AND8162/D

CS4122 Application Considerations

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APPLICATION NOTE

Application Considerations

Like all semiconductor products, the parametric and reliability qualities of the CS4122 depend on the application and its environment where attention to power dissipation is imperative to long−term reliability. This note is offered as a guide to estimating the performance of the CS4122 in an automotive passenger compartment environment. Application examples, each with unique considerations toward power dissipation, will be examined along with suggestions for performance improvements.

Peak Power Points

For each of the major and minor gauges there are deflection angles that result in maximum power dissipation in the CS4122. These points occur whenever the coil voltages are equal to ½V_{BB} and are readily calculated according to major and minor gauge angular formulas found in the CS4122 data sheet. The occurrence of these maximum power points is a natural result of the tangential behavior of the CS4122 together with the V_{BB} power supply voltage and the self−resistance of the gauge coils.

Specifically:

$$\theta = \Theta \pm \mathrm{Tan}^{-1}\left[\frac{(VSIN+) - (VSIN-)}{(VCOS+) - (VCOS-)}\right] \quad \text{(eq. 1)}$$

for the major gauge, and;

$$\theta = 56.1^{\circ} \pm \mathrm{Tan}^{-1}\left[\frac{(VC+) - (VC-)}{\frac{1}{2}V_{BB}}\right] \quad \text{(eq. 2)}$$

for the minor gauges, where:

Θ for the major gauge is dependent on the quadrant of operation and θ is the programmed angle.

In the first octant of operation of the major gauge, (VCOS+) – (VCOS−) is fixed at ≈0.748 V_{BB} while (VSIN+) – (VSIN−) varies with the programmed angle. In the two quadrants of operation of the minor gauges, one coil voltage is fixed at ½V_{BB} while the remaining coil voltage varies with the programmed angle. Thus it can be seen that the maximum power points occur once for each octant of operation of the major gauge and once for each quadrant of the minor gauges. The approximate peak power dissipation angles for each gauge type are summarized in Table 1, and power dissipation curves for the major gauge and one of the minor gauges are shown in Figures 1 and 2.

Table 1. CS4122 Peak Power Angles

Major Gauges	33.7°
	56.3°
	123.7°
	146.3°
	213.7°
	236.3°
	303.7°
	326.3°
Minor Gauges	11°
	101°

