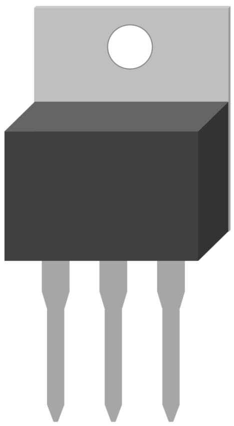
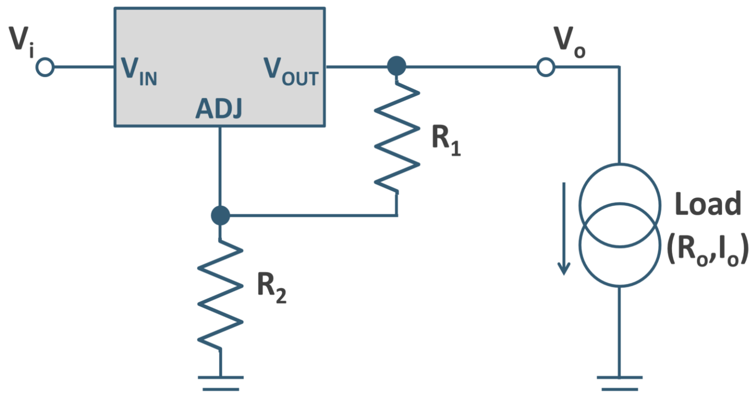
Worst Case Analysis - Three-Pin Regulator

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.

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

2. Create the parameter list

Define the conditions of parameters.

Parameters $\qquad Par := \left[R_1, R_2, V_{ref}, I_{adj}, R_o, I_o\right]$

Nominal value $\qquad Nom := \left[243, 715, 1.25, 50 \cdot 10^{-6}, 0.007, 0.6\right]$

Tolerance $\qquad Tol := \left[1.24, 1.24, 4.00, 25, 100, 100\right]$

List of parameters based on tolerance

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

3. Sensitivity analysis

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

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

Thus, the sensitivity of each parameter is shown below:

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

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

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

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

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

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

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

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

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

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

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

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

4. Extreme Value analysis

Calculate the output voltage with all patterns of parameter values.

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

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

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

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

$$nomvalue := eval\left(rhs\left(Eq_{vout} \right), \left[seq(Par[i] = Nom[i], i = 1 ..nops(Par)) \right] \right)$$

Organize results

$$MaxPattern := seq(Par[i] = PList[maxpos][i], i = 1 ..nops(Par))$$

$$NomPattern := seq(Par[i] = Nom[i], i = 1 ..nops(Par))$$

$$MinPattern := seq(Par[i] = PList[minpos][i], i = 1 ..nops(Par))$$

Final result of Maximum/Nominal/Minimum

Nominal

$nomvalue = 4.947$

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

Maximum

$maxvalue = 5.266$

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

Minimum

$minvalue = 4.671$

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