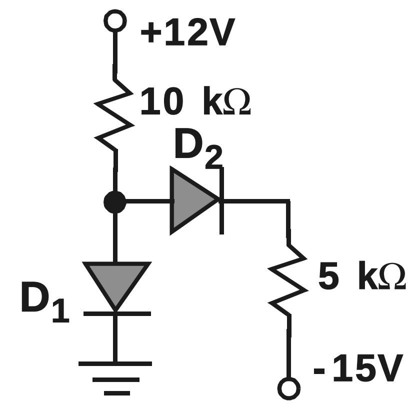
2. Analysis with mathematical model of diode



Iteration #	V_D	f	f'	I_D
0	0.8000	-7.895×10^{4}	-3.159×10^{6}	7.896×10^{0}
1	0.7750	-2.904×10^{4}	-1.162×10^{6}	2.905×10^{0}
11	0.5743	-5.989×10^{-2}	-3.804×10^{2}	9.486×10^{-4}
12	**0.5742**	**-1.876×10^{-4}**	**-3.780×10^{2}**	**9.426×10^{-4}**

Example:

For the circuit shown, find the Q-points for the diodes using constant voltage drop model with $V_{on} = 0.7$ V.



Assume D_1 is on and D_2 is on,

$$\therefore I_{D2} = \frac{0.7 - 0.7 - (-15)}{5k} = 3.00mA$$

but $$I_{D1} = \frac{12 - 0.7}{10k} - 3.00m = -1.87mA$$

Therefore, assumption is wrong.

Now, assume D_1 is off and D_2 is on,

$$\therefore I_{D1} = 0A$$

$$I_{D2} = \frac{12 - 0.7 - (-15)}{10k + 5k} = 1.75mA$$

$$V_{D1} = 12 - 10^4 I_{D2} = -5.53V$$

Therefore, D_1 is $(0A, -5.53V)$ and D_2 is $(1.75mA, 0.7V)$.