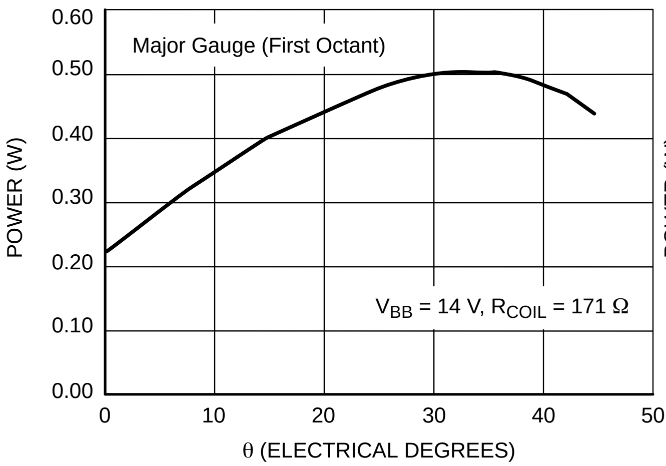

Figure 1. Power Dissipation in the CS4122 for Both Coils of the Major Gauge

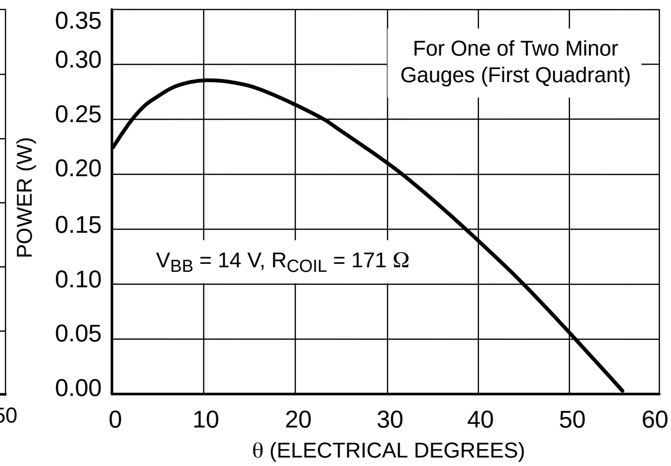

Figure 2. Power Dissipation in the CS4122 for One Coil of One Minor Gauge

APPLICATION DIAGRAMS

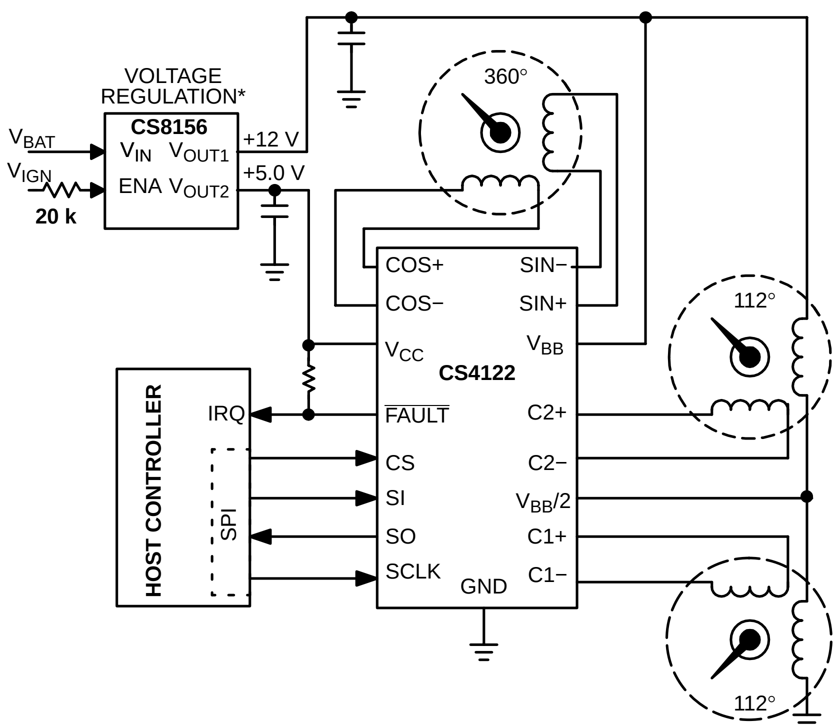

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Figure 3. Full Application

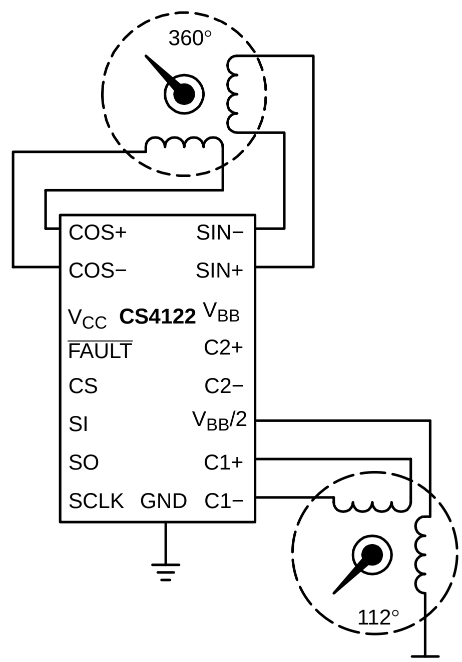

Figure 4. Application with One Minor Gauge

Peak Power Estimation

The peak power of the CS4122 in a particular application can be estimated when the V_{BB} voltage and the load resistances are known, and when the gauge angles are set to the peak power points. The following formulas may be applied:

$$P_{TOT} = \left[P_{Q(VBB)} + P_{Q(VCC)}\right] + P_{MAJOR} + P_{MINOR1} + P_{MINOR2} + P_{(VBB/2)} \quad \text{(eq. 3)}$$

where:

$$P_{Q(VBB)} = V_{BB} \times I_{QVBB(MAX)} \quad \text{(eq. 4)}$$

$$P_{Q(VCC)} = V_{CC} \times I_{QVCC(MAX)} \quad \text{(eq. 5)}$$

$$P_{MAJOR} = \frac{\left[\left(\frac{1}{2}V_{BB}\right)^2 + \left(V_{BB}{}^2 \times (0.748 - 0.748^2)\right)\right]}{R_{MAJOR}}$$

(At Peak Power Points) (eq. 6)

$$P_{MINORX} = \frac{\left(\frac{1}{2}V_{BB}\right)^2}{R_{MINORX}}$$

(At Peak Power Points) (eq. 7)

R_{MAJOR} and R_{MINOR} are the respective coil self−resistances at a specific temperature and

$$P_{(VBB/2)} = \left(\frac{1}{2}V_{BB}\right)^2 \times \left(\frac{1}{R_{MINOR1}} - \frac{1}{R_{MINOR2}}\right) \quad \text{(eq. 8)}$$

for two minor gauges connected between V_{BB} and GND, and

$$P_{(VBB/2)} = \frac{V_{BB}{}^2}{(4 \times R_{MINOR})} \quad \text{(eq. 9)}$$

for a single minor gauge connected between ½V_{BB} and GND.

