EE 456

Buck-Boost Regulator Design
Continuous Mode Operation

Specify Input Voltage $V_D := 15 \cdot volt$

Specify Output Voltage $V_o := -20 \cdot volt$

Specify Switching Frequency $F_S := 20 \cdot kHz$

$\mu s \equiv 10^{-6} \cdot sec$

$$T_S := \frac{1}{F_S} \qquad T_S = 50 \cdot \mu s$$

Specify the Assumed Efficiency $Eff := 90\ \%$

Specify the Max output Current

The output Power is $P_{out} := \frac{50 \cdot watt}{Eff}$

The output current is $I_o := \left| \frac{P_{out}}{V_o} \right|$ $I_o = 2.778 \cdot amp$

Find Ton and Toff

$T_{off} := 1 \cdot \mu s$ $T_{on} := 1 \cdot \mu s$

Given

$$-V_o = V_D \cdot \left(\frac{T_{on}}{T_S - T_{on}} \right)$$

$T_{on} := find(T_{on})$

$T_{on} = 28.571 \cdot \mu s$

Find the range of Inductors that will operate in discontinuous mode

Specify the minimum current we want the supply to operate in the continuous mode

$$I_{min} := \frac{I_o}{10}$$

$$D := \frac{T_{on}}{T_S}$$

$$L := \frac{V_D \cdot T_{on}}{2 \cdot I_{min}} \cdot (1 - D)$$

For Continuous Mode, We need L greater than $L = 330.612 \cdot \mu H$

Choose the Inductor $L := 560 \cdot \mu H$ Coilcraft PCV-2-564-08

Find the Min and max inductor currents

$I_1 := 1 \cdot amp$ $I_2 := 1 \cdot amp$

Given

$$\frac{I_1 + I_2}{2} = \frac{I_o}{1 - D}$$

$$I_1 - I_2 = V_D \cdot \frac{T_{on}}{L}$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} := \text{Find}(I_1, I_2)$$ $I_1 = 6.864 \cdot amp$ $I_2 = 6.099 \cdot amp$

Now choose the capacitor

Energy dissipated per cycle $E_o := |V_o| \cdot I_o \cdot T_S$ $E_o = 2.778 \cdot 10^{-3} \cdot joule$

Specify the ripple desired. $V_{CR} := 60 \cdot mV$

Initial Guess $C := 1000 \cdot \mu F$

Given

$$\frac{1}{2} \cdot C \cdot (|V_o| + V_{CR})^2 - \frac{1}{2} \cdot C \cdot (|V_o|)^2 = E_o$$

$C := \text{find}(C)$

$C = 2.311 \cdot 10^{3} \cdot \mu F$

Choose the next standard value $C := 10000 \cdot \mu F$

Calculate the ripple with the chosen capacitor.

Given

$$\frac{1}{2} \cdot C \cdot \left(\left| V_o \right| + V_{CR} \right)^2 - \frac{1}{2} \cdot C \cdot \left(\left| V_o \right| \right)^2 = E_o$$

$V_{CR} := \text{find}\left(V_{CR}\right)$ $V_{CR} = 13.884 \cdot mV$

Choose the filter capacitor using the capacitor ESR.

Assume that the major component of the ripple comes from the capacitor ESR

Specify the ripple due to the ESR $V_{CR} := 60 \cdot mV$

$$ESR := \frac{V_{CR}}{\left(I_1\right)} \qquad ESR = 8.741 \cdot 10^{-3} \cdot \Omega$$

For all electrolytic caps, assume that ESR*C=80ms

$$C := \frac{80 \cdot \mu s}{ESR} \qquad C = 9152.17939 \cdot \mu F$$

Choose the next size std capacitor $C := 10000 \cdot \mu F$

Calculate the Capacitor RMS Ripple Current

$$I_x := \frac{I_1 + I_2}{2} \qquad I_x = 6.481 \cdot amp$$

Use came cap as boost converter.

$$I_{rms} := \sqrt{\frac{1}{T_S} \cdot \left[\int_{0 \cdot sec}^{T_{on}} I_o^2 \, dt + \int_{T_{on}}^{T_S} \left(I_o - I_x \right)^2 dt \right]}$$