Some Diode Circuits

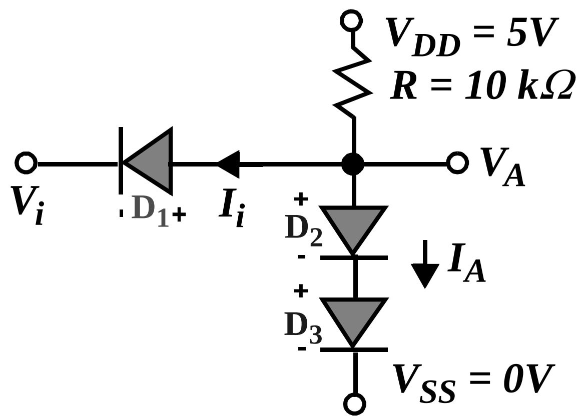
Diode Switching Circuit

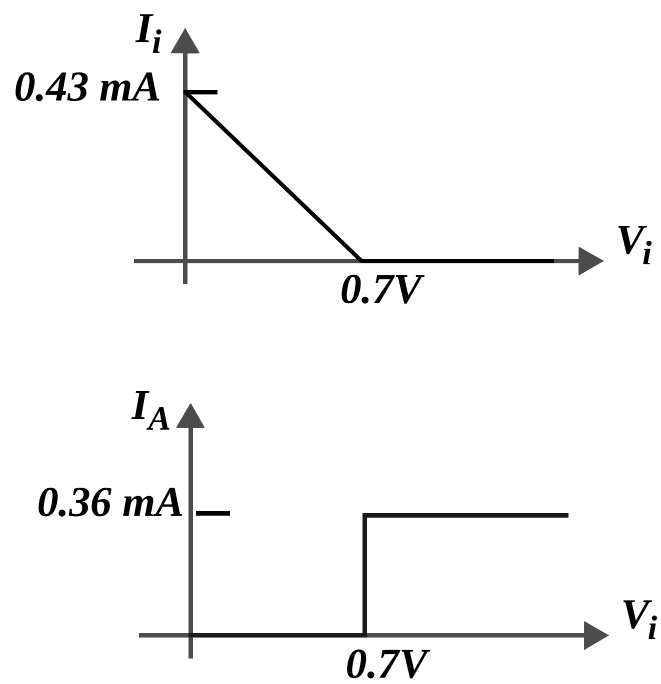
$V_A \leq V_i + 0.7V$

Critical Value $V_A = 1.4V$

$\Rightarrow V_i = 0.7V$

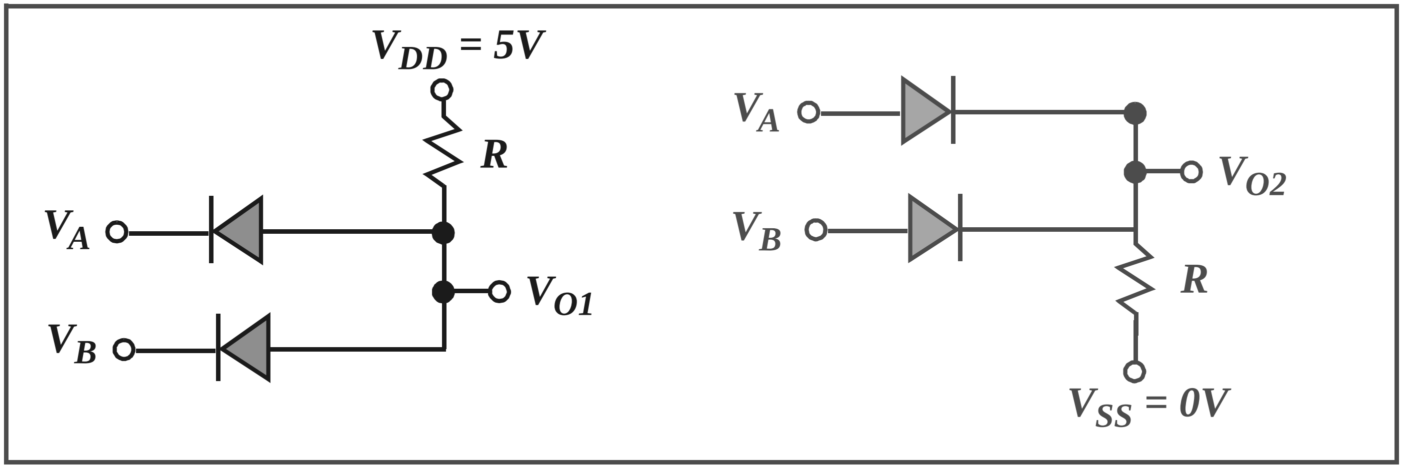
$V_{ON} = 0.7V$





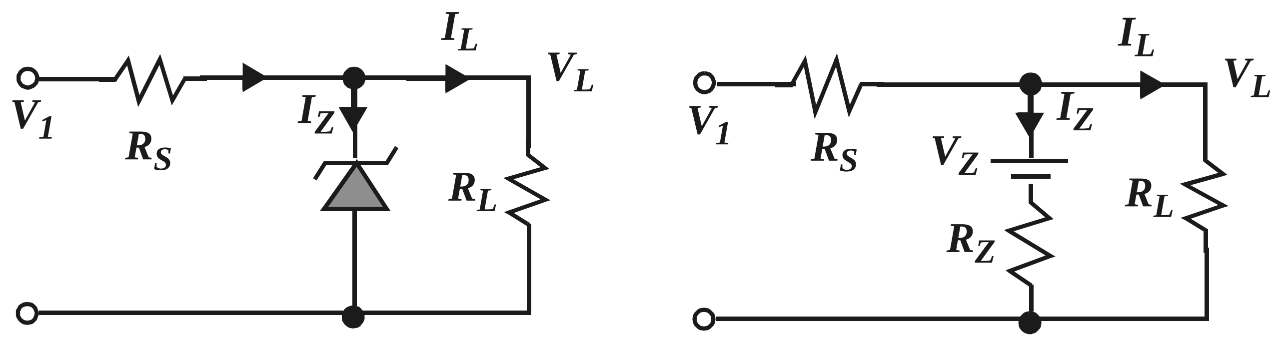
As an exercise, determine the value of V_A for the following values of input voltage V_i = 2V, 1 V, 0 V and -1V.