Note that while these formulas estimate the power dissipation in the CS4122 and not the power dissipation in the gauges, the user should be aware that power dissipation due to self−heating in the gauges may raise the temperature of the CS4122 if the gauges or other dissipative loads (such as incandescent lamps) are located in close proximity.

Example Peak Power Estimates

In all examples in this note, we'll use the CS4122 data sheet quiescent current value for the V_{DD} power supply at 5.5 V, and either the data sheet V_{BB} power supply quiescent current at 14 V or an adjusted value at 12 V. First we'll examine the application diagrams of Figures 3 and 4 at V_{BB} = 14 V, without a voltage regulator.

Example 1

A full application (see Figure 3) is implemented with one major and two minor gauges (all gauges at peak power points) with the following assumptions:

V_{BB} = 14 V
Ambient temperature = +85°C
$I_{QVBB(MAX)}$ = 25 mA (see CS4122 data sheet)
$I_{QVCC(MAX)}$ = 1.5 mA (see CS4122 data sheet)
R_{MAJOR} = 171 Ω @ +25°C (both coils, matched resistances.)
R_{MINOR} = 171 Ω @ +25°C (C1, C2 coils, matched resistances.)
R_{MINOR} Mismatch = 12.5% for minor coils series−connected between V_{BB} and GND.

The maximum quiescent power dissipation can be expressed as:

$$\begin{aligned}[P_{Q(VBB)} + P_{Q(VCC)}] &= V_{BB} \times I_{QVBB(MAX)} + V_{CC} \times I_{QVCC(MAX)} \\ &= (14\ \text{V} \times 25\ \text{mA}) + (5.5\ \text{V} \times 1.5\ \text{mA}) \\ &\approx 358\ \text{mW}\end{aligned}$$

by Equations 4 and 5.

Assuming that the gauge coils are constructed with copper wire with a typical +0.4%/°C temperature coefficient, the self−resistance of the gauges at +85°C can be calculated as:

$$\begin{aligned}R_{COIL(T)} &= R_{COIL(TREF)} \times 1 + (0.004 \times (T - TREF)) \\ &= 171\ \Omega \times 1 + (0.004 \times (85 - 25)) \\ &\approx 212\ \Omega\end{aligned}$$

Note that this result does not include an estimate of additional resistance change with regard to the expected temperature rise in the gauges due to self−heating effects.

The maximum power dissipation resulting from the major coils (SIN, COS) can be expressed as:

$$\begin{aligned}P_{MAJOR} &= \frac{\left[\left(\frac{1}{2}V_{BB}\right)^2 + \left(V_{BB}{}^2 \times (0.748 - 0.748^2)\right)\right]}{R_{MAJOR}} \\ &= \frac{[(7.0\ \text{V})^2 + (14\ \text{V}^2 \times 0.1885)]}{212\ \Omega} \\ &\approx 405\ \text{mW}\end{aligned}$$

by Equation 6.

The maximum power dissipation resulting from the minor coils (C_X+, C_X−) can be expressed as:

$$\begin{aligned}P_{MINORX} &= \frac{\left(\frac{1}{2}V_{BB}\right)^2}{R_{MINORX}} \\ &= \frac{(7.0\ \text{V})^2}{212\ \Omega} \\ &\approx 231\ \text{mW}\end{aligned}$$

by Equation 7.

When both minor gauges are driven at peak power points, the power is $2 \times P_{MINORX}$ or ≈462 mW.

The power dissipation resulting from the mismatched minor coils driven from ½V_{BB} can be expressed as:

$$\begin{aligned}P_{(VBB/2)} &= \left(\frac{1}{2}V_{BB}\right)^2 \times \left(\frac{1}{R_{MINOR1}} - \frac{1}{R_{MINOR2}}\right) \\ &= (7.0\ \text{V}) \times \left(\frac{1}{212\ \Omega} - \frac{1}{238.5\ \Omega}\right) \\ &\approx 25.7\ \text{mW}\end{aligned}$$

by Equation 8.