$I_{rms} = 3.208 \cdot amp$

Summary

$L = 560 \cdot \mu H$ $I_2 = 6.099 \cdot amp$

$T_{on} = 28.571 \cdot \mu s$ $T_{off} = 1 \cdot \mu s$

$V_D = 15 \cdot volt$ $V_o = -20 \cdot volt$ $I_o = 2.778 \cdot amp$

$C = 1 \cdot 10^4 \cdot \mu F$ $V_{CR} = 60 \cdot mV$

Average Inductor Current $\frac{I_1 + I_2}{2} = 6.481 \cdot amp$

EE 456

Buck-Boost Regulator Design
Continuous Mode Operation

Specify Input Voltage $V_D := 12 \cdot volt$ Specify Output Voltage $V_o := -20 \cdot volt$

Specify Switching Frequency $F_S := 20 \cdot kHz$ $\mu s \equiv 10^{-6} \cdot sec$

$$T_S := \frac{1}{F_S} \qquad T_S = 50 \cdot \mu s$$

Specify the Assumed Efficiency $Eff := 90\ \%$

Specify the Max output Current

The output Power is $$P_{out} := \frac{50 \cdot watt}{Eff}$$

The output current is $$I_o := \left| \frac{P_{out}}{V_o} \right| \qquad I_o = 2.778 \cdot amp$$

Find Ton and Toff

$T_{off} := 1 \cdot \mu s$ $T_{on} := 1 \cdot \mu s$

Given

$$-V_o = V_D \cdot \left(\frac{T_{on}}{T_S - T_{on}} \right)$$

$$T_{on} := find(T_{on})$$

$T_{on} = 31.25 \cdot \mu s$

Find the range of Inductors that will operate in discontinuous mode

Specify the minimum current we want the supply to operate in the continuous mode

$$I_{min} := \frac{I_o}{10}$$

$$D := \frac{T_{on}}{T_S}$$

$$L := \frac{V_D \cdot T_{on}}{2 \cdot I_{min}} \cdot (1 - D)$$

For Continuous Mode, We need L greater than $L = 253.125 \cdot \mu H$

Choose the Inductor $L := 560 \cdot \mu H$ Coilcraft PCV-2-564-08

Find the Min and max inductor currents

$I_1 := 1 \cdot amp$ $I_2 := 1 \cdot amp$

Given

$$\frac{I_1 + I_2}{2} = \frac{I_o}{1 - D}$$

$$I_1 - I_2 = V_D \cdot \frac{T_{on}}{L}$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} := \text{Find}(I_1, I_2)$$ $I_1 = 7.742 \cdot amp$ $I_2 = 7.073 \cdot amp$

Now choose the capacitor

Energy dissipated per cycle $E_o := |V_o| \cdot I_o \cdot T_S$ $E_o = 2.778 \cdot 10^{-3} \cdot joule$

Specify the ripple desired. $V_{CR} := 60 \cdot mV$

Initial Guess $C := 1000 \cdot \mu F$

Given

$$\frac{1}{2} \cdot C \cdot (|V_o| + V_{CR})^2 - \frac{1}{2} \cdot C \cdot (|V_o|)^2 = E_o$$

$C := \text{find}(C)$

$C = 2.311 \cdot 10^{3} \cdot \mu F$

Choose the next standard value $C := 10000 \cdot \mu F$

Calculate the ripple with the chosen capacitor.

Given

$$\frac{1}{2} \cdot C \cdot \left(\left| V_o \right| + V_{CR} \right)^2 - \frac{1}{2} \cdot C \cdot \left(\left| V_o \right| \right)^2 = E_o$$

$V_{CR} := \text{find}\left(V_{CR}\right)$ $V_{CR} = 13.884 \cdot mV$

Choose the filter capacitor using the capacitor ESR.

