OUTPUT CURRENT TELEMETRY CIRCUIT

Specifications: The output current telemetry circuit will supply a voltage between 0V and 2.55V for EPC DC output current between 0A and 9A. The true maximum secondary current in this curcuit is 9 amperes.

The output current telemetry will be "calibrated" over temperature and BOL tolerances by a calibration curve generated for each unit. Therefore, the BOL and temperature (Temp) component tolerances can be removed from the analysis.

Tolerances and specs:

NOTE: Calibration removes the BOL and temperature (Temp) effects (not thermal drift, TC) in each of the following components.

M55342 Resistors:

Tolerance = 0.1% (BOL) +0.6% (TC over -34 to 61 Deg C) + 0.89% (AGE) = 0.89% (EOL, only)

TC = 0.01%/Deg C for Characteristic K material $TC := 0.0001 \cdot 60$ $TC = 0.6 \cdot \%$

$TOL\_M55342 := 0.0089$ $NTOL := 1 - TOL\_M55342$ $PTOL := 1 + TOL\_M55342$

$R13 := 100 \cdot k\Omega$ $R13\_min := R13 \cdot NTOL$ $R13\_max := R13 \cdot PTOL$

$R12 := 1.00 \cdot k\Omega$ $R12\_min := R12 \cdot NTOL$ $R12\_max := R12 \cdot PTOL$

$R9 := 1.00 \cdot k\Omega$ $R9\_min := R9 \cdot NTOL$ $R9\_max := R9 \cdot PTOL$

$R10 := 100 \cdot k\Omega$ $R10\_min := R10 \cdot NTOL$ $R10\_max := R10 \cdot PTOL$

Shunt Resistor, R1 (similar to RWR81 Resistors):

Tolerance = 1.0% (BOL) + 0.0100%/C (-35C to 71C) (TC) + 1.0% (EOL) = 1% (EOL, only)

$TOL\_RWR81 := 0.01$ $NTOL := 1 - TOL\_RWR81$ $PTOL := 1 + TOL\_RWR81$

$R1 := 0.0025\Omega$ $R1\_min := R1 \cdot NTOL$ $R1\_max := R1 \cdot PTOL$

$R1 = 2.5 \cdot m\Omega$ $R1\_min = 2.475 \cdot m\Omega$ $R1\_max = 2.525 \cdot m\Omega$

OP-27A (Applied voltage: 12V max.): [Only EOL & RAD factors will apply due to calibration.]

INPUT/OFFSET VOLTAGE, Vos = 60uV (BOL+TC) + 60uV (EOL) + 103uV (100Krad) = 103uV: (EOL, only)

$V_{Vos} := 103 \cdot \mu V$ $Ios\_eol := 0.25 \cdot 35 \eta A$ $V_{Vos} = 103 \cdot \mu V$

INPUT/OFFSET CURRENT, Ios = 35nA (BOL+TC) + 8.75nA (EOL) + 60nA (100Krad) = 69nA: (EOL, only)

$I_{os} := 69 \cdot \eta A$ $I_{os} = 69 \cdot \eta A$

This creates an offset voltage of:

$V_{Ios} := R12 \cdot I_{os}$ $V_{Ios} = 69 \cdot \mu V$

TOTAL INPUT/OFFSET VOLTAGE, Vos (EOL+150Krad):

$Vos := V_{Vos} + V_{Ios}$ $Vos = 172 \cdot \mu V$

CALCULATE THE END-OF-LIFE TELEMETRY TOLERANCE:

Extreme Values Method of Computation:

$Iout := 9.00A$ (maximum dc output current)

$R1\_min = 2.475\cdot m\Omega$ $R9\_max = 1.0089\cdot k\Omega$ $R10\_min = 99.11\cdot k\Omega$

$$VOUT\_min := \left(Iout\cdot R1\_min\cdot\frac{R10\_min}{R9\_max + R10\_min} - Vos\right)\cdot\left(1 + \frac{R13\_min}{R12\_max}\right)$$