Note that it does not matter that the coils are mismatched in one or the other direction, the CS4122 will compensate the mismatch by either sourcing or sinking the appropriate current to make each coil voltage equal to ½V_{BB}. The power dissipation will be similar for either case. Also, gauges of considerably different self−resistance may be used provided the combination is within the capability (70 mA min) of the CS4122's ½V_{BB} driver to correctly bias the gauges. Of course, power dissipation in the ½V_{BB} driver will be proportionally higher.

The resulting sum of the power dissipations is:

$$P_{TOT} = \left[P_{Q(VBB)} + P_{Q(VCC)}\right] + P_{MAJOR} + P_{MINOR} + P_{MINOR2} + P_{(VBB/2)}$$
$$= (358 + 405 + 231 + 231 + 25.7)\ \text{mW}$$
$$\approx 1.251\ \text{W}$$

by Equation 3.

Example 2

An application (see Figure 4) is implemented with one major and one minor gauge with the following assumptions:

V_{BB} = 14 V
Ambient temperature = +85°C.
$IQ_{VBB(MAX)}$ = 25 mA
$IQ_{VCC(MAX)}$ = 1.5 mA
R_{MAJOR} = 171 Ω @ +25°C (both coils, matched resistances.)
R_{MINOR} = 171 Ω @ +25°C (C1 or C2 coils, matched resistances.)

Both gauges are at peak power points.

As in Example 1, the maximum power dissipations are:

$$\left[P_{Q(VBB)} + P_{Q(VCC)}\right] \approx 358\ \text{mW}$$
$$P_{MAJOR} \approx 405\ \text{mW}$$
$$P_{MINORX} \approx 231\ \text{mW}$$

by Equations 4 through 7.

The power dissipation resulting from the minor coil driven from ½V_{BB} can be expressed as:

$$P_{(VBB/2)} = \frac{V_{BB}^2}{(4 \times R_{MINOR})}$$
$$= \left[\frac{14\ V^2}{(4 \times 212\ \Omega)}\right]$$
$$\approx 231\ \text{mW}$$

by Equation 9.

The resulting sum of the power dissipations is:

$$P_{TOT} = \left[P_{Q(VBB)} + P_{Q(VCC)}\right] + P_{MAJOR} + P_{MINOR} + P_{(VBB/2)}$$
$$= (358 + 405 + 231 + 231)\ \text{mW}$$
$$\approx 1.225\ \text{W}$$

by Equation 3.

The power dissipation in Example 2 is nearly identical to that in Example 1 and would be exactly the same if there were no mismatch in the resistance of the static minor gauge coils. In Example 1, the CS4122 supplies current to the driven coils of the two minor gauges and supplies only a mismatch current to the static coils from the ½V_{BB} driver. In Example 2, the CS4122 supplies current to both coils of a single minor gauge. In either case, the current supplied by the CS4122 is similar and so accounts for nearly identical power dissipation in both examples.

Thermal Performance Estimation

The junction temperature of the CS4122 can be estimated for Examples 1 and 2 based on the θ_{JC} and the θ_{JA} thermal performance characteristics of the package. The thermal performance of the package at best, will be related to the θ_{JC} estimate, and at worst, will be related to the θ_{JA} estimate stated in the data sheet. Typically, the thermal performance will be between the θ_{JC} and θ_{JA} estimates and can be improved by the addition of a thermal plane (additional copper area) on the application's printed circuit board and connected to the 8 fused GND leads, as shown in Figure 5.

Data sheet thermal performance estimates are obtained under laboratory conditions and may not necessarily predict the performance of a product in any given application, but are useful for comparative analyses. Performance improvements gained by added thermal planes are best evaluated in the actual application, since they may conduct heat into as well as away from the product. In any case, it is best to measure the *actual* junction temperature of a product in the *actual* application. Several references are given at the end of this document to help accomplish the task.