Some Diode Circuits



For the two circuits above, determine V_{Oi} for all four combinations of V_A and V_B, of 0V and 5V, that is (0V,0V), (0V,5V), (5V,0V) and (5V,5V). How best can V_{O1} and V_{O2} be written in terms of V_A and V_B.

Zener Voltage Regulator Circuit



R_S = 200Ω, V_Z = 100V, I_L = 50 mA and R_Z = 20 Ω

$$V_L = V_Z + I_Z \cdot R_Z = 100 + 0.01x20 = 100.2V$$. $I_Z = \dfrac{V_L - V_Z}{R_Z}$

$$V_1 = V_L + \left(I_L + \frac{V_L - V_Z}{R_Z}\right) R_S = 100.2 + \left(0.05 + \frac{0.2}{20}\right) 200 = 112.2V$$

V_1 increases by 10% to V_1'; $V_1' = 123.42$

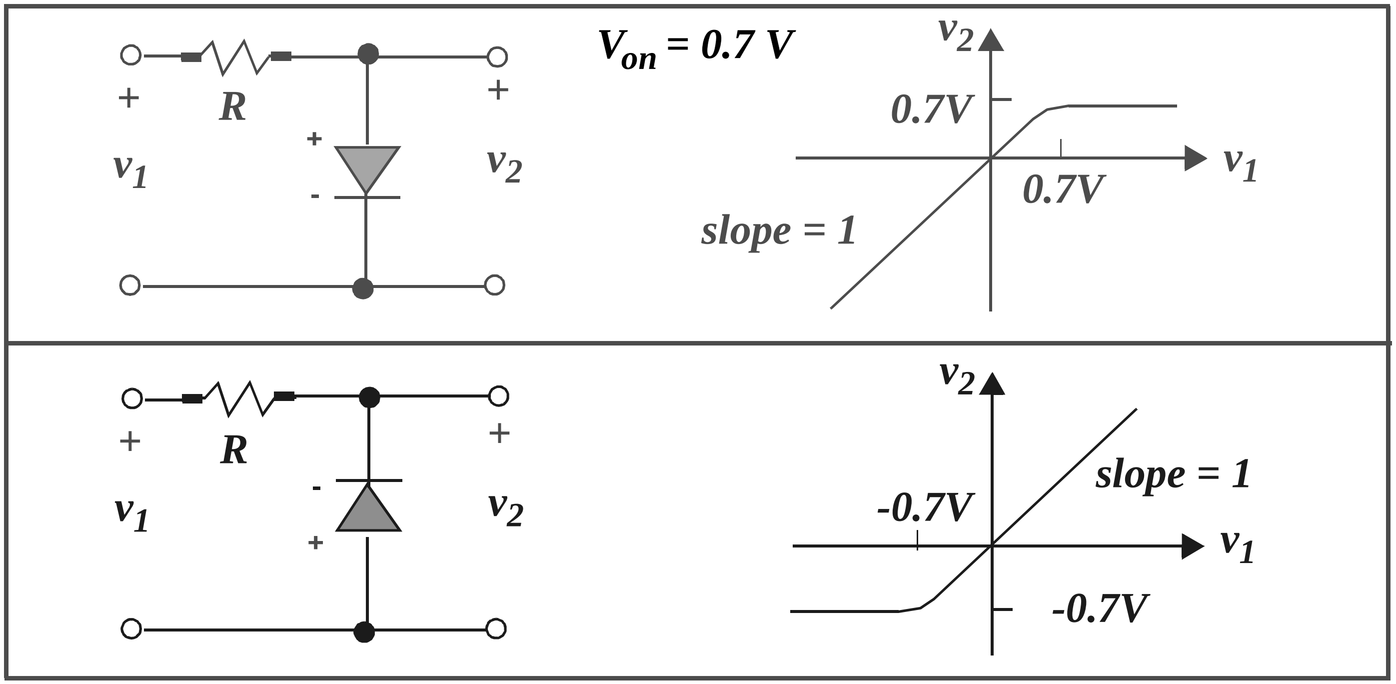
$$V_1' = V_L' + \left(I_L + \frac{V_L' - V_Z}{R_Z}\right) \cdot R_S = V_L' + \left(0.05 + \frac{V_L' - 100}{20}\right) 200$$