Assume that the major component of the ripple comes from the capacitor ESR

Specify the ripple due to the ESR $V_{CR} := 60 \cdot mV$

$$ESR := \frac{V_{CR}}{\left(I_1\right)} \qquad ESR = 7.75 \cdot 10^{-3} \cdot \Omega$$

For all electrolytic caps, assume that ESR*C=80ms

$$C := \frac{80 \cdot \mu s}{ESR} \qquad C = 10322.97178 \cdot \mu F$$

Choose the next size std capacitor $C := 10000 \cdot \mu F$

Calculate the Capacitor RMS Ripple Current

$$I_x := \frac{I_1 + I_2}{2} \qquad I_x = 7.407 \cdot amp$$

Use came cap as boost converter.

$$I_{rms} := \sqrt{\frac{1}{T_S} \cdot \left[\int_{0 \cdot sec}^{T_{on}} I_o^2 \, dt + \int_{T_{on}}^{T_S} \left(I_o - I_x \right)^2 dt \right]}$$

$I_{rms} = 3.586 \cdot amp$

Summary

$L = 560 \cdot \mu H$ $I_2 = 7.073 \cdot amp$

$T_{on} = 31.25 \cdot \mu s$ $T_{off} = 1 \cdot \mu s$

$V_D = 12 \cdot volt$ $V_o = -20 \cdot volt$ $I_o = 2.778 \cdot amp$

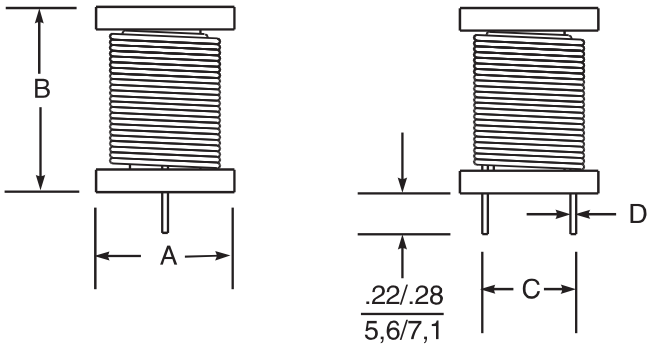
$C = 1 \cdot 10^4 \cdot \mu F$ $V_{CR} = 60 \cdot mV$

Average Inductor Current $\frac{I_1 + I_2}{2} = 7.407 \cdot amp$

Power Chokes – Vertical Mount

The PCV-2 Series uses a ferrite bobbin core to provide the highest possible inductance at the lowest cost. It features 130°C class insulation and comes in a wide range of standard values.

Coilcraft **Designer's Kit P205** contains samples of the parts shown in bold as well as values from our PCV-0 Series. To order, contact Coilcraft.



Part Number	Inductance[1] ±10% (μH)	Current Rating[2] (Amps)	DCR Max (Ω)	A Max	B Max	C ±.015/0,38	D ±.004/0,10
PCV-2-103-05	10	5	.015	.61/15,49	.83/21,08	.42/10,67	.042/1,07
PCV-2-103-10	10	10	.010	.61/15,49	.83/21,08	.50/12,70	.054/1,37
PCV-2-223-05	22	5	.020	.61/15,49	.83/21,08	.42/10,67	.042/1,07
PCV-2-223-10	22	10	.015	.86/21,84	.83/21,08	.58/14,73	.054/1,37
PCV-2-473-05	47	5	.035	.70/17,78	.83/21,08	.48/12,19	.038/0,97
PCV-2-473-10	47	10	.020	1.00/25,40	.83/21,08	.70/17,78	.054/1,37
PCV-2-104-03	100	3	.080	.84/21,34	.83/21,08	.58/14,73	.031/0,79
PCV-2-104-05	100	5	.045	.84/21,34	.83/21,08	.70/17,78	.042/1,07
PCV-2-104-10	**100**	**10**	**.032**	**1.05/26,67**	**1.10/27,94**	**.88/22,35**	**.054/1,37**
PCV-2-184-05	180	5	.092	.80/20,32	.90/22,86	.58/14,73	.035/0,89
PCV-2-184-10	180	10	.048	1.44/36,58	1.10/27,94	1.05/26,67	.054/1,37
PCV-2-224-05	220	5	.075	1.05/26,67	1.10/27,94	.75/19,05	.042/1,07
PCV-2-274-03	**270**	**3**	**.13**	**1.00/25,40**	**.83/21,08**	**.75/19,05**	**.035/0,89**
PCV-2-274-05	**270**	**5**	**.080**	**1.05/26,67**	**1.05/26,67**	**.80/20,32**	**.042/1,07**
PCV-2-274-10	**270**	**10**	**.060**	**1.50/38,10**	**1.10/27,94**	**1.08/27,43**	**.054/1,37**
PCV-2-394-05	390	5	.13	1.10/29,34	.83/21,08	.85/21,59	.038/0,97
PCV-2-564-02	560	2	.27	.80/20,32	.90/22,86	.57/14,48	.028/0,71
PCV-2-564-06	560	6	.17	1.21/30,73	1.10/27,94	.90/22,86	.038/0,97
PCV-2-564-08	560	8	.090	1.50/38,10	1.43/36,32	1.08/27,43	.054/1,37
PCV-2-684-01	680	1	.70	.70/17,78	.83/21,08	.50/12,70	.018/0,46
PCV-2-105-02	1000	2	.37	1.00/25,40	.83/21,08	.72/18,29	.028/0,71