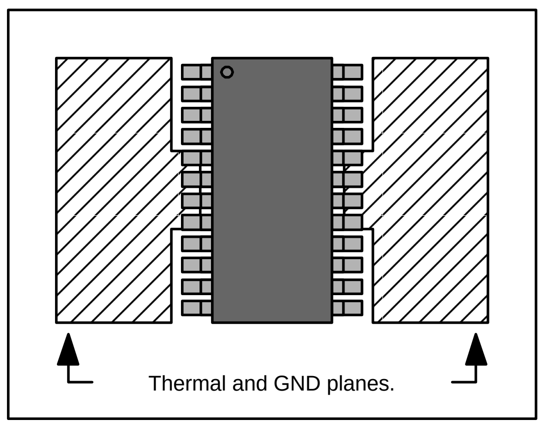

Figure 5. The addition of a thermal plane improves the package thermal performance.

Example Thermal Estimates

From the CS4122 data sheet, the estimated θ_{JC} value is 9°C/W and the estimated θ_{JA} value is 55°C/W for the package. The following thermal performance estimations are based on the estimated θ_{JC} and θ_{JA} values and the peak powers calculated in the previous two examples.

Example 1

The total power dissipation is estimated to be 1.251 W. Given an estimate of θ_{JC} = 9°C/W, θ_{JA} = 55°C/W, and an ambient temperature of +85°C, the junction temperature (T_J) can be estimated to be:

$$T_{J(MIN)} \approx T_{AMB} + (1.251\ W \times 9^\circ C/W)$$
$$\approx +85^\circ C + 11.26^\circ C$$
$$\approx +96.26^\circ C \text{ (best case)}$$
$$T_{J(MAX)} \approx T_{AMB} + (1.251\ W \times 55^\circ C/W)$$
$$\approx +85^\circ C + 11.26^\circ C$$
$$\approx +153.81^\circ C \text{ (worst case).}$$

Example 2

The total power dissipation is estimated to be 1.225 W. Given an estimate of θ_{JC} = 9°C/W, θ_{JA} = 55°C/W, and an ambient temperature of +85°C, the junction temperature (T_J) can be estimated to be:

$$T_{J(MIN)} \approx T_{AMB} + (1.225\ W \times 9^\circ C/W)$$
$$\approx +85^\circ C + 11.03^\circ C$$
$$\approx +96.26^\circ C \text{ (best case)}$$
$$T_{J(MAX)} \approx T_{AMB} + (1.225\ W \times 55^\circ C/W)$$
$$\approx +85^\circ C + 67.4^\circ C$$
$$\approx +152.4^\circ C \text{ (worst case).}$$

Thermal Performance Improvement

In addition to the use of a thermal plane, the CS4122's thermal performance can be further improved by reducing the V_{BB} operating voltage by using a voltage regulator. In fact, in applications where V_{BB} may exceed the CS4122's 16.5 V maximum supply voltage, a regulator is required. The CS8156 can be used to reduce V_{BB} to 12 V and offers several other benefits such as reverse−battery and transient protection, and an enable control to minimize standby power. Consult the CS8156 data sheet for full details on the use and benefits of the product. The power savings can be demonstrated by substituting V_{BB} = 12 V in the previous examples.

Assuming that $IQ_{VBB(MAX)}$ will be reduced by 12 V / 14 V or 14.3% to 21.4 mA:

$$P_{TOT} = \left[P_{Q(VBB)} + P_{Q(VCC)}\right] + P_{MAJOR} + P_{MINOR1} + P_{MINOR2} + P_{(VBB/2)}$$
$$= (265 + 298 + 170 + 170 + 19)\ mW$$
$$\approx 922\ mW$$

for the first example and

$$P_{TOT} = \left[P_{Q(VBB)} + P_{Q(VCC)}\right] + P_{MAJOR} + P_{MINOR} + P_{(VBB/2)}$$
$$= (265 + 298 + 170 + 170)\ mW$$
$$\approx 903\ mW$$

for the second example.

The results are an improvement of about 26%. Applying these results to the thermal estimates:

$$T_{J(MIN)} \approx T_{AMB} + (0.922\ W \times 9^\circ C/W)$$
$$\approx +85^\circ C + 8.3^\circ C$$
$$\approx +93.3^\circ C \text{ (best case)}$$
$$T_{J(MAX)} \approx T_{AMB} + (0.922\ W \times 55^\circ C/W)$$
$$\approx +85^\circ C + 50.7^\circ C$$
$$\approx +135.7^\circ C \text{ (worst case).}$$

for the first example and

$$T_{J(MIN)} \approx T_{AMB} + (0.903\ W \times 9^\circ C/W)$$
$$\approx +85^\circ C + 8.13^\circ C$$
$$\approx +93.13^\circ C \text{ (best case)}$$
$$T_{J(MAX)} \approx T_{AMB} + (0.903\ W \times 55^\circ C/W)$$
$$\approx +85^\circ C + 49.7^\circ C$$
$$\approx +134.7^\circ C \text{ (worst case).}$$

for the second example.

