

Application Note

I C s f o r M o t o r C o n t r o l

Current Limiter for the Motor Control ICs of the TDA514x-family

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R. Galema

Product Concept & Application Laboratory Eindhoven, the Netherlands.

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Summary: The Motor control ICs of the TDA514x family have been provided with a current limiter circuit. This current limit, however, cannot be set externally.
Therefore the need exists to have a current limiter circuit of which the current limit can be set externally.
In this report two current limiter circuits will be described all suitable to be used with the ICs of the TDA514x family.

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1. Introduction.

The Motor control ICs of the TDA514x family have been provided with an on-chip current limiter circuit. The current limit value, however, can not be set externally. Therefore the need came-up for an adjustable current limiter circuit. The method of current limiting is based upon the voltage drop across a current sensing resistor in series with the motor supply.

To obtain a negligible effect on the motor torque it is very important that the voltage drop across the current sense resistor is as small as possible.

We have to deal with the motor control ICs, i.e. TDA5143, TDA5144 and TDA5145, with on-chip output transistors.

In this report a current limiter is given for the ICs with on-chip output drivers and the IC with external output driver.

The input voltage V_{in} (figure 1), connected to the AMPIN- input of the motor control IC, is used to control the voltage V_{mot} . The control range of V_{in} is determined by the resistor divider of 39 K Ω and 10 K Ω , which have been connected to the AMPIN+ input. This part of the circuit is not further discussed.

Because in this report only different current limiting circuits are described, the capacitors for the timing of the motor control IC have not been discussed here.

2. Circuit description.

In the figures 1, 3 and 4 different types of current limiter circuit are given for the TDA5143, TDA5144 and TDA5145.

For all circuit diagrams applies that the current sense resistor has to be connected in series with the transistor or power MOSFET that controls the voltage on the V_{mot} input. Because of the fact all GND pins are internally interconnected, it is not possible to have a current sense resistor in series with the common GND pin of the output driver stage.

Figure 1 shows a simple one-transistor controlled current limiter and figures 3 and 4 show the circuits for op-amp controlled current limiters. The op-amp controlled current limiters allow a much lower voltage drop across the current sensing resistor than the one-transistor current limiter.

2.1 One-transistor controlled current limiter.

The circuit of figure 1 is based upon the voltage drop of about 0.8 V across a current sense resistor R2. At a voltage of about 0.8 V across R2 the transistor T1 turns-on and decreases the drive for the MOSFET that determines the voltage V_{mot} . The current sensing resistor R2 has to be determined (TBD) by user and is of course dependent on the current limiting value.

This is a simple low-cost solution, easy to implement, that can be used in applications where a relative high voltage drop across the current sensing resistor is allowed. This high voltage drop reduces the efficiency of this circuit.

Due to the fact current limiting value is mainly determined by the V_{be} of one transistor, The V_{be} has a temperature coefficient of $-2 \text{ mV}/^\circ\text{C}$. This gives at a V_{be} of 800 mV a tolerance on the current limiting value of $-0.25 \text{ }^\circ\text{C}$. So, the value at which the current is limited is temperature dependent.

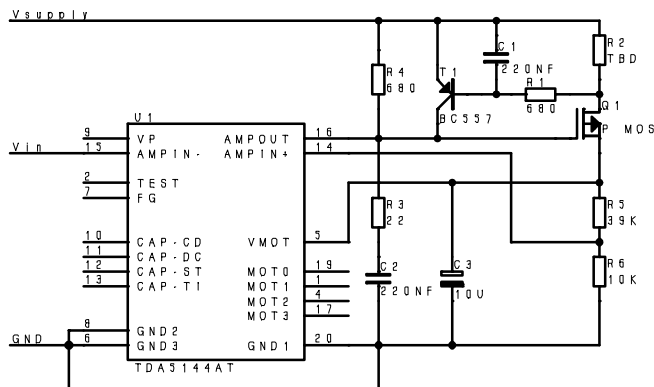


Figure 1

In figure 2 a typical relation has been given between the current sense resistor value and the current limiting value. This relationship has been determined by measuring the start-up current of the motor at different values of R2.