[1] Tested at 15.75 kHz, .1 Vrms, with DC bias applied up to the rated current.

[2] Parts are designed for 40°C Max temperature rise at the rated current.

Parts in bold type are included in Coilcraft Designer's Kit No. P205.

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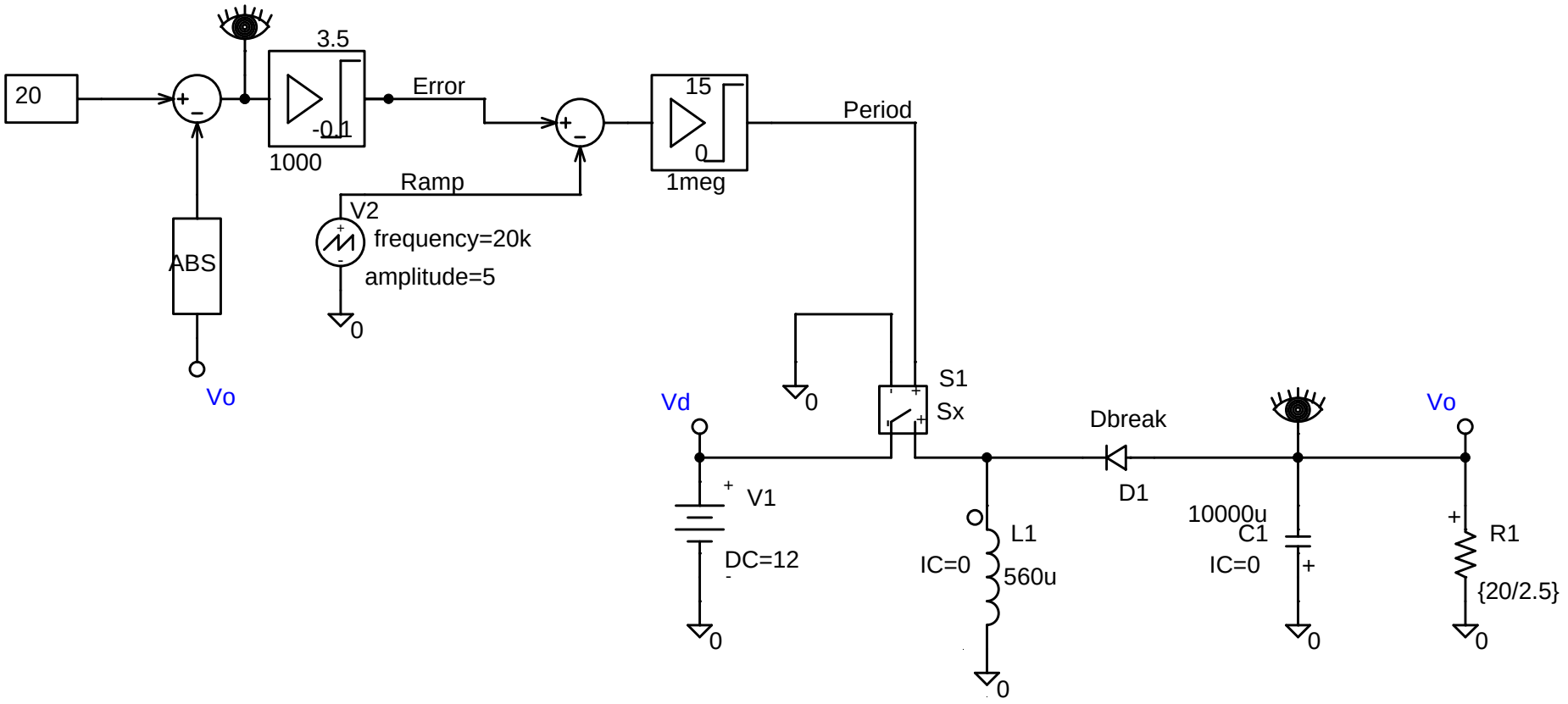