Another improvement that can be made for applications using a single minor gauge includes the use of bias resistor R_B to supply the bulk of the current to the static minor gauge coil. Also, using R_B to reduce power dissipation in the CS4122 doesn't increase the current in the application. This modification of Figure 4 is shown in Figure 6.

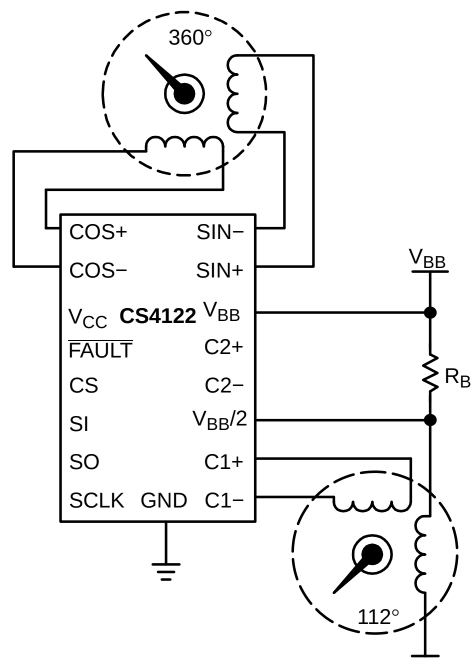

Figure 6. Application with One Minor Gauge and Bias Resistor R_B

R_B's value should be chosen to be substantially equal to the resistance of the gauge coil at the highest expected ambient temperature. The CS4122 then supplies only a compensating current to maintain the coil voltage at ½V_{BB} over the entire range of ambient temperature. This allows the selection of a standard resistor type and value that need not track the coil's 4000 ppm/°C resistance temperature coefficient (TCR). The resistor can be a ¼ W unit, as will be shown in the following example.

Example 3

Figure 6 is implemented with a major gauge, one minor gauge, and a bias resistor with the following assumptions:

V_{BB} = 12 V
Ambient temperature = +85°C
$IQ_{VBB(MAX)}$ = 25 mA
$IQ_{VCC(MAX)}$ = 1.5 mA
R_{MAJOR} = 212 Ω @ +85°C
(both coils, matched resistances)
R_{MINOR} = 212 Ω @ +85°C
(C1 or C2 coils, matched resistances)
R_B = 220 Ω ±5% @ +25°C, TCR = ±300 ppm/°C
Both gauges are at peak power points.

The amount compensating current that the CS4122 supplies at this temperature will be highest when R_B is at its worst−case maximum value. The value of R_B from tolerance and TCR effects can be determined by:

$$R_B = R_{NOM} \times (1 \pm \%TOL) \times (1 \pm TCR \times \Delta T)$$

Assuming +5% and +300 ppm/°C, R_B can have a maximum value of about 235 Ω at +85°C.

The maximum power dissipation for R_B occurs when R_B is adjusted to its worst−case minimum value and, assuming –5% and –300 ppm/°C, can have a minimum value of about 205 Ω at +85°C. R_B's power dissipation in this case is:

$$\begin{aligned} P_{RB} &= \left(\frac{1}{2}V_{BB}\right)^2 / R_B \\ &= (6)^2 / 205\ \Omega \\ &\approx 176\ \text{mW} \end{aligned}$$

The power dissipation in the CS4122 due to the compensating current can then be determined using Equation 8, and for this example is about 17 mW when R_B is 235 Ω. As in the previous example with V_{BB} = 12 V:

$$\begin{aligned} \left[P_{Q(VBB)} + P_{(VCC)}\right] &\approx 265\ \text{mW} \\ P_{MAJOR} &\approx 298\ \text{mW} \\ P_{MINOR} &\approx 170\ \text{mW} \end{aligned}$$

The resulting sum of the power dissipations is:

$$\begin{aligned} P_{TOT} &= \left[P_{Q(VBB)} + P_{Q(VCC)}\right] + P_{MAJOR} \\ &\quad + P_{MINOR} + P_{(VBB/2)} \\ &= (265 + 298 + 170 + 17)\ \text{mW} \\ &= 750\ \text{mW} \end{aligned}$$

By using R_B, the CS4122's power dissipation is reduced from 903 mW to 750 mW, an improvement of about 17%. The thermal estimates are calculated as before and are:

$$T_{J(MIN)} \approx 92^\circ C$$

$$T_{J(MAX)} \approx 127^\circ C.$$

Using the CS8156 reduces the CS4122's junction temperature by between 3% and 12% at the +85°C application temperature. An additional temperature reduction of between 1% and 6% can be gained by using R_B in applications with one minor gauge. Of course, the improvement comes at the cost of the added power dissipation of the CS8156. An examination of the added power is given next for each of the previous examples and for completeness, the cases where all of the gauges have maximum voltages applied across the coils.

