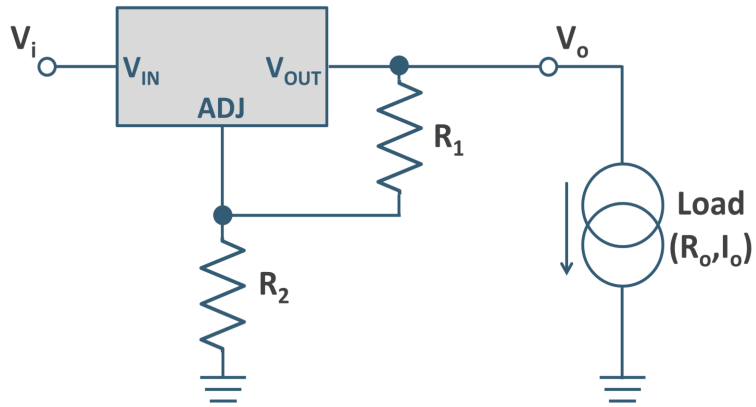
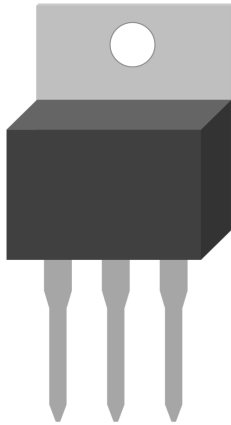


Worst Case Analysis - Three-Pin Regulator

In this application, the worst case analysis for a circuit with Three-pin regulator is performed. Extreme value analysis and Sensitivity analysis are used for the circuit.



1. Equation of Output voltage

The output voltage is calculated with the following equation.

$$Eq_{v_{out}} := V_o = (V_{ref} - (I_o \cdot R_o)) \cdot \left(1 + \frac{R_2}{R_1} \right) + I_{adj} \cdot R_2$$

2. Create the parameter list

Define the conditions of parameters.

Parameters	Par := [R ₁ , R ₂ , V _{ref} , I _{adj} , R _o , I _o]
Nomical value	Nom := [243, 715, 1.25, 50·10 ⁻⁶ , 0.007, 0.6]
Tolerance	Tol := [1.24, 1.24, 4.00, 25, 100, 100]

List of parameters based on tolerance

$$PList := \left[\text{seq} \left(\text{Nom} + \sim \text{Nom} \cdot \sim \text{Tol} \cdot \sim \left(\text{Bits} : - \text{Split} (i, \text{bits} = \text{nops}(\text{Nom})) \cdot 2 - \sim 1 \right) \cdot 0.01, \right. \right. \\ \left. \left. i = 1 .. \text{nops}(\text{Nom})^2 \right) \right]$$

3. Sensitivity analysis

The sensitivity of each parameter can be obtained with the following equations.

$$\text{Sensitivity} := \left[\text{seq} \left(\text{cat} \left(d_{\text{Par}}[i] \right) = \text{diff} \left(\text{rhs} \left(\text{Eq}_{\text{vout}} \right), \text{Par}[i] \right), i = 1 \dots \text{nops}(\text{Par}) \right) \right]$$

Thus, the sensitivity of each parameter is shown below:

$$\text{Sensitivity}[1] = d_{R_1} = -\frac{(-I_o \cdot R_o + V_{\text{ref}}) \cdot R_2}{R_1^2}$$

$$\text{eval}(\text{Sensitivity}[1], [\text{seq}(\text{Par}[i] = \text{Nom}[i], i = 1 \dots \text{nops}(\text{Par}))]) = d_{R_1} = -0.015$$

$$\text{Sensitivity}[2] = d_{R_2} = \frac{-I_o \cdot R_o + V_{\text{ref}}}{R_1} + I_{\text{adj}}$$

$$\text{eval}(\text{Sensitivity}[2], [\text{seq}(\text{Par}[i] = \text{Nom}[i], i = 1 \dots \text{nops}(\text{Par}))]) = d_{R_2} = 0.005$$