$VOUT\_min = 2.1711\cdot V$

$$VOUT := \left(Iout\cdot R1\cdot\frac{R10}{R9 + R10}\right)\cdot\left(1 + \frac{R13}{R12}\right)$$

$VOUT = 2.25\cdot V$

$$VOUT\_max := \left(Iout\cdot R1\_max\cdot\frac{R10\_max}{R9\_min + R10\_max} + Vos\right)\cdot\left(1 + \frac{R13\_max}{R12\_min}\right)$$

$VOUT\_max = 2.331\cdot V$

$$TOL\_min := \frac{|VOUT\_min - VOUT|}{VOUT}$$ $TOL\_min = 3.5053\cdot\%$

$$TOL\_max := \frac{|VOUT\_max - VOUT|}{VOUT}$$ $TOL\_max = 3.5998\cdot\%$

Select the largest tolerence of the two:

$i := 0, 1 .. 1$

$$TOL_i := \begin{bmatrix} TOL\_min \\ TOL\_max \end{bmatrix}$$

$TOL\_max := \max(TOL)$

$TOL\_max = 3.5998\cdot\%$ <=== Extreme. Values (EOL & RAD)

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Summary:

EXTREME VLAUES METHOD

$VOUT\_min = 2.1711\cdot V$ $VOUT = 2.25\cdot V$ $VOUT\_max = 2.331\cdot V$

$TOL\_max = 3.5998\cdot\%$

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Breakdown of individual errors, for Extreme Value RSS calculation:

Error due to M55342 resistors:

$$VOUT\_min\_M55342 := \left(Iout \cdot R1 \cdot \frac{R10\_min}{R9\_max + R10\_min}\right) \cdot \left(1 + \frac{R13\_min}{R12\_max}\right)$$

$$VOUT\_min\_M55342 = 2.2103 \cdot V$$

$$VOUT\_max\_M55342 := \left(Iout \cdot R1 \cdot \frac{R10\_max}{R9\_min + R10\_max}\right) \cdot \left(1 + \frac{R13\_max}{R12\_min}\right)$$

$$VOUT\_max\_M55342 = 2.2904 \cdot V$$

$$TOL\_min\_M55342 := \frac{|VOUT\_min\_M55342 - VOUT|}{VOUT}$$

$$TOL\_min\_M55342 = 1.7643 \cdot \%$$

$$TOL\_max\_M55342 := \frac{|VOUT\_max\_M55342 - VOUT|}{VOUT}$$

$$TOL\_max\_M55342 = 1.796 \cdot \%$$

$$VOUT\_min\_Vos := \left(Iout \cdot R1 \cdot \frac{R10}{R9 + R10} - Vos\right) \cdot \left(1 + \frac{R13}{R12}\right)$$

$$VOUT\_min\_Vos = 2.2326 \cdot V$$

$$VOUT\_max\_Vos := \left(Iout \cdot R1 \cdot \frac{R10}{R9 + R10} + Vos\right) \cdot \left(1 + \frac{R13}{R12}\right)$$

$$VOUT\_max = 2.331 \cdot V$$

$$TOL\_min\_Vos := \frac{|VOUT\_min\_Vos - VOUT|}{VOUT}$$

$$TOL\_min\_Vos = 0.7721 \cdot \%$$

$$TOL\_max\_Vos := \frac{|VOUT\_max\_Vos - VOUT|}{VOUT}$$

$$TOL\_max\_Vos = 0.7721 \cdot \%$$

$$VOUT\_min\_R1 := \left(Iout \cdot R1\_min \cdot \frac{R10}{R9 + R10}\right) \cdot \left(1 + \frac{R13}{R12}\right)$$

$$VOUT\_min\_R1 = 2.2275 \cdot V$$

$$VOUT\_max\_R1 := \left(Iout \cdot R1\_max \cdot \frac{R10}{R9 + R10}\right) \cdot \left(1 + \frac{R13}{R12}\right)$$

$$VOUT\_max\_R1 = 2.2725 \cdot V$$

$$TOL\_min\_R1 := \frac{|VOUT\_min\_R1 - VOUT|}{VOUT}$$

$$TOL\_min\_R1 = 1 \cdot \%$$

$$TOL\_max\_R1 := \frac{|VOUT\_max\_R1 - VOUT|}{VOUT}$$

$$TOL\_max\_R1 = 1 \cdot \%$$

Select the largest tolerence of the two:

$i := 0, 1 .. 1$

$$TOL_i := \begin{bmatrix} TOL\_min\_R1 \\ TOL\_max\_R1 \end{bmatrix}$$

$$TOL\_max\_R1 := \max(TOL)$$

$$TOL\_max\_R1 = 1 \cdot \%$$

This is no surprise as the shunt (R1) is a 1% resistor.

RSS of percent errors:

$$RSS := \sqrt{TOL\_max\_R1^2 + TOL\_max\_Vos^2 + TOL\_max\_M55342^2}$$

$RSS = 2.1958 \cdot \%$ <=== Extreme Values RSS Method (EOL & RAD)

Sensitivity Method of Error Computation:

The equation for Vo is given as:

$$VOUT = \left(Iout \cdot R1 \cdot \frac{R10}{R9 + R10} + Vos\right) \cdot \left(1 + \frac{R13}{R12}\right)$$

The change in Vo wrt each variable (component) of interest is given by:

$$Pct\_Vo_X = \frac{\left(\frac{\delta Vo}{\delta(X)}\right) \cdot \delta(X)}{Vo} = \frac{\frac{\delta Vo}{\delta(X)} \cdot X \cdot TOL\_X}{\left(Iout \cdot R1 \cdot \frac{R10}{R9 + R10} + Vos\right) \cdot \left(1 + \frac{R13}{R12}\right)}$$

Since we are interested in the effects of R13, R12, R9, R1, R10, and Vos on the output voltage (Vo) for a given input signal (Iout), we find:

R13:

$$\frac{\left(\frac{\delta Vo}{\delta(R13)}\right) \cdot \delta(R13)}{Vo} = \frac{\frac{\left[Iout \cdot R1 \cdot \frac{R10}{(R9 + R10)} + Vos\right]}{R12} \cdot R13 \cdot TOL\_M55342}{\left(Iout \cdot R1 \cdot \frac{R10}{R9 + R10} + Vos\right) \cdot \left(1 + \frac{R13}{R12}\right)}$$

$$Pct\_Vo_{R13} := R13 \cdot \frac{TOL\_M55342}{(R12 + R13)} \qquad Pct\_Vo_{R13} = 0.8812 \cdot \%$$

R12:

$$\frac{\left(\frac{\delta Vo}{\delta(R12)}\right) \cdot \delta(R12)}{Vo} = \frac{-\left[Iout \cdot R1 \cdot \frac{R10}{(R9 + R10)} + Vos\right] \cdot \frac{R13}{R12^2} \cdot R12 \cdot TOL\_M55342}{\left(Iout \cdot R1 \cdot \frac{R10}{R9 + R10} + Vos\right) \cdot \left(1 + \frac{R13}{R12}\right)}$$

$$Pct\_Vo_{R12} := -R13 \cdot \frac{TOL\_M55342}{(R12 + R13)} \qquad Pct\_Vo_{R12} = -0.8812 \cdot \%$$

R9:

$$\frac{\left(\frac{\delta Vo}{\delta(R9)}\right) \cdot \delta(R9)}{Vo} = \frac{-Iout \cdot R1 \cdot \frac{R10}{(R9 + R10)^2} \cdot \left(1 + \frac{R13}{R12}\right) \cdot R9 \cdot TOL\_M55342}{\left(Iout \cdot R1 \cdot \frac{R10}{R9 + R10} + Vos\right) \cdot \left(1 + \frac{R13}{R12}\right)}$$

$$Pct\_Vo_{R9} := -TOL\_M55342 \cdot R10 \cdot Iout \cdot R1 \cdot \frac{R9}{[(R9 + R10) \cdot (Iout \cdot R1 \cdot R10 + Vos \cdot R9 + Vos \cdot R10)]}$$

$$Pct\_Vo_{R9} = -8.7444 \times 10^{-3} \cdot \%$$

R1:

$$\frac{\left(\frac{\delta Vo}{\delta(R1)}\right)\cdot\delta(R1)}{Vo} = \frac{Iout\cdot\frac{R10}{(R9 + R10)}\cdot\left(1 + \frac{R13}{R12}\right)\cdot R1\cdot TOL\_RWR81}{\left(Iout\cdot R1\cdot\frac{R10}{R9 + R10} + Vos\right)\cdot\left(1 + \frac{R13}{R12}\right)}$$

$$Pct\_Vo_{R1} := TOL\_RWR81\cdot Iout\cdot R1\cdot\frac{R10}{(Iout\cdot R1\cdot R10 + Vos\cdot R9 + Vos\cdot R10)}$$

$$Pct\_Vo_{R1} = 0.9923\cdot\%$$

R10:

$$\frac{\left(\frac{\delta Vo}{\delta(R10)}\right)\cdot\delta(R10)}{Vo} = \frac{\left[Iout\cdot\frac{R1}{(R9 + R10)} - Iout\cdot R1\cdot\frac{R10}{(R9 + R10)^2}\right]\cdot\left(1 + \frac{R13}{R12}\right)\cdot R10\cdot TOL\_M55342}{\left(Iout\cdot R1\cdot\frac{R10}{R9 + R10} + Vos\right)\cdot\left(1 + \frac{R13}{R12}\right)}$$

$$Pct\_Vo_{R10} := TOL\_M55342\cdot R10\cdot Iout\cdot R1\cdot\frac{R9}{[(R9 + R10)\cdot(Iout\cdot R1\cdot R10 + Vos\cdot R9 + Vos\cdot R10)]}$$

$$Pct\_Vo_{R10} = 8.7444\times 10^{-3}\cdot\%$$

Vos:

$$\frac{\left(\frac{\delta Vo}{\delta(Vos)}\right)\cdot\delta(Vos)}{Vo} = \frac{\left(1 + \frac{R13}{R12}\right)\cdot Vos}{\left(Iout\cdot R1\cdot\frac{R10}{R9 + R10} + Vos\right)\cdot\left(1 + \frac{R13}{R12}\right)}$$

$$Pct\_Vo_{Vos} := Vos\cdot\frac{(R9 + R10)}{(Iout\cdot R1\cdot R10 + Vos\cdot R9 + Vos\cdot R10)}$$

$$Pct\_Vo_{Vos} = 0.7662\cdot\%$$

Straight Sum of Errors:

$$Pct\_Tot := \left|Pct\_Vo_{R13}\right| + \left|Pct\_Vo_{R12}\right| + \left|Pct\_Vo_{R9}\right| + \left|Pct\_Vo_{R1}\right| + \left|Pct\_Vo_{R10}\right| + \left|Pct\_Vo_{Vos}\right|$$

$$Pct\_Tot = 3.5384\cdot\%$$

<=== Straight (EOL & RAD)

RSS Sum of Errors:

$$Pct\_Tot_{RSS} := \sqrt{\left(\left|Pct\_Vo_{R13}\right|\right)^2 + \left(\left|Pct\_Vo_{R12}\right|\right)^2 + \left(\left|Pct\_Vo_{R9}\right|\right)^2 \ldots + \left(\left|Pct\_Vo_{R1}\right|\right)^2 + \left(\left|Pct\_Vo_{R10}\right|\right)^2 + \left(\left|Pct\_Vo_{Vos}\right|\right)^2}$$

$$Pct\_Tot_{RSS} = 1.7677\cdot\%$$

<=== RSS (EOL & RAD)