The effects of the CS8156's quiescent power, and power resulting from all other loads, are not considered for the following estimations. These effects should be considered separately based on the total loading of the CS8156 and its thermal performance estimates at specific temperatures. Consult the CS8156 data sheet for full performance details.

At the CS8156's nominal 12 V regulation voltage, the currents for the previous application examples are:

$$\begin{aligned} I_{MAX(1)} &= I_{Q(VBB)} + I_{MAJOR\ (SIN)} + I_{MAJOR\ (COS)} \\ &\quad + (4 \times I_{MINOR}) \\ &= I_{Q(VBB)} + \left(\frac{V_{SIN}}{R_{MAJOR}}\right) + \left(\frac{V_{COS}}{R_{MAJOR}}\right) \\ &\quad + \left[4 \times \left(\frac{V_{MINOR}}{R_{MINOR}}\right)\right] \text{mA} \\ &= 21.4 + \left(\frac{6\ \text{V}}{212\ \Omega}\right) + \left(\frac{8.98\ \text{V}}{212\ \Omega}\right) \\ &\quad + \left[4 \times \left(\frac{6\ \text{V}}{212\ \Omega}\right)\right] \text{mA} \\ &= 21.4 + 28.3 + 42.4 + 113.2\ \text{mA} \\ &= 205.3\ \text{mA} \end{aligned}$$

for Example 1, and

$$\begin{aligned} I_{MAX(2,3)} &= I_{Q(VBB)} + I_{MAJOR\ (SIN)} \\ &\quad + I_{MAJOR\ (COS)} + (2 \times I_{MINOR}) \\ &= 21.4 + 28.3 + 42.4 + 56.6\ \text{mA} \\ &= 148.7\ \text{mA} \end{aligned}$$

for Examples 2 and 3. At V_{IN} = 14 V and V_{OUT} =12 V, the CS8156's power dissipation for these cases is:

$$\begin{aligned} P_{TOT(1)} &= (V_{IN} - V_{OUT}) \times I_{MAX(1)} \\ &= 2\ \text{V} \times 205.3\ \text{mA} \\ &= 410.6\ \text{mW} \\ P_{TOT(2,3)} &= (V_{IN} - V_{OUT}) \times I_{MAX(2,3)} \\ &= 2\ \text{V} \times 148.7\ \text{mA} \\ &= 297.4\ \text{mW} \end{aligned}$$

Examples 1 − 3 represent the peak power cases for the CS4122 when the appropriate coils have ½V_{BB} across them. However, peak power in the CS8156 occurs when all coils have the maximum voltages across them. Peak coil current in the major gauge first occurs at a deflection angle of 45° and repeats at 90° intervals. Peak current in the driven coils of the minor gauges occurs at 0° and again at 112°. The currents for the cases of maximum gauge voltages are:

$$I_{MAJOR} = \frac{2 \times 0.748\ V_{BB}}{R_{MAJOR}} = \frac{17.952\ V}{212\ \Omega} = 84.7\ mA$$

for both major gauge coils, and

$$I_{MINOR} = \frac{2 \times 0.744\ V_{BB}}{R_{MINOR}} = \frac{8.928\ V}{212\ \Omega} = 42.1\ mA$$

for each minor gauge coil driven by ± C1 and ± C2, and

$$I_{VBB/2} = \frac{\frac{1}{2} V_{BB}}{R_{MINOR}} = \frac{6.0\ V}{212\ \Omega} = 28.3\ mA$$

for two equal resistance minor gauges connected between V_{BB} and GND, or for one minor gauge connected between ½V_{BB} and GND.