$$V_L' = (123.42 + 1000 - 10)/11 = 101.22V \Rightarrow 1\% \ \ change \ \ V_L$$

.Limiter or Clipper Circuits

Used in signal processing circuits; Limits voltage between IPs of Op-Amp.

Provides $v_{out} \propto v_{in}$ up to a certain value(s), beyond which voltage is clipped off.

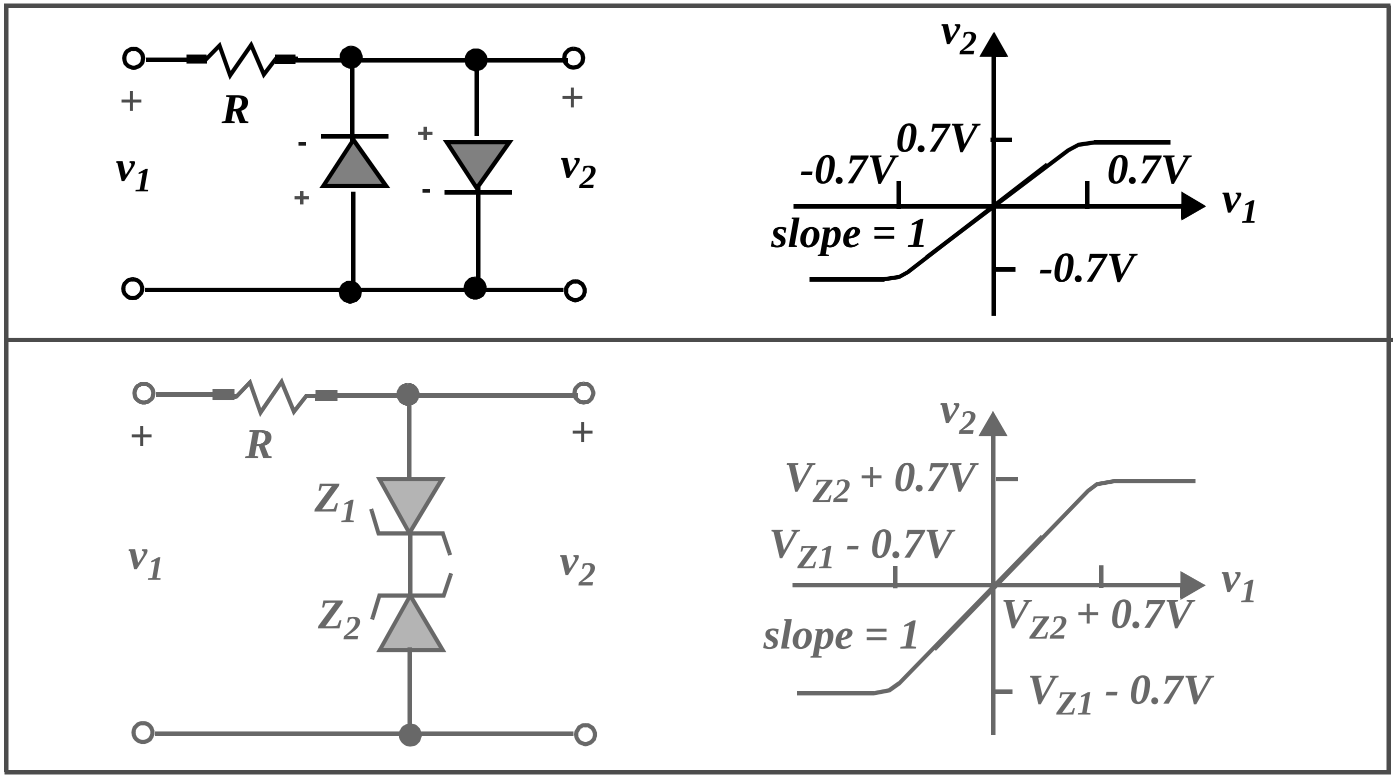


Limiter or Clipper Circuits

Used in signal processing circuits;

Limits voltage between two inputs of Op-Amp.

Provides $v_{out} \propto v_{in}$ up to a certain value(s), beyond which voltage is clipped off.