From this figure we see good linear relationship between the current sense resistor (R2) and the current limiting value.

The voltage drop across the current sensing resistor can be found by multiplying the resistor value and current limit value.

2.2 Op-amp controlled current limiter.

In figure 3 the diagram of an op-amp controlled current limiter has been depicted. By using an op-amp the voltage drop across the current sense resistor R7 can be much lower than the one-transistor solution.

For this application a minimum current limiting sense voltage V_{cs} of 100 mV is assumed. For lower values of V_{cs} the accuracy of the current limiting value decreases.

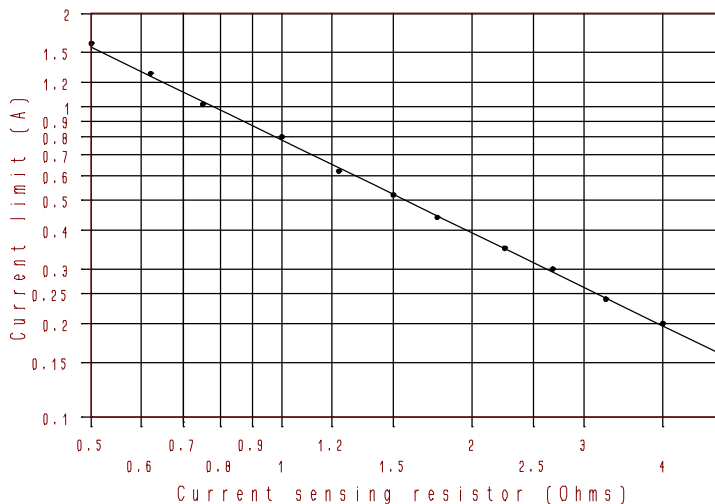


Figure 2

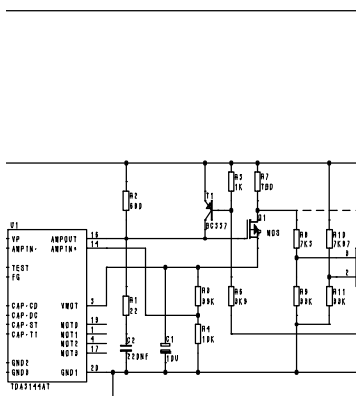


Figure 3

The current limiting sense voltage is referenced to the positive supply rail. To measure this voltage an op-amp has to be used that allows common mode input voltages that are equal to the positive supply voltage of the op-amp. Most general purpose low-cost op-amp can not handle this kind of input voltages.

To be able to use a low-cost general purpose op-amp the input voltage has to be shifted to a level of about 2 to 3 V below the positive supply voltage. For a $\mu A741$ type op-amp this voltage shift must be at least 3 V and for an LM358 type this voltage must be 2 V. Because of its smaller necessary DC voltage shift the LM358 has been used for further calculations.

This voltage level shift is been realized by the resistors R8 and R9. These resistor values have been determined in such a way that the voltage on the V_+ terminal of the op-amp is 8.8 V at a supply voltage V_{supply} of 12 -10%. The reference value for the current limiting value is set by the resistors R10 and R11.

Since we are operating in this application with DC voltages of 100 mV the offset voltage of the op-amp has to be considered as well. An offset voltage of ± 10 mV, which is normal for general purpose low-cost op-amps, introduces a tolerance of $\pm 10\%$ on the current limiting value at a V_{cs} of 100 mV.

By shifting the DC level of the sense voltage, the amplitude of V_{cs} on the op-amp input is reduced

and thus the influence of the offset of the op-amp increases. To minimize this influence as much as possible the level shift should be kept as small as possible.

This can be explained with following example.

$$V_+ = V_{\text{supply}} \times R9/(R8+R9) - V_{\text{cs}} \times R9/(R8+R9); \quad (1)$$

The values for R8 (7.5 K Ω) and R9 (33 K Ω), mentioned in figure 3, have been calculated for a level shift of 2 V at a V_{supply} of 12 V -10% and $V_{\text{cs}} = 0$ V.

Substituting the values for R8 and R9 in expression 1 gives:

$$V_+ = 0.815 V_{\text{supply}} - 0.815 V_{\text{cs}} \quad (2)$$

From this result we see that a actual current sense voltage on the op-amp input is reduced by a factor of 0.815. This gives a voltage 81.5 mV on op-amp input at $V_{\text{cs}} = 100$ mV.

The LM358 has a maximum offset voltage of ± 9 mV. With this offset voltage and a V_{cs} of 100 mV the output of the op-amp will become active at input voltages varying between 90.5 and 72.5 mV, which means a tolerance $\pm 11\%$.

Another parameter that influences the current sense level is the supply voltage V_{supply} .

Equation 2 can also be written as:

$$V_+ = A \cdot V_{\text{supply}} - A \cdot V_{\text{cs}} \quad (3)$$

$$V_- = V_{\text{supply}} \cdot R11/(R10+R11) \quad \text{or} \quad V_- = B \cdot V_{\text{supply}} \quad (4)$$

$$V_+ = V_-$$

$$B \cdot V_{\text{supply}} = A \cdot V_{\text{supply}} - A \cdot V_{\text{cs}} \quad (5)$$

$$V_{\text{cs}} = V_{\text{supply}} - B/A \cdot V_{\text{supply}} \quad (6)$$

From eq. 6 one can see that V_{cs} is direct proportional to V_{supply} . So, with a tolerance on the supply voltage of $\pm 10\%$ this gives a tolerance on the current limiting value of $\pm 10\%$.

With eq. 6 also the resistors R10 and R11 can be determined for a certain current limiting value.

$$B = A \cdot (V_{\text{supply}} - V_{\text{cs}})/V_{\text{supply}} \quad (7)$$

For a current limiting sense voltage of 100 mV the factor B as follows:

$$B = 0.815 \times (10.8 - 0.1)/10.8 = 0.807 \quad (8)$$

When taking for R11 the same value as R9 (33 K Ω) than R10 becomes 7.87 K Ω .

The current sensing resistor R7 (TBD) has to be determined by the user and is dependent on the current limiting value and the maximum allowable value of V_{cs} . The tolerance of this resistor, which has a very low value, is important for the overall tolerance on the current limiting value.

From calculations above one may conclude that the tolerances for the current limiting value are fairly high.

The influence of the offset voltage can be reduced by using an op-amp with a lower offset voltage, or by allowing a higher value for V_{cs} . A current sense voltage V_{cs} of 200 mV halves the influence of the offset voltage.

The influence of the supply voltage can only be reduced by using a power supply with lower tolerance.

The resistors R8, R9, R10 and R11, used to realize the DC voltage shift, introduce an extra tolerance on current limiting value. Resistor tolerances of $\pm 5\%$ result in a tolerance on current limiting value of $\pm 5\%$.

The total tolerance on the current limiting value, caused by the offset, supply voltage variations and resistor tolerances, is as follows:

Offset related tolerance at V_{cs} is 100 mV:	$\pm 11\%$ (offset ± 9 mV)
Supply related tolerance:	$\pm 10\%$ (V_{supply} 12 V $\pm 10\%$)
Resistors tolerance:	$\pm 5\%$
Total (1.11 x 1.1 x 1.05):	$\pm 28\%$

An improved circuit is given in figure 4. In this set-up the DC voltage shift part is bridged by a zener diode. In this way a more stable supply voltage for the DC voltage shift and the reference voltage for the op-amp is obtained. Zener diodes are available with tolerances 5, 3, 2 and 1%. With the introduction of the zener diode the tolerances on current limiting value will change. These changes will be calculated below.

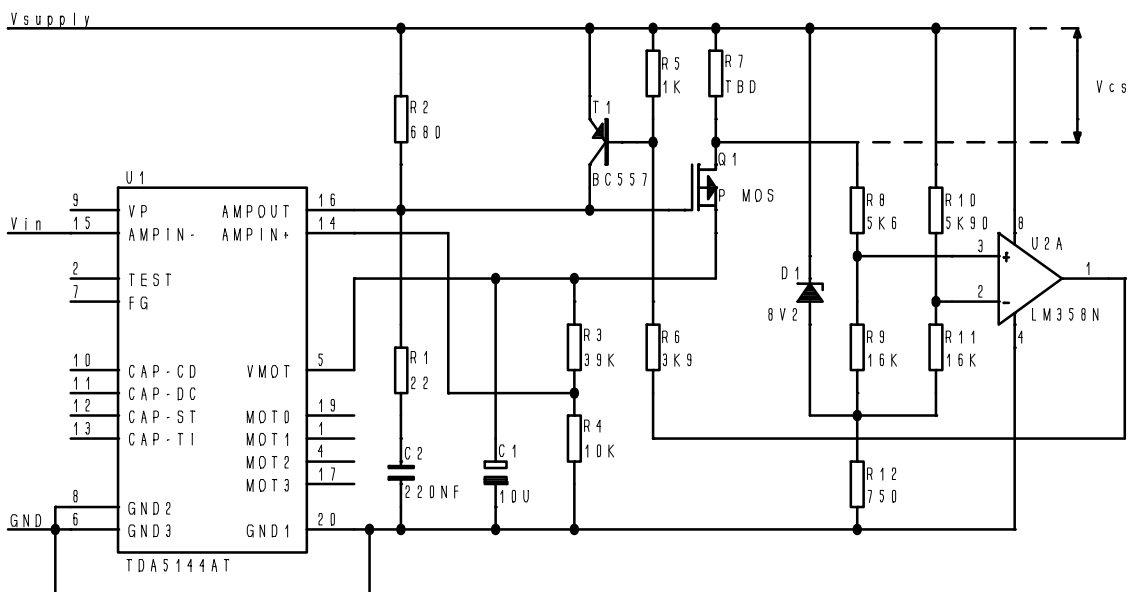


Figure 4

Assume a zener diode of $8.2 \text{ V} \pm 5\%$ (BZX79 C 8V2).

The minimum zener voltage is $0.95 \times 8.2 = 7.7 \text{ V}$. For the calculations only the minimum zener diode voltage is important, to obtain the required voltage of at least 2 V

We still have to realize a DC voltage shift for the op-amp of 2 V . The factor A from eq. 3, which was 0.815, will now be 0.74. This makes the influence of an offset voltage of $\pm 9 \text{ mV}$ on current limiting value $\pm 12\%$. As already said before the influence of the offset can be reduced by using an op-amp with a lower offset voltage.

The second parameter that influences the current limiting value is the supply for the op-amp reference and the DC voltage shift.

The temperature drift of a BZX C 8V2 zener diode is max. $6.2 \text{ mV}/^\circ\text{C}$. This means for a temperature range of $25^\circ\text{C} \pm 25^\circ\text{C}$ a zener voltage variation of $\pm 150 \text{ mV}$, or related to a zener voltage of 7.7 V at 25°C an additional tolerance of $\pm 2\%$.

Together with a zener diode tolerance of $\pm 5\%$ the overall tolerance of the zener diode voltage is then $\pm 7\%$.

The total tolerance on the current limiting value, caused by the offset, zener diode variations and resistor tolerances, is as follows:

Offset related tolerance at V_{cs} is 100 mV :	$\pm 12\%$ (offset $\pm 9 \text{ mV}$)
Zener diode related tolerance:	$\pm 7\%$
Resistor tolerances	$\pm 5\%$

Total (1.12 x 1.07 x 1.05): $\pm 26\%$

With a 1 % zener diode (i.e BZX79 A 8V2) the zener diode related tolerance, including the temperature drift, will decrease to $\pm 3\%$, and then the total tolerance is $\pm 21\%$.