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S1
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Dbreak
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D1
10000u
C1
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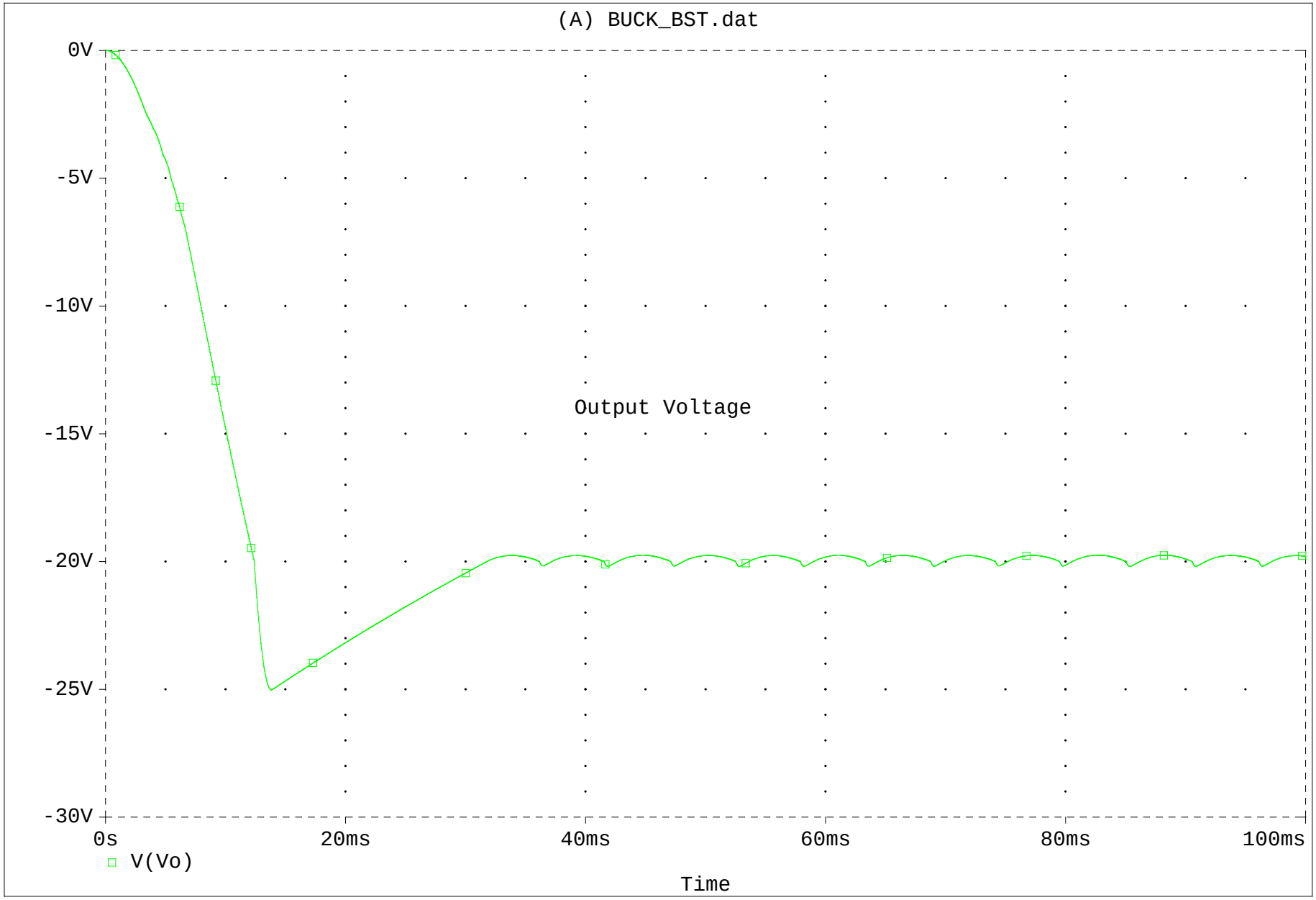
Date/Time run: 10/30/100 14:18:42 Temperature: 27.0



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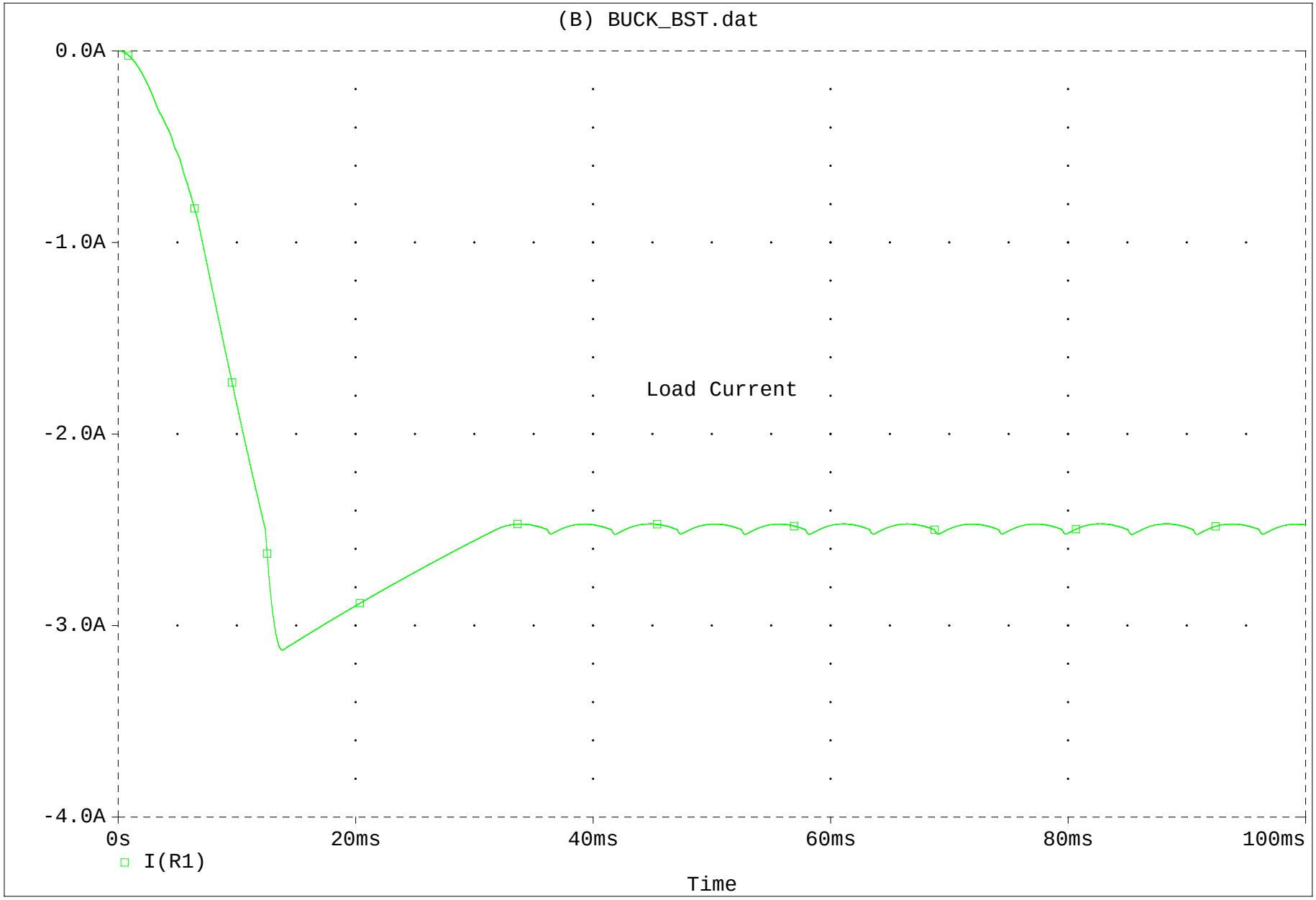

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