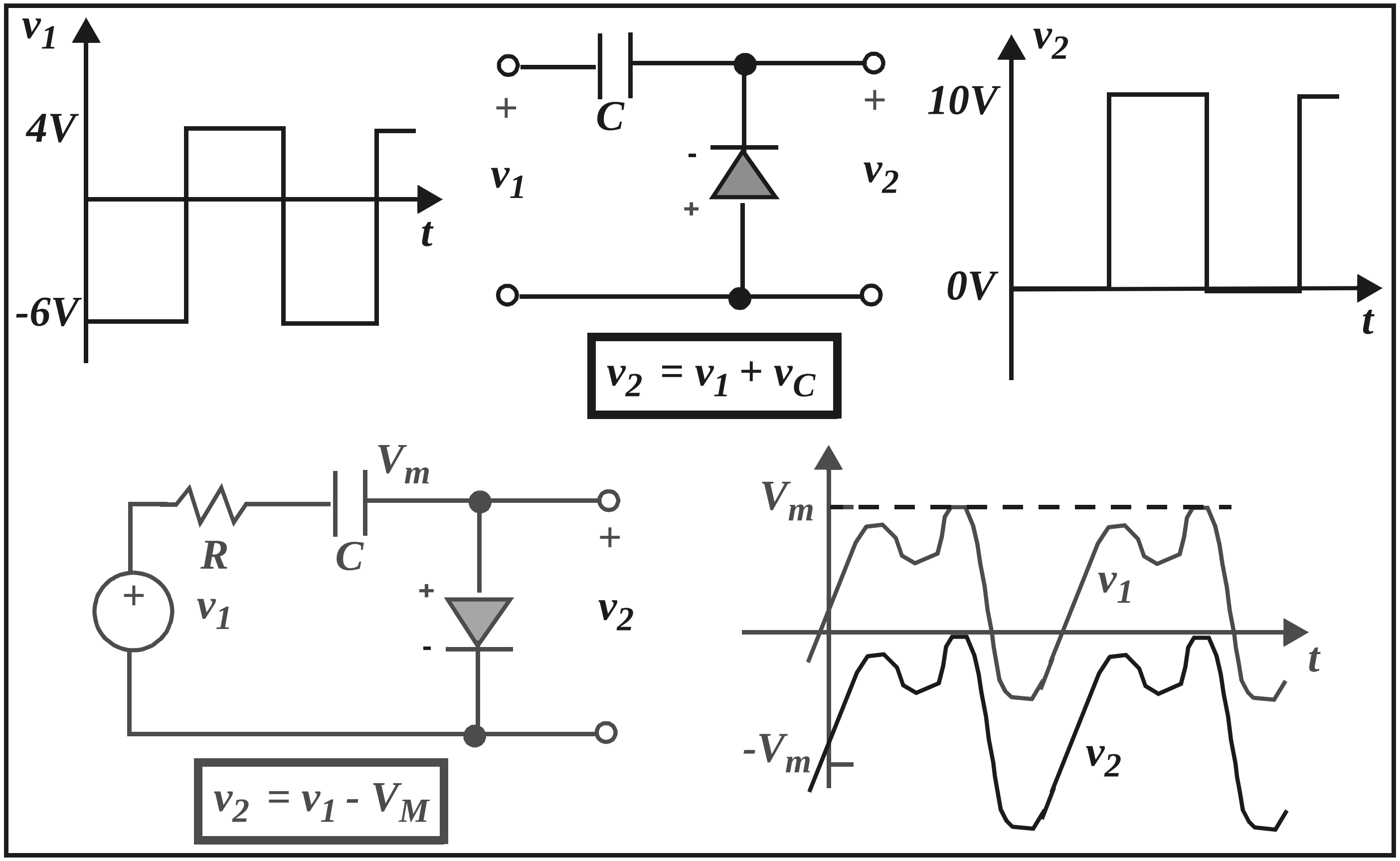


Clamping Circuits

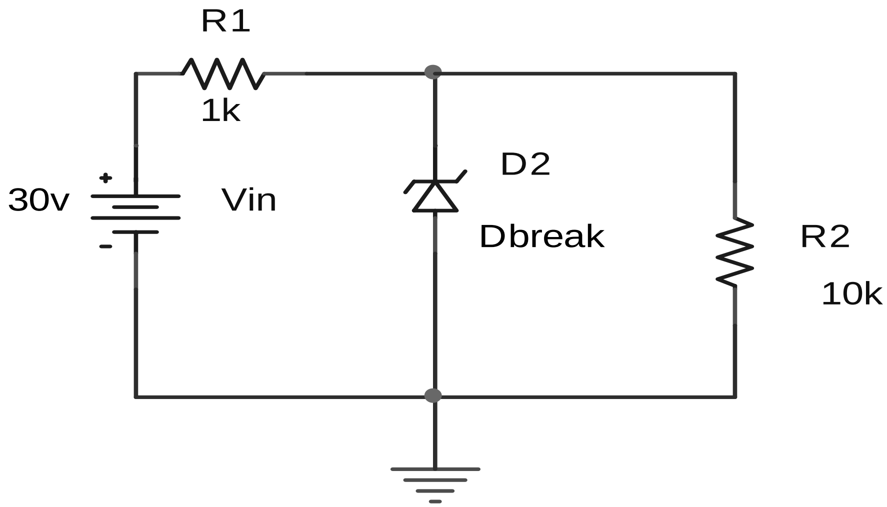
In TV receivers, peak values of certain signals must be held clamped to pre-determined levels

Provides $v_{out} \propto v_{in}$ but clamps v_{out} to a certain value.

In clamping, the variable component of v_{in} is transmitted and the dc value is restored.



PSPICE EXAMPLE




```
*Libraries:
* Local Libraries :
.LIB ".\example5.lib"
* From [PSPICE NETLIST] section of C:\Program Files\OrcadLite\PSpice\PSpice.ini file:
.lib "nom.lib"
*Analysis directives:
.OP
.PROBE V(*) I(*) W(*) D(*) NOISE(*)
.INC ".\example5-SCHEMATIC1.net"
**** INCLUDING example5-SCHEMATIC1.net ****
* source EXAMPLE5
R_R1         N00125 N00047  1k
D_D2         0 N00047 Dbreak
```

PSPICE EXAMPLE (Cont'd)

```
V_Vin         N00125 0 30v
R_R2          0 N00047  10k

**** RESUMING example5-SCHEMATIC1-Example5Profile.sim.cir ****
.END
 ****     Diode MODEL PARAMETERS
Dbreak
IS   10.000000E-15
BV   20
IBV   10.000000E-09
CJO  100.000000E-15

 ****     SMALL SIGNAL BIAS SOLUTION       TEMPERATURE =   27.000 DEG C
******************************************************************************
NODE   VOLTAGE     NODE   VOLTAGE     NODE   VOLTAGE     NODE   VOLTAGE

(N00047)   20.3500 (N00125)   30.0000
```