The currents for the cases of maximum coil voltages are:

$$I_{MAX(4)} = I_{Q(VBB)} + I_{MAJOR} + (2 \times I_{MINOR}) + I_{VBB/2} = (21.4 + 84.7 + 84.2 + 28.3)\ mA = 218.6\ mA$$

for an application with one major and two minor gauges, and

$$I_{MAX(5)} = I_{Q(VBB)} + I_{MAJOR} + I_{MINOR} + I_{VBB/2} = (21.4 + 84.7 + 42.1 + 28.3)\ mA = 176.5\ mA$$

for an application with one major and one minor gauge. The CS8156’s peak power dissipation for these cases is:

$$P_{TOT(4)} = (14\ V - 12\ V) \times I_{MAX(4)} = 2\ V \times 218.6\ mA = 437.2\ mW$$

$$P_{TOT(5)} = (14\ V - 12\ V) \times I_{MAX(5)} = 2\ V \times 176.5\ mA = 353\ mW$$

All of the results are well within the 750 mA capability of the CS8156, and the user is advised to consider its benefits when combined in an application with the CS4122. The total estimated CS4122 power dissipation for Examples 1 and 2, with and without the CS8156, and the additional power dissipation in the CS8156 are summarized in Table 2.

Table 2. Performance Summary at +85°C

CS4122	Power	$T_{J(MIN)}$	$T_{J(MAX)}$	Power	$T_{J(MIN)}$	$T_{J(MAX)}$	Power	T_J
	V_{BB} = 14 V			V_{BB} = 12 V			% Improvement	
Example 1:	1.251 W	96.3°C	153.8°C	0.922 W	93.3°C	135.7°C	26	3−12
Example 2:	1.225 W	96.0°C	152.4°C	0.903 W	93.1°C	134.7°C	26	3−12
Example 3:	–	–	–	0.750 W	92.0°C	127.0°C	39	4−17

CS8156	–	V_{IN} = 14 V, V_{OUT} = 12 V		
Example 1:	–	0.411W	–	
Example 2 and 3:		0.297 W		
Major Gauge at 45°, 2 Minor Gauges at 0°		0.437 W		
Major Gauge at 45°, Minor Gauge at 0°		0.353 W		

Minor Gauge V_{BB} Connections

A simplified diagram typical of the CS4122's gauge driver amplifiers is shown in Figure 7. Diodes D1 and D2 provide recirculation paths for the coil currents when power is removed or when the drivers are turned off due to fault conditions. Most of the gauge coils are driven differentially, but in applications with two minor gauges or with one minor gauge and R_B, D2 in the $V_{BB}/2$ driver can provide a path to power−up the CS4122 if the minor gauges are connected to a voltage different from the CS4122's V_{BB} pin. To prevent back−powering the CS4122, the static minor gauge coils (or R_B) should be connected to the same power source as the CS4122's V_{BB} Pin.

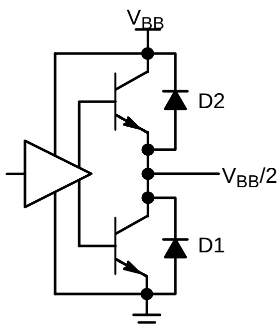

Figure 7. Simplified Output Amplifier

Application Hints

- Use a voltage regulator to reduce CS4122 power dissipation and to protect it from overvoltage transients and power supply reversal.
- Locate the CS4122 and its voltage regulator away from heat sources such as the gauges, incandescent warning and panel illumination lamps, other voltage regulators, etc.
- Place the CS4122 at the bottom and place the regulator at the top of the printed circuit board (assuming the typical vertical orientation of an automotive dashboard gauge assembly.)
- Include thermal planes on the printed circuit board to improve thermal performance.
- Ensure sufficient airflow to allow efficient heat removal.
- Connect the CS4122's V_{BB} Pin and the static minor gauge coils to the same power supply to prevent back−feeding the CS4122 through the $V_{BB}/2$ pin.

Additional Considerations

The mission profile of an application should be examined with regard to the probability and frequency of concurrent peak power points, due to pointer positions of the respective gauges. The applications and loads examined in the examples are a limited set of cases for the CS4122, and the effects of all extremes of power supply voltages, power supply transients, temperatures, and loads should be considered to ensure maximum reliability of the product in any application. For additional information on thermal performance, the following application notes and reference manual are available from the ON Semiconductor website, http://onsemi.com.

- AN1570/D, "Basic Semiconductor Thermal Measurement".
- AN569/D, "Transient Thermal Resistance − General Data and its Use".
- AND8036/D, "Thermal Management".
- CASERM/D, "Case Outline and Packaging Reference Manual".

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