$$\text{Sensitivity}[3] = d_{V_{\text{ref}}} = 1 + \frac{R_2}{R_1}$$

$$\text{eval}(\text{Sensitivity}[3], [\text{seq}(\text{Par}[i] = \text{Nom}[i], i = 1 \dots \text{nops}(\text{Par}))]) = d_{V_{\text{ref}}} = 3.942$$

$$\text{Sensitivity}[4] = d_{I_{\text{adj}}} = R_2$$

$$\text{eval}(\text{Sensitivity}[4], [\text{seq}(\text{Par}[i] = \text{Nom}[i], i = 1 \dots \text{nops}(\text{Par}))]) = d_{I_{\text{adj}}} = 715$$

$$\text{Sensitivity}[5] = d_{R_o} = -I_o \cdot \left(1 + \frac{R_2}{R_1} \right)$$

$$\text{eval}(\text{Sensitivity}[5], [\text{seq}(\text{Par}[i] = \text{Nom}[i], i = 1 \dots \text{nops}(\text{Par}))]) = d_{R_o} = -2.365$$

$$\text{Sensitivity}[6] = d_{I_o} = -R_o \cdot \left(1 + \frac{R_2}{R_1} \right)$$

$$\text{eval}(\text{Sensitivity}[6], [\text{seq}(\text{Par}[i] = \text{Nom}[i], i = 1 \dots \text{nops}(\text{Par}))]) = d_{I_o} = -0.028$$

4. Extreme Value analysis

Calculate the output voltage with all patterns of parameter values.

$$\text{Res} := \left[\text{seq} \left(\text{eval} \left(\text{rhs} \left(\text{Eq}_{\text{vout}} \right), \left[\text{seq} \left(\text{Par}[i] = \text{PList}[j][i], i = 1 \dots \text{nops}(\text{Par}) \right) \right], j = 1 \dots \text{nops}(\text{PList}) \right) \right]$$

Search max/min value and the position of parameter values in the list.

$$\text{maxvalue}, \text{maxpos} := \text{ListTools}:-\text{FindMaximalElement}(\text{Res}, \text{position})$$

$$\text{minvalue}, \text{minpos} := \text{ListTools}:-\text{FindMinimalElement}(\text{Res}, \text{position})$$

$$\text{nomvalue} := \text{eval} \left(\text{rhs} \left(\text{Eq}_{\text{vout}} \right), \left[\text{seq} \left(\text{Par}[i] = \text{Nom}[i], i = 1 \dots \text{nops}(\text{Par}) \right) \right] \right)$$

Organize results

$$\text{MaxPattern} := \text{seq} \left(\text{Par}[i] = \text{PList}[\text{maxpos}][i], i = 1 \dots \text{nops}(\text{Par}) \right)$$

$$\text{NomPattern} := \text{seq} \left(\text{Par}[i] = \text{Nom}[i], i = 1 \dots \text{nops}(\text{Par}) \right)$$

$$\text{MinPattern} := \text{seq} \left(\text{Par}[i] = \text{PList}[\text{minpos}][i], i = 1 \dots \text{nops}(\text{Par}) \right)$$

Final result of Maximum/Nominal/Minimum

Nominal

$$\text{nomvalue} = 4.947$$

$$\text{NomPattern} = R_1 = 243, R_2 = 715, V_{\text{ref}} = 1.250, I_{\text{adj}} = 5.000 \times 10^{-5}, R_o = 0.007, I_o = 0.600$$

Maximum

$$\text{maxvalue} = 5.266$$

$$\text{MaxPattern} = R_1 = 239.987, R_2 = 723.866, V_{\text{ref}} = 1.300, I_{\text{adj}} = 6.250 \times 10^{-5}, R_o = 0., I_o = 0.$$

Minimum

$$\text{minvalue} = 4.671$$

$$\text{MinPattern} = R_1 = 246.013, R_2 = 706.134, V_{\text{ref}} = 1.200, I_{\text{adj}} = 3.750 \times 10^{-5}, R_o = 0., I_o = 0.$$