



Maxim > Design Support > Technical Documents > Application Notes > Automotive > APP 5271  
Maxim > Design Support > Technical Documents > Application Notes > Power-Supply Circuits > APP 5271

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## APPLICATION NOTE 5271

# Selecting External Components for an Automotive Dual Remote Antenna Current-Sense LDO/Switch

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*Abstract: This application note helps system designers choose the correct external components for use with the MAX16948 dual remote antenna LDO/switch, thus ensuring that automobile-regulated phantom antenna supply and output-current-monitoring circuitry meet performance objectives. An [electronic calculator](#) is provided that helps specify the critical external components for the MAX16948, thus reducing design time. The calculator also determines the device's analog output voltage, output current-limit threshold, and output current-sensing accuracies. The calculator includes new automatic **Step By Step** feature that assists designers with component choice. To use the new automatic feature, click on the **Step By Step** button relative to the desired section.*

## Introduction

The [MAX16948](#) is a dual high-voltage low dropout linear regulator (LDO)/switch with output-current sensing. The device provides phantom power over a coax cable to remote radio frequency (RF) low-noise amplifiers (LNAs) in automotive systems with a maximum current of 300mA per channel. The MAX16948 is designed to operate with an input voltage range from 4.5V to 28V (45V load dump tolerant).

The device provides a fixed regulated output voltage of 8.5V or an adjustable 1V to 12V regulated output voltage (LDO mode). The device can also be configured as a switch (SW mode).

The MAX16948 monitors the load current for each channel and provides two analog output currents proportional to the sensed output current (sourced from the SENSE\_1 pin). Accurate internal adjustable current limits protect the input supply against both overcurrent and short-circuit conditions.

The device features short-to-battery protection, reverse current detection, input overvoltage and thermal overload shutdown to latch off the internal LDO/switch during these fault conditions. The MAX16948 includes two independent active-low, high-voltage-compatible shutdown inputs (active-low SHDN\_) to place each channel in low-power shutdown mode and two active-low open-drain error outputs (active-low ERR\_).

# External Components for the MAX16948

Figure 1 shows a typical application circuit for the MAX16948. The main external components and their functions are as follows:

- R1\_ and R2\_ set the regulated output voltage when the device is in LDO mode with adjustable output voltage.
- R<sub>LIM</sub>\_ sets the current-limit threshold.
- R<sub>SENSE</sub> determines the ADC full-scale input voltage and the output current-sensing accuracy.

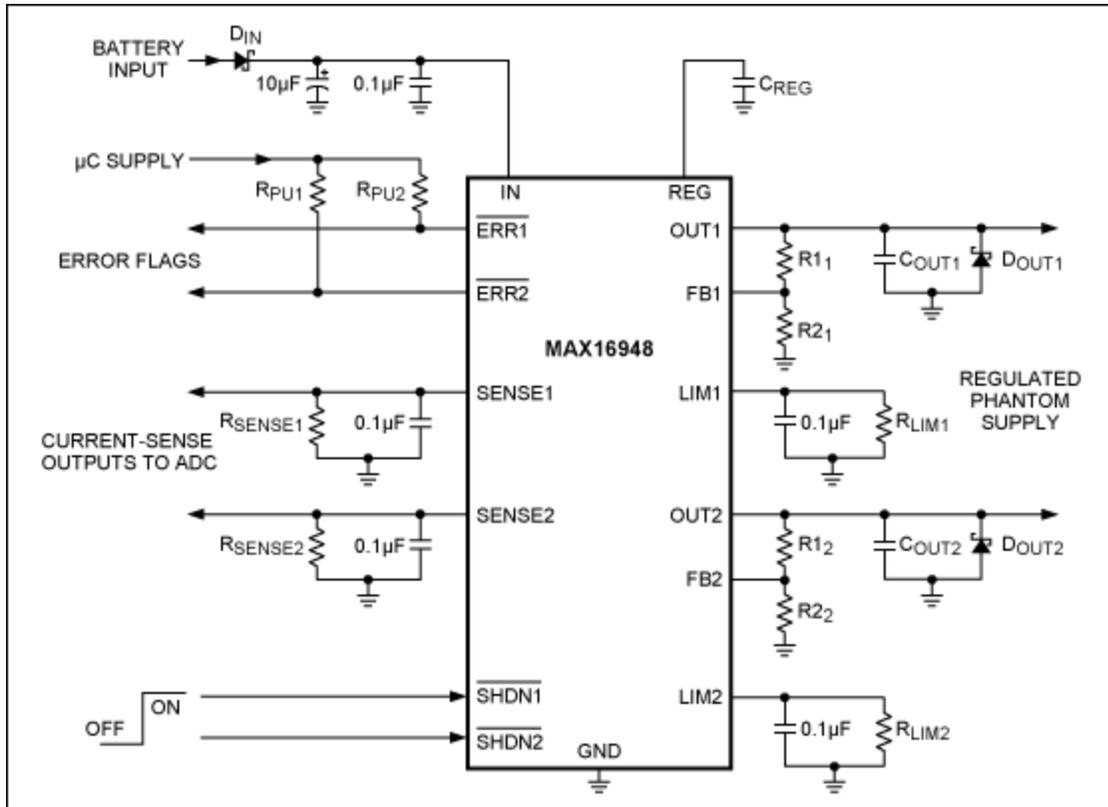


Figure 1. The MAX16948 typical application circuit.

With these external components, the user can easily configure the MAX16948 to work properly for an application. Other external components are necessary. They will be discussed below.

## Input Capacitors

Connect a parallel electrolytic capacitor and a low-ESR ceramic capacitor from IN and GND to limit the input-voltage drop during momentary output short-circuit conditions and to protect the device against transients due to inductance on the IN line. For example, use at least a 0.1µF ceramic capacitor in parallel with at least a 10µF electrolytic capacitor if the input inductance (including any stray inductance) is estimated to be 20µH.

When the MAX16948 is operated with input voltage close to the output voltage, as in SW mode

operation or LDO mode in dropout, care must be taken to avoid a false reverse-current detection in the presence of a short circuit-to-ground fault. If both channels are enabled and one channel is shorted to ground after startup, the current drawn from  $C_{IN}$  may result in a temporary dip in the input voltage, which may trigger the reverse current detection fault. Occurrence of this erroneous fault detection is accentuated at low output current (under 80mA). To avoid this false trigger event, use an input electrolytic capacitor of at least 100 $\mu$ F.

## LDO Mode Output Voltage

When used in LDO mode, the device is configurable to provide a fixed 8.5V output or an adjustable 1V to 12V output voltage for each of the two channels. The output voltage can be set to 8.5V by connecting the FB\_ pin to REG. In this mode, higher output voltage accuracy is achieved as the tolerance of external resistors does not need to be taken into account.

In case a different output voltage is necessary, connect a resistive divider between OUT\_, FB\_, and GND. Equations to determine the resistive divider value are shown below.

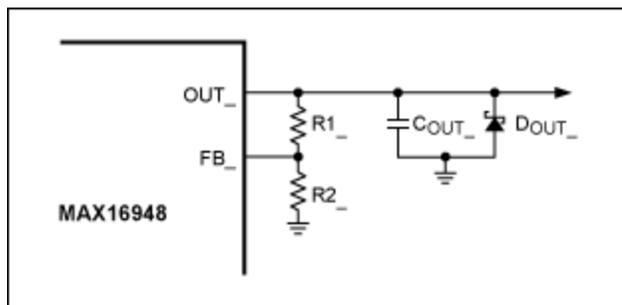


Figure 2. The MAX16948 regulated phantom supply.

The resistors  $R1_$  and  $R2_$  (Figure 2) set the output voltage of the MAX16948. Choose an  $R2_$  standard resistor ( $R2_{(STD)}$ ) that is less than or equal to 1k $\Omega$ . Calculate the optimum  $R1_$  value with the following equation:

$$R1_ = R2_{(STD)} \times \left( \frac{V_{OUT_}}{V_{FB_}} - 1 \right)$$

Where  $V_{FB_}$  is the voltage at the feedback pin in regulation (1V nominal).

Once a standard resistor<sup>2</sup> ( $R1_{(STD)}$ ) that is as close as possible to  $R1_$  has been selected, the typical output voltage is:

$$V_{OUT_{(TYP)}} = V_{FB_} \times \left( \frac{R1_{(STD)}}{R2_{(STD)}} + 1 \right)$$

Considering the tolerance on the resistors ( $R_{TOL}$ ), the minimum and maximum values of the output voltage are:

$$V_{OUT_{(MIN)}} = V_{FB_{(MIN)}} \times \left( \frac{R1_{(MIN)}}{R2_{(MAX)}} + 1 \right)$$

And

$$V_{OUT\_MAX} = V_{FB\_MAX} \times \left( \frac{R1\_MAX}{R2\_MIN} + 1 \right)$$

Where  $V_{FB\_MIN}$  is 0.97V and  $V_{FB\_MAX}$  is 1.03V (over an output current range from 5mA to 150mA).  $R1\_MIN$ ,  $R1\_MAX$ ,  $R2\_MIN$ , and  $R2\_MAX$  are the minimum and maximum values of  $R1\_$  and  $R2\_$ , respectively:

$$R1,2\_MIN = R1,2\_STD \times \left( 1 - \frac{RTOL}{100} \right)$$

$$R1,2\_MAX = R1,2\_STD \times \left( 1 + \frac{RTOL}{100} \right)$$

If the nominal output voltage is too far removed from the desired output voltage, serial or parallel combinations of standard resistors can be used to obtain the optimal resistor divider.

The user can easily determine the value of  $R1\_$  by filling in the appropriate section of the [MAX16948 Calculator](#) with the desired output voltage ( $V_{OUT\_}$ ), the standard value of  $R2\_$ , and the tolerance on these resistors. Once the calculator has determined the optimum  $R1\_$  value, insert a standard value in the correct cell in order to estimate the  $V_{OUT\_}$  range limits. Otherwise, click on the **Step By Step** button to be guided through the calculator's LDO Mode Output Voltage section.

Connect > 1 $\mu$ F in parallel with 0.1 $\mu$ F low-ESR (< 900m $\Omega$ ) capacitors between  $OUT\_$  and GND for regulator stability. These capacitors should be placed as close to the device as possible. Utilize capacitors with an X7R dielectric to ensure stability over the operating temperature range of the device.

In analogous fashion to the input capacitor, an output capacitor protects the device against transients due to any series inductance in the output. Under no conditions should the voltage on  $OUT\_$  go below -0.3V, as indicated in the *Absolute Maximum Ratings* section of the data sheet. A Schottky diode is required as a clamp if transients are expected to go below ground, especially if an output inductance before the load is present on the PCB. The forward voltage of the selected Schottky diode must be under 0.3V with a forward current equal to the current-limit threshold.<sup>3</sup>

## Current-Limit Threshold

The MAX16948 limits the output current of  $OUT\_$  when the voltage on the  $LIM\_$  pin reaches the  $V_{LIM}$  threshold (2.5V typ). The current sourced from  $LIM\_$  is proportional to the load current sourced from  $OUT\_$  by a factor called current-sense amplifier (CSA) gain. In this way, the current-limit threshold  $I_{LIM\_}$  is set with the  $R_{LIM\_}$  resistor.

Determine the optimum  $R_{LIM\_}$  value using the following equation:

$$R_{LIM\_} = \frac{V_{LIM(TYP)}}{I_{LIM\_} \times A(TYP)}$$

Where  $I_{LIM\_}$  is the desired current-limit threshold,  $V_{LIM(TYP)}$  is the typical voltage threshold on the LIM\_ pin where the output current is limited (2.5V), and  $A_{(TYP)}$  is the typical value of the CSA gain (0.005mA/mA).

Select a standard resistor value ( $R_{LIM\_ (STD)}$ ) as close as possible to  $R_{LIM\_}$ . Then the typical current-limit threshold is:

$$I_{LIM\_ (TYP)} = \frac{V_{LIM(TYP)}}{R_{LIM\_ (STD)} \times A_{(TYP)}}$$

Considering the uncorrelated tolerances, the worst-case current-limit threshold range is between the following two equations:

$$I_{LIM\_ (MIN)} = \frac{V_{LIM(MIN)}}{R_{LIM\_ (MAX)} \times A_{(MAX)}}$$

And

$$I_{LIM\_ (MAX)} = \frac{V_{LIM(MAX)}}{R_{LIM\_ (MIN)} \times A_{(MIN)}}$$

Where  $V_{LIM\_ (MIN)}$  is 2.375V and  $V_{LIM\_ (MAX)}$  is 2.625V;  $A_{(MIN)}$  is 0.00485mA/mA and  $A_{(MAX)}$  is 0.00515mA/mA (for a typical output current of 100mA); and  $R_{LIM\_ (MIN)}$  and  $R_{LIM\_ (MAX)}$  are the minimum and maximum values of  $R_{LIM\_}$  based on the value of  $R_{TOL}$ .

$$R_{LIM\_ (MIN)} = R_{LIM\_ (STD)} \times \left(1 - \frac{R_{TOL}}{100}\right)$$

$$R_{LIM\_ (MAX)} = R_{LIM\_ (STD)} \times \left(1 + \frac{R_{TOL}}{100}\right)$$

If the current-limit threshold range is not suitable, a serial or parallel combination of standard resistors can be used to obtain the optimal range.

The [MAX16948 Calculator](#)<sup>4</sup> helps the user choose the  $R_{LIM\_}$  resistor by selecting the current-limit threshold range limit ( $I_{LIM\_ (TYP)}$ ,  $I_{LIM\_ (MIN)}$ , or  $I_{LIM\_ (MAX)}$ ) to calculate the optimum value of  $R_{LIM\_}$ . This is done by selecting the  $I_{LIM\_ (TYP)}$ ,  $I_{LIM\_ (MIN)}$ , or  $I_{LIM\_ (MAX)}$ ; the relative current-limit threshold value; and the tolerance on  $R_{LIM\_}$ . Once the calculator has determined the optimum  $R_{LIM\_}$  value, insert a standard resistor value in the appropriate cell in order to estimate the  $I_{LIM\_}$  range limits. Otherwise, click on the **Step By Step** button to be guided through the calculator's Current-Limit Threshold section.

A 0.1μF compensation capacitor ( $C_{LIM\_}$ ) must be placed in parallel with  $R_{LIM\_}$  to establish a dominant pole in the current limiting loop. This maintains stability and prevents fast current transients from prematurely triggering the current limit (**Figure 3**).

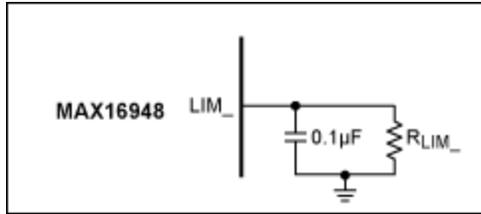


Figure 3. The MAX16948 output-current limit.

## ADC Input Range and Output Current-Sensing Accuracy

The MAX16948 sources a current proportional to the load current from the OUT\_ pin by the CSA gain. This current flowing across R<sub>SENSE\_</sub> produces a voltage proportional to the output current. With this feature, it is possible to monitor the output current by sampling the voltage on the SENSE\_ pin with an ADC.

The ADC full-scale input voltage (V<sub>ADCFS\_</sub>) is set with R<sub>SENSE\_</sub>.

Determine the optimum R<sub>SENSE\_</sub> value using the following equation:

$$R_{SENSE\_} = \frac{V_{ADCFS\_}}{I_{LIM\_}(TYP) \times A_{(TYP)}}$$

Where I<sub>LIM\_(TYP)</sub> is the typical current-limit threshold calculated in the previous section and A<sub>(TYP)</sub> is the typical value of the CSA gain (0.005mA/mA).

Select a standard resistor value (R<sub>SENSE\_(STD)</sub>) as close as possible to R<sub>SENSE\_</sub>. Then the typical ADC full-scale input voltage is:

$$V_{ADCFS\_}(TYP) = R_{SENSE\_}(STD) \times I_{LIM\_}(TYP) \times A_{(TYP)} = R_{SENSE\_}(STD) \times \frac{V_{LIM}(TYP)}{R_{LIM\_}(STD)}$$

Considering the tolerance on the resistors (R<sub>TOL</sub>), the minimum and maximum values of the ADC full-scale input voltage are:

$$V_{ADCFS\_}(MIN) = R_{SENSE\_}(MIN) \times \frac{V_{LIM}(MIN)}{R_{LIM\_}(MAX)}$$

And

$$V_{ADCFS\_}(MAX) = R_{SENSE\_}(MAX) \times \frac{V_{LIM}(MAX)}{R_{LIM\_}(MIN)}$$

Where V<sub>LIM\_(MIN)</sub> is 2.375V and V<sub>LIM\_(MAX)</sub> is 2.625V; R<sub>LIM\_(MIN)</sub> and R<sub>LIM\_(MAX)</sub> are been calculated in the previous section; and R<sub>SENSE\_(MIN)</sub> and R<sub>SENSE\_(MAX)</sub> are the minimum and maximum values of R<sub>SENSE\_</sub> based on the value of R<sub>TOL</sub>.

$$R_{SENSE\_MIN} = R_{SENSE\_STD} \times \left(1 - \frac{RTOL}{100}\right)$$

$$R_{SENSE\_MAX} = R_{SENSE\_STD} \times \left(1 + \frac{RTOL}{100}\right)$$

Using the Output Current Sensing section of the electronic calculator<sup>5</sup>, the user can easily determine the  $R_{SENSE\_}$  value after inserting the desired ADC full-scale input voltage ( $V_{ADCFS\_}$ ) and the tolerance on  $R_{SENSE\_}$ . Once the calculator has determined the optimum  $R_{SENSE\_}$  value, insert a standard value in the corresponding cell in order to estimate the  $V_{ADCFS\_}$  range limits. Otherwise, click on the **Step By Step** button to be guided through the calculator's Output Current Sensing section.

However, before using this section, it is necessary to determine the  $I_{LIM\_}$  range limits in the calculator's Current-Limit Threshold section.

Place a 0.1µF capacitor ( $C_{SENSE}$ ) in parallel with  $R_{SENSE\_}$  to hold the voltage during ADC sampling cycles (**Figure 4**).

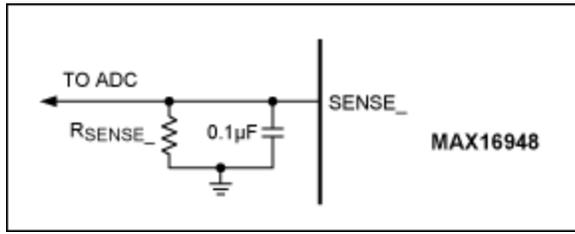


Figure 4. ADC input range.

Once the voltage on the  $SENSE\_$  pin has been measured with the ADC ( $V_{ADC\_}$ ), the output current can be estimated by the following formula:

$$I_{EVALUATED\_} = \frac{V_{ADC\_}}{R_{SENSE\_STD} \times A_{(TYP)}} = \frac{I_{OUT\_} \times A \times R_{SENSE\_}}{R_{SENSE\_STD} \times A_{(TYP)}}$$

Due to the  $R_{SENSE\_}$  tolerance and the parameter spread on the CSA gain, the estimated output current can vary between the following two equations:

$$I_{EVALUATED(MIN)\_} = \frac{I_{OUT\_} \times A_{(MIN)} \times R_{SENSE\_MIN}}{A_{(TYP)} \times R_{SENSE\_STD}} = I_{OUT\_} \times \frac{A_{(MIN)}}{A_{(TYP)}} \times \left(1 - \frac{RTOL}{100}\right)$$

And

$$I_{EVALUATED(MAX)\_} = \frac{I_{OUT\_} \times A_{(MAX)} \times R_{SENSE\_MAX}}{A_{(TYP)} \times R_{SENSE\_STD}} = I_{OUT\_} \times \frac{A_{(MAX)}}{A_{(TYP)}} \times \left(1 + \frac{RTOL}{100}\right)$$

Replace the value of the CSA gain for a typical output current of 100mA:

$$I_{EVALUATED(MIN)\_} = \frac{I_{OUT\_} \times A_{(MIN)} \times R_{SENSE\_MIN}}{A_{(TYP)} \times R_{SENSE\_STD}} = I_{OUT\_} \times 0.97 \times \left(1 - \frac{RTOL}{100}\right)$$

$$I_{EVALUATED(MAX)\_} = \frac{I_{OUT\_} \times A_{(MAX)} \times R_{SENSE\_ (MAX)}}{A_{(TYP)} \times R_{SENSE\_ (STD)}} = I_{OUT\_} \times 1.03 \times \left(1 + \frac{R_{TOL}}{100}\right)$$

Finally, the accuracy of the current measurement made by the ADC is:

$$I_{EVALUATED\_ ACCURACY\_ (\%)} = \frac{I_{OUT\_} - I_{EVALUATED\_}}{I_{OUT\_}} \times 100 = \left[1 - 0.97 \times \left(1 - \frac{R_{TOL}}{100}\right)\right] \times 100$$

This parameter can also be determined in the O.C.S. Accuracy row of the calculator's Output Current Sensing section.

## Detection of Open-Load and Overcurrent Conditions

In addition to ADC sampling, open-load or overcurrent conditions can be detected by utilizing external comparators and splitting  $R_{SENSE\_}$  into resistive dividers ( $R3\_$ ,  $R4\_$ , and  $R5\_$ ) (**Figure 5**).

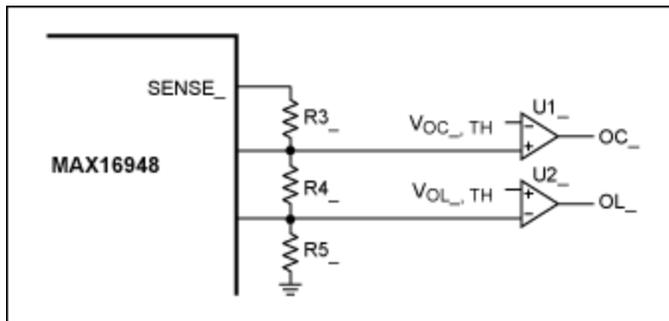


Figure 5. Open-load and overcurrent detection.

The output of the comparators ( $OC\_$  and  $OL\_$ ) indicates the operating state of the circuit as shown Table 1.

OC	OL	State
0	0	Normal Operation
0	1	Open-Load Condition
1	0	Overcurrent Condition
1	1	Invalid State

Determine the  $R5\_$  value with the following equation:

$$R5\_ = \frac{V_{OL\_ , TH}}{I_{OPEN-LOAD\_} \times A_{(TYP)}}$$

Where  $I_{OPEN-LOAD\_}$  is the desired open-load threshold for the current flowing through the LDO/switch,  $V_{OL\_ , TH}$  is the open-load voltage threshold for comparator  $U2\_$ , and  $A_{(TYP)}$  is the typical value of the

CSA gain (0.005mA/mA). Once the R5\_ resistor value has been calculated, determine the R4\_ value using the following equation:

$$R4\_ = \frac{V_{OC\_TH}}{I_{OVERCURRENT\_} \times A_{(TYP)}} - R5\_$$

Where I<sub>OVERCURRENT\_</sub>, which must be less than I<sub>LIM\_(MIN)</sub>, is the desired overcurrent threshold for the current flowing through the LDO/switch; V<sub>OC\_TH</sub> is the overcurrent voltage threshold for comparator U1\_; and A<sub>(TYP)</sub> is the typical value of the CSA gain (0.005mA/mA).

Finally, calculate R3\_:

$$R3\_ = R_{SENSE\_} - R4\_ - R5\_$$

Considering the tolerance of the R3\_, R4\_, and R5\_ standard resistors (R<sub>TOL</sub>), the minimum, typical, and maximum values of the open-load and overcurrent threshold are:

$$I_{OPEN-LOAD\_ (MIN)} = \frac{V_{OL\_TH}}{R5\_ (MAX) \times A_{(MAX)}}$$

$$I_{OPEN-LOAD\_ (TYP)} = \frac{V_{OL\_TH}}{R5\_ (STD) \times A_{(TYP)}}$$

$$I_{OPEN-LOAD\_ (MAX)} = \frac{V_{OL\_TH}}{R5\_ (MIN) \times A_{(MIN)}}$$

$$I_{OVERCURRENT\_ (MIN)} = \frac{V_{OC\_TH}}{(R5\_ (MAX) + R4\_ (MAX)) \times A_{(MAX)}}$$

$$I_{OVERCURRENT\_ (TYP)} = \frac{V_{OC\_TH}}{(R5\_ (STD) + R4\_ (STD)) \times A_{(TYP)}}$$

$$I_{OVERCURRENT\_ (MAX)} = \frac{V_{OC\_TH}}{(R5\_ (MIN) + R4\_ (MIN)) \times A_{(MIN)}}$$

Where A<sub>(MIN)</sub> is 0.00485mA/mA and A<sub>(MAX)</sub> is 0.00515mA/mA (for a typical output current of 100mA); R4\_<sub>(MIN)</sub>, R4\_<sub>(MAX)</sub>, R5\_<sub>(MIN)</sub>, and R5\_<sub>(MAX)</sub> are the minimum and maximum values of R4\_ and R5\_ based on the tolerance of R<sub>TOL</sub>.

$$R4\_ (MIN) = R4\_ (STD) \times \left(1 - \frac{R_{TOL}}{100}\right)$$

$$R4\_ (MAX) = R4\_ (STD) \times \left(1 + \frac{R_{TOL}}{100}\right)$$

$$R5_{(MIN)} = R5_{(STD)} \times \left(1 - \frac{RTOL}{100}\right)$$

$$R5_{(MAX)} = R5_{(STD)} \times \left(1 + \frac{RTOL}{100}\right)$$

The user can determine the values of R4\_, R5\_, and R6\_ using the Open-Load & Overcurrent Detection section of the calculator<sup>6</sup>. Insert I<sub>OPEN-LOAD\_</sub> (I<sub>OL\_</sub>), I<sub>OVERCURRENT\_</sub> (I<sub>OC\_</sub>), V<sub>OL\_,TH</sub>, V<sub>OC\_,TH</sub>, and the tolerance on the resistors. Once you have used the calculator to determine the optimum values for R4\_, R5\_, and R6\_, insert standard resistor values in the appropriate cells in order to estimate the I<sub>OPEN-LOAD\_</sub> and I<sub>OVERCURRENT\_</sub> range limits. Click on the **Step By Step** button to be guided through the calculator's Open-Load & Overcurrent Detection section.

Before using the calculator's Open-Load and Overcurrent Detection section, it is necessary to determine the R<sub>SENSE\_</sub> value in the Output Current Sensing section.

## Example Calculations

For these example calculations, we assume an antenna phantom supply application where the supply input voltage is 5V, the typical load current is 100mA, the maximum current-limit threshold value is 120mA, and the output current is monitored with a 3.3V input range ADC.

Assuming that the IN pin of the MAX16948 is directly connected to the battery, the device must be configured in LDO mode to obtain an OUT\_ voltage of 5V. For this purpose, the external resistor divider composed of R1\_ and R2\_ must be dimensioned. Choose a standard value for R2\_ (R2\_(STD)) less than or equal to 1kΩ and calculate R1\_ :

$$R2_{(STD)} = 750\Omega, RTOL = 1\% \text{ (E96 Series)}$$

$$R1_ = R2_{(STD)} \times \left(\frac{V_{OUT_}}{V_{FB_}} - 1\right) = 750\Omega \times \left(\frac{5V}{1V} - 1\right) = 3000\Omega$$

Selecting a standard resistor from the E96 Series R1\_(STD) = 3010Ω, the output voltage range is:

$$V_{OUT_(TYP)} = V_{FB_} \times \left(\frac{R1_{(STD)}}{R2_{(STD)}} + 1\right) = 1V \times \left(\frac{3010\Omega}{750\Omega} + 1\right) = 5.013V$$

$$V_{OUT_(MIN)} = V_{FB_(MIN)} \times \left(\frac{R1_{(MIN)}}{R2_{(MAX)}} + 1\right) = 0.97V \times \left(\frac{2979.9\Omega}{757.5\Omega} + 1\right) = 4.786V$$

$$V_{OUT_(MAX)} = V_{FB_(MAX)} \times \left(\frac{R1_{(MAX)}}{R2_{(MIN)}} + 1\right) = 1.03V \times \left(\frac{3040.1\Omega}{742.5\Omega} + 1\right) = 5.247V$$

To obtain a maximum current-limit threshold (I<sub>LIM\_(MAX)</sub>) equal to 120mA, R<sub>LIM\_</sub> can be calculated after rearranging the I<sub>LIM\_(MAX)</sub> equation:

$$R_{LIM\_MIN} = \frac{V_{LIM(MAX)\_}}{I_{LIM(MAX)\_} \times A_{(MIN)}} = \frac{2.625V}{120mA \times 0.00485} = 4510\Omega$$

$$R_{LIM\_MIN} = \frac{V_{LIM(MAX)\_}}{I_{LIM(MAX)\_} \times A_{(MIN)}} = \frac{2.625V}{120mA \times 0.00485} = 4510\Omega$$

Selecting a standard resistor from the E96 Series ( $R_{LIM\_STD} = 4530\Omega$ ), the current-limit threshold range is:

$$I_{LIM(MAX)} = \frac{V_{LIM(MAX)}}{R_{LIM\_MIN} \times A_{(MIN)}} = \frac{2.625V}{4484.7\Omega \times 0.00485} = 120.685mA$$

$$I_{LIM(TYP)} = \frac{V_{LIM(TYP)}}{R_{LIM\_STD} \times A_{(TYP)}} = \frac{2.5V}{4530\Omega \times 0.005} = 110.375mA$$

$$I_{LIM(MIN)} = \frac{V_{LIM(MIN)}}{R_{LIM(MAX)} \times A_{(MAX)}} = \frac{2.375V}{4575.3\Omega \times 0.00515} = 100.794mA$$

With an ADC input range of 3.3V, calculate the optimum  $R_{SENSE\_}$  as follows:

$$R_{SENSE\_} = \frac{V_{ADCFS\_}}{I_{LIM(TYP)} \times A_{(TYP)}} = \frac{3.3V}{110.375mA \times 0.005} = 5979.6\Omega$$

Selecting a standard resistor from the E96 Series ( $R_{SENSE\_STD} = 6040\Omega$ ,  $R_{TOL} = 1\%$ ), the ADC full-scale input voltage range is:

$$V_{ADCFS(TYP)} = R_{SENSE\_STD} \times I_{LIM(TYP)} \times A_{(TYP)} = 6040\Omega \times 110.375mA \times 0.005 = 3.333V$$

$$V_{ADCFS(MIN)} = R_{SENSE(MIN)} \times I_{LIM(MIN)} \times A_{(MIN)} = 5979.6\Omega \times 100.794mA \times 0.00485 = 3.104V$$

$$V_{ADCFS(MAX)} = R_{SENSE(MAX)} \times I_{LIM(MAX)} \times A_{(MAX)} = 6100.4\Omega \times 120.685mA \times 0.00515 = 3.571V$$

The accuracy of the output current monitoring is then as follows:

$$I_{EVALUATED\_ACCURACY(\%)} = \left[ 1 - 0.97 \times \left( 1 - \frac{R_{TOL}}{100} \right) \right] \times 100 = \pm 3.970\%$$

\*For more details on these calculations, refer to the [MAX16948 data sheet](#).

## References

1. An underscore after a pin name is used to indicate the possibility of multiple channels (e.g., SENSE\_ means SENSE1/SENSE2).
2. A Standard Resistor Table is available in the MAX16948 Calculator.
3. See the following paragraph.
4. Default  $A_{(MIN)}$  and  $A_{(MAX)}$  are used by the MAX16948 Calculator for a typical output current of 100mA; it is possible to modify these values by changing them in the MAX16948 EC sheet.

5. Default  $A_{(MIN)}$  and  $A_{(MAX)}$  are used by the MAX16948 Calculator for a typical output current of 100mA; it is possible to modify these values by changing them in the MAX16948 EC sheet.
6. Default  $A_{(MIN)}$  and  $A_{(MAX)}$  are used by the MAX16948 Calculator for a typical output current of 100mA; it is possible to modify these values by changing them in the MAX16948 EC sheet.

#### Related Parts

[MAX16948](#)

Automotive Dual Remote Antenna Current-Sense  
LDO/Switch

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#### More Information

For Technical Support: <http://www.maximintegrated.com/support>

For Samples: <http://www.maximintegrated.com/samples>

Other Questions and Comments: <http://www.maximintegrated.com/contact>

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APPLICATION NOTE 5271, AN5271, AN 5271, APP5271, Appnote5271, Appnote